Connected Communities: A Multi-Building Energy Management Approach

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1 Rocky Mountain Institute
2 National Renewable Energy Laboratory

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5500-75528
May 2020

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Suggested Citation
Olgyay, Victor, Seth Coan, Brett Webster, and William Livingood. 2020. *Connected Communities: A Multi-Building Energy Management Approach*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-75528. https://www.nrel.gov/docs/fy20osti/75528.pdf.

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National Renewable Energy Laboratory
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Golden, CO 80401
303-275-3000 • www.nrel.gov

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Acknowledgments

The authors thank Ryan Meyer for his work as the technical monitor from the National Renewable Energy Laboratory (NREL). The authors are also appreciative of the following individuals and organizations for offering their insights and perspectives on this work:

Joe Bourg – Olivine Inc.
Larry Brackney – NREL
Rich Brown – Lawrence Berkeley National Lab
Andrew Burr – U.S. Department of Energy (DOE)
Cara Carmichael – Rocky Mountain Institute (RMI)
Sunil Cherian – Spirae, LLC
John Dilliott – University of California, San Diego (UCSD)
Mark Dyson – RMI
Angelique Fathy – RMI
Robert Flores – University of California, Irvine
Justin Hill – Southern Company
Scott Hinson – Pecan Street Inc.
Peter Jacobson – Panasonic Corporation of North America
Amy Jiron – DOE
Larsh Johnson – Stem
Ben Joseph – Nikola Power
Liam Kelly, James Shaw, Bud Vos – Enbala
James Leverette – Southern Company
Scott Mackenzie – Advanced Microgrid Solutions
Ram Narayanamurthy – Electric Power Research Institute (EPRI)
David Nemtzow – DOE
Chris Parr – Sun Valley EcoDistrict
Michelle Tirto – LINC Housing
Craig Wright – Aurora Public School District
Sarah Zaleski – DOE

List of Acronyms

ADR	automated demand response
BAS	building automation system
BPS	bulk power system
CAPEX	capital expenditure
CC	connected community
CCA	community choice aggregator
CCHP	combined cooling, heat and power
CHP	combined heat and power
DER	distributed energy resource
DERMS	distributed energy resource management system
DLAP	default load aggregation point
DR	demand response
ESS	energy storage system
EV	electric vehicle
FERC	Federal Energy Regulatory Commission
GEB	grid-interactive efficient building
GHG	greenhouse gas
IDSM	integrated demand side management
IESP	integrated energy services provider
IOU	investor owned utility
ISO	Independent System Operator
ITC	investment tax credit
OEM	original equipment manufacturer
OPEX	operating expense
POI	point of interconnection
PPA	Power Purchase Agreement
PV	photovoltaics
RE	renewable energy
REC	Renewable Energy Certificates
ROI	return on investment
SOC	state of charge
T&D	transmission and distribution
TOU	time of use
V2G	vehicle to grid
VGI	vehicle-to-grid integration
VNM	virtual net metering
VPP	virtual power plant

Executive Summary

Connected Communities (CCs) are collections of buildings and distributed energy resources (DERs) that incorporate integrated energy management strategies at the multi-building scale. Based on the research conducted for this report, the Rocky Mountain Institute (RMI) and the National Renewable Energy Laboratory (NREL) have identified examples of CCs that are enabling increasingly integrated solutions, sharing resources among buildings, and providing services back to the grid. As demonstrated by these examples, CCs can provide real and scalable solutions to mitigate energy costs, enable more flexibility in grid operations, and offer choices in meeting greenhouse gas (GHG) emissions goals. Nationwide examples of these solutions are included in the appendix of this report.

In order to understand the most promising practices for the design, operation, and business models associated with CCs, a search was performed to create a nationwide inventory of CCs, and multiple stakeholder interviews were conducted. Based on that research, this report explores the many factors that influence the development and operation of CCs and evaluates their potential value. This study was a qualitative analysis of CCs and their potential value. A follow-up quantitative analysis is also being conducted to further support this research.

Characteristics

A CC is one that incorporates central controls (or intelligence) to manage multiple distributed energy resources at the multi-building scale, enabling communication to and from the grid for optimized and coordinated operations and dispatch. Buildings in a CC may or may not be within a contiguous area or region of land. A CC may or may not share a single owner. The case studies and project inventory provided in the Appendix of this report indicate that the key characteristics of CCs described below are able to be implemented in almost any multi-building use-case (including residential, commercial, mixed use, campuses, and non-contiguous portfolios). The four key elements of CCs that emerged through this study are:

1. Grid-interactive and efficient: Consistent with the Department of Energy's (DOE's) framework for grid-interactive efficient buildings (GEBs) (DOE, 2019), CCs are made up of buildings that have the capability to shed, shift, or modulate energy use in response to grid signals. CCs accomplish this through a connected controls platform enabling grid-interactivity at the multi-building scale.

2. Multiple technologies: Some CCs incorporate multiple energy technologies including building load flexibility, renewable energy generation, and energy storage.

3. Multi-building optimization: As distinguished from managing energy resources at the single building level, some CCs not only *manage* energy across multiple buildings, but employ strategies to *optimize* energy use and dispatch of DERs across multiple buildings. By coordinating energy management across multiple buildings, the potential to maximize the benefit across multiple value streams exists beyond that of a building-by-building approach.

4. Shared systems: Some CCs incorporate physically connected, shared systems, such as district thermal plants, community solar, or energy storage installations, to increase

utilization of the resource across multiple facilities, to leverage economies of scale regarding first costs and O&M costs, as well as to balance local loads across buildings.

Varying combinations and configurations of these elements were found through this study, indicating a spectrum of smartness and "connectedness" in existing projects (see Spectrum of CC Solutions). The key take-away from these observations is that the greater the extent to which a CC incorporates the full spectrum of capabilities, the greater the CC is able to unlock the potential value.

Value Proposition

The key question asked in assessing the merits of CCs is: what is the additional value of employing energy strategies that involve multiple buildings? In other words, what can a well-designed, multi-building CC do better to unlock value propositions, compared to a building-by-building approach? The following table summarizes the potential added benefits of CCs.

Potential Value of CCs (multi-building approach)

Customer Benefits	Utility/System Operator Benefits
• **Capital Expenditures (CAPEX) Savings.** First cost savings with centrally installed systems (e.g., RE, energy storage) are made possible through bulk purchasing, streamlined installation, and reduced total capacity requirements. Also, maintenance savings associated with shared systems from reduced operator costs and reduced maintenance and repairs costs. • **Energy bill savings - Energy efficiency:** Economies of scale with multi-building energy upgrades. District thermal approaches have inherent efficiency advantages. • **Energy bill savings - Rate switching/arbitrage:** When aggregating load, customers may be able to switch to a more favorable rate schedule. Sophisticated automated controls to enable load flexibility and price arbitrage may be more achievable and cost-effective at the community scale. These automated controls can mitigate challenges with behavioral changes and enable value capture beyond manual controls. • **Energy bill savings: Demand charge reduction**. Greater load diversity provides opportunity for greater demand reduction per unit of shared DER capacity (i.e., a single DER can reduce peak demand of multiple buildings that have non-coincident peaks). A CC with a master meter may reduce demand charges, because the community peak is typically lower than sum of individual peaks.	• **Reduced capacity requirements for generation and transmission and distribution (T&D) infrastructure:** *Deregulated markets*: CCs may enable more shifting of energy use away from peak periods through coordinated market response to price signals, saving suppliers from high spot prices. *All markets*: CCs may enable more shifting of energy use away from peak periods, thus reducing investment requirements in generation capacity and T&D infrastructure. • **Streamline EE program delivery:** Energy efficiency campaigns and programs can be scaled more efficiently at the district level through lower customer acquisition costs.

Potential Value of CCs (multi-building approach)

Customer Benefits	Utility/System Operator Benefits
• **Demand response/Ancillary services:** Aggregating load may enable a CC to participate in a wider variety of demand response programs and events, Participating in wholesale markets may augment the value stack of aggregated resources.	• **Increased reliability:** CC aggregated resources can better respond to grid needs at a more meaningful scale (frequency regulation, voltage support, etc.) than individual resources.
• **Resilience:** CCs may enable a larger portion of the building loads within a community to be supported in an islanded state by taking advantage of load diversity and shared assets. Also, when sophisticated controls are leveraged (perhaps more cost-effectively at the multi-building scale), CCs may enable greater islanding capability, and thus the ability to ride out longer duration outages.	Utilities' risks may be mitigated by communities' ability to island during periods of grid stress and the ability of utilities to prioritize responses during grid outages.
• **GHG reduction goals:** Meeting higher percent of annual load per unit installed capacity of on-site renewables may be possible with CCs by taking advantage of load diversity and shared assets. CCs can result in strategies that dispatch aggregated resources to reduce consumption during times of greatest emissions intensity on the grid. By offering on-site, community scale options through aggregating available land, or rooftop resources, CCs may enable more on-site renewable energy projects rather than off-site Power Purchase Agreements (PPAs) or purchasing Renewable Energy Certificates (RECs).	• **GHG reduction goals:** CCs can help meet mandated or voluntary GHG goals.

Market and Technical Challenges

This study indicates that CCs have significant value potential beyond a building-by-building approach. However, as noted by the collection of projects in the inventory (see Appendix B), few projects are currently leveraging the full extent of value proposition described in this report. In part, this is because the CC approach is relatively novel and market conditions (as well as regulatory regimes) are not fully aligned to support high levels of "connectedness" in retrofit or new construction projects. Additionally, specific technical challenges still exist. The following enumerates some of the barriers and challenges:

Market challenges

- Utility rates and incentives – In many cases, rates and incentives are not yet dynamic enough to fully reflect the needs and constraints on the electric grid and further enable CC approaches.
- Regulatory landscape – The patchwork of U.S. regulations in the energy sector poses challenges to developing viable CC business models. In some cases, regulations are more

conducive to CCs, while in other states regulations are hindering the adoption of CC practices.

- Multiple owners – When multiple building owners are involved in a CC project, there may be challenges associated with organizing and coordinating the CC projects, as well as challenges associated with allocating costs and benefits of the project across stakeholders.
- Valuation of indirect value streams – A lack of standardized approaches to identify and value energy resilience investments hinders the ability of decision makers to perform meaningful cost-benefit analyses to inform decision making and incorporate resilience into the design process.
- Capital cost of shared systems – Physically connecting energy systems to leverage benefits of shared systems, such as shared storage, may require costly infrastructure and logistical planning that can be prohibitive for projects, especially for retrofit projects. Note that capital costs, financing, operations and maintenance expenses and cost recovery are often distributed very differently across land and building owners, utility companies, third-party energy companies, etc. depending on the individual building and CC approach, which makes capital cost and total cost of ownership comparisons complex (e.g., split incentive effects, first costs vs. total costs of ownership).
- Market awareness of the CC approach – Adoption of the SCC approach by stakeholders may be hindered by a lack of familiarity with the concepts that represent changes to the way building systems are managed and operated.

Technical challenges

- Interoperability of systems – A lack of adoption of open data models and communication protocols that enable interoperability of technologies remains a barrier to progress in accelerating the implementation of CCs.
- Multi-objective analysis and design – Multi-objective analysis and design, such as planning a CC project to take advantage of the full value stack, is a complex endeavor. Designing to optimize across multiple value streams including energy cost savings, GHG reductions, resilience, and perhaps others is technically and logistically challenging.
- Cybersecurity – Ensuring that networked solutions for multi-building energy management are secure from cyberthreat and cyberattack poses significant challenges but is paramount to gaining broader adoption of CCs.
- Subsurface piping installation – With district thermal and central thermal storage systems, there can be technical challenges associated with piping installation in some subsurface conditions, as well as efficiency losses from transporting thermal energy over long distances. Although, so called, ambient temperature loop systems, also referred to as fifth generation district heating and cooling networks, overcome heat loss challenges.

Summary of Findings

Based on the research and interviews conducted to date across a diverse set of CCs, the following inferences were derived:

1. CC projects can provide solutions that enable grid flexibility for reliability and efficiency and help meet GHG emissions reduction goals. Some individual projects have realized fractions of the total value that CCs may enable but, to a large extent, this potential is untapped across the country.

2. The CC approach can unlock greater value and economies of scale, versus the building-by-building approach. In other words, with the CC approach, the whole may be greater than the sum of the parts.

3. There are multiple value streams including customer value (e.g., CAPEX cost savings, energy bill reductions, and revenue streams from grid services) as well as utility system operational value (e.g., reduced capacity requirements, flexibility to utilize a variety of generation resources, and deferred or averted grid infrastructure and connection costs) to be accessed by various stakeholders, through developing CC projects for both new and existing developments.

4. Central control systems that are designed to optimize the operations of DERs, such as solar photovoltaics (PV) and energy storage systems (ESS) in conjunction with buildings' operations, are a critical component of CCs in order to provide maximum benefits to building owners, occupants, and the grid. A central control system in this context means a multi-building-scale control system, but not a large region-scale control system like an Independent System Operator (ISO) control center. However, an ISO control center in a hierarchal controls topology could influence the multi-building-scale control system.

5. In general, projects that connect more buildings of various types and greater load diversity (e.g., mixed-use developments) and a broad array of integrated technologies (DERs), are better able to leverage multiple value streams.

6. Where feasible, shared assets that are physically connected to multiple buildings (e.g., shared on-site generation, energy storage, and thermal systems) may have better life-cycle costs than individual building level systems due to potential lower first costs, lower O&M costs, and/or higher utilization, more optimization pathways per unit installed capacity.

Table of Contents

List of Figures

List of Tables

Introduction

There is a need for broad energy management solutions that enhance grid reliability, efficiency, and flexibility, and that help to reduce greenhouse gas (GHG) emissions. Rapidly evolving electricity market conditions, including growth in the number of distributed energy resources (DERs), has underscored the need for coordination between the Bulk Power System (BPS) and DERs (NERC, 2018), (FERC, 2018). In addition, as concerns related to climate change (DOD, 2019) and associated GHG emissions goals continue to be brought to the forefront (USGCRP, 2018), distributed solutions that support both grid balancing and emissions reductions are increasingly important. Considering that commercial and residential buildings consume 75% of generated electricity in the United States (EIA, 2018), account for 39% of carbon emissions (Global Alliance for Building and Construction, 2018), and incorporate increasing quantities of DERs, innovative energy management strategies for buildings are ever more critical to solving both utility constraints and meeting GHG emissions goals.

Connected Communities (CCs) that incorporate energy management strategies at the multi-building scale, can provide real and scalable solutions to these issues. For purposes of this report, a CC can be defined as a group of contiguous or non-contiguous buildings that incorporates central controls to manage multiple DERs at the multi-building scale, enabling communication to and from the grid for optimized and coordinated operations and dispatch. CCs represent a distinction from demand side management strategies at the individual building level principally through their capability for coordinated energy management across multiple buildings.

The purpose of this report is to assess the state of the market for CCs, explore the various configurations and design features of existing projects and those in development, and examine a set of working hypotheses about the potential value that CCs can deliver. A nationwide search was performed to create an inventory of CCs (see Appendix B), and a series of interviews with project stakeholders was conducted; although the authors made best attempts within the project constraints, it should be considered a partial inventory. Interviewees included building owners, utility representatives, and third-party developers (see Appendix C for a list of the questions asked of stakeholders in these interviews).

During the course of the study, the following key questions were central to gaining a better understanding of the potential for CCs to provide scalable solutions:

1. What are the defining elements of a CC as they relate to energy management?

2. What are the value propositions of CC energy management strategies at the multi-building scale?

3. What are the critical stakeholder arrangements and the most prevalent models that govern asset ownership and control?

To assess the spectrum of possibilities for CCs, a variety of CC project types across the United States were reviewed. In addition to exploring various building and asset ownership structures, the following provides a list of the building types assessed for this study:

- Residential
- Commercial (both contiguous and noncontiguous building portfolios)
- Mixed-use
- Campus.

This report is a synthesis of the insights gained from the interviews and research conducted, which have formed the basis for the theoretical and qualitative findings presented here.

Spectrum of CC Solutions

This research identified four key elements of CCs. Projects employ varying combinations of these elements, creating a spectrum of connectedness. The four key elements of CCs are:

1. Grid-interactive and efficient: Consistent with the Department of Energy's (DOE's) framework for grid-interactive efficient buildings (GEBs) (DOE, 2019), CCs are made up of buildings that have the capability to shed, shift, or modulate energy use in response to grid signals. CCs accomplish this through a connected controls platform enabling grid-interactivity at the multi-building scale.

2. Multiple technologies: Some CCs incorporate multiple energy technologies including building load flexibility, renewable energy generation, and energy storage.

3. Multi-building optimization: As distinguished from managing energy resources at the single building level, some CCs not only *manage* energy across multiple buildings, but employ strategies to *optimize* energy use and dispatch of DERs across multiple buildings. By coordinating energy management across multiple buildings, the potential to maximize the benefit across multiple value streams exists beyond that of a building-by-building approach.

4. Shared systems: Some CCs incorporate physically connected, shared systems, such as district thermal plants, waste heat recovery, ambient temperature loops (illustrated in Figure 1), community solar, or energy storage installations, to increase utilization of the resource across multiple facilities, to leverage economies of scale, and to balance local loads across buildings.

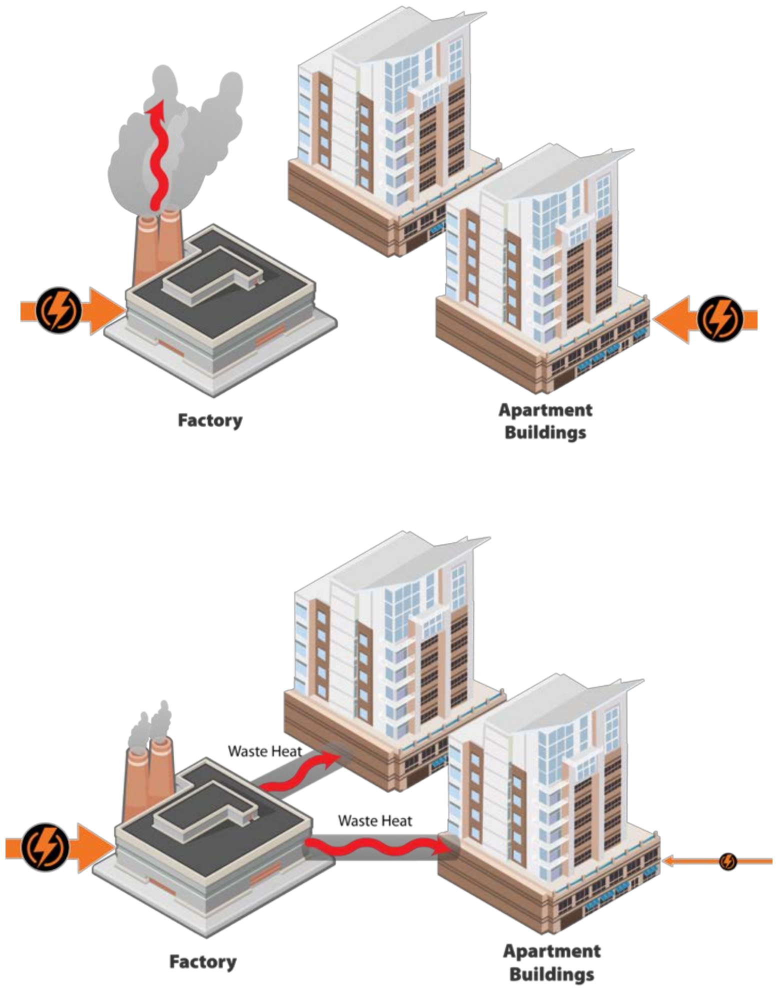

Figure 1: Some CCs Incorporate Physically Connected, Shared Systems, such as Waste Heat Recovery and Ambient Temperature Loops
Credit: NREL-Marj Schott

The following brief descriptions are illustrative of the spectrum of possibilities for employing various combinations of the four key elements described above.

Utility DR Program – Demand response (DR) programs are implemented by some electric utilities (retail programs) and system operators (wholesale programs) as a means of balancing supply and demand and reducing capacity constraints on the grid. DR programs provide an opportunity for consumers to respond to grid needs by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives (DOE, 2019). DR programs that dispatch signals to networked devices that respond automatically to the grid signals fall under the CC definition, while DR programs that involve manual load curtailment in response to utility requests do not fall under the CC definition. Nevertheless, these automated DR programs represent the most basic level on the CC spectrum. Though utilities may communicate with multiple buildings and multiple resources, these resources are typically not connected or optimized in any way; they simply receive and respond to a signal to curtail load.

Utilities and system operators may enroll customers into DR programs directly or enroll customers through third-party aggregators that procure customers on behalf of the utilities. In some cases, utilities and system operators may focus DR programs on a specific connected technology, such as smart water heaters, thermostats, clothes washers and dryers, or heat pump/air conditioning units that can receive network signals and respond to DR events automatically by curtailing loads in real time.[1] In other cases, DR programs may be technology-agnostic and focused on the individual customer's energy resource and flexible capacity.[2]

DR aggregator – Demand response (DR) aggregators procure customers and aggregate energy resources to participate in wholesale and/or retail DR markets. These entities may aggregate multiple types of energy resources such as smart water heaters, thermostats, and other flexible building loads. While aggregators connect to multiple energy resources in multiple buildings, they do not necessarily incorporate sophisticated controls to optimize loads across buildings. As the quantity and diversity of DERs proliferates, the legacy role of DR aggregators is increasingly evolving into distributed energy resource management systems (DERMS) providers (Navigant, 2018).

DERMS providers (single technology) – Distributed energy resource management systems (DERMS) are software platforms that manage and optimize operations of DERs. In some cases, DERMS providers are developing projects focused on a single technology such as energy storage, deployed at multiple buildings within a service territory. The DERMS providers control the storage resources through a central controls platform to reduce demand charges at the individual building level and to maximize benefits to the grid.

DERMS providers (multiple technologies) – In some cases, DERMS providers integrate multiple DERs across multiple buildings onto a DERMS platform to monitor, forecast, and control these resources for both customer and grid benefits. These systems may be operated by customers, third-parties, or utilities (Navigant 2018, NREL 2018). See Figure 2.

[1] See Appendix B.43 for an example.

[2] see Appendix A.6 and Appendix B.1 for examples.

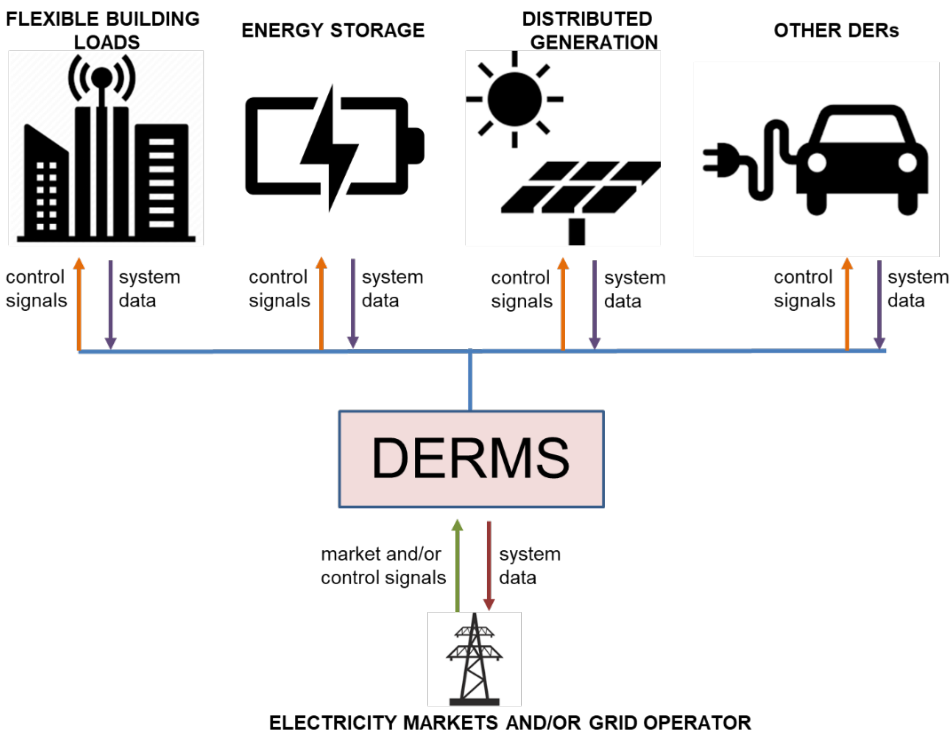

Figure 2: Generalized Diagram of a DERMS Platform

District thermal systems – In district thermal systems, heating, cooling, and/or hot water are provided to multiple buildings from centralized sources. The central plant may consist of a range of sources (waste heat from industrial processes or wastewater, large chillers or boilers, ground source heat pumps, combined heat and power plant, including those that are fueled by renewable natural gas, biofuel and biomass), and may also be connected to a central controls platform to operate the systems in response to grid signals.

Microgrid with multiple technologies – A microgrid is a multi-building electric network with energy generation and/or storage devices, generally one central point of interconnection (POI) to the utility grid, and often, the capability to operate in islanded mode. The operation of the system can be managed through integration of DERMS and a microgrid controller to achieve local load balancing, resilience, and grid-interactive controls.

Figure 3 presents these various solutions along the CC spectrum. While all of the solutions described involve multiple buildings and provide grid-interactive capabilities, there are increasing levels of sophistication, integration, and optimization along the spectrum.

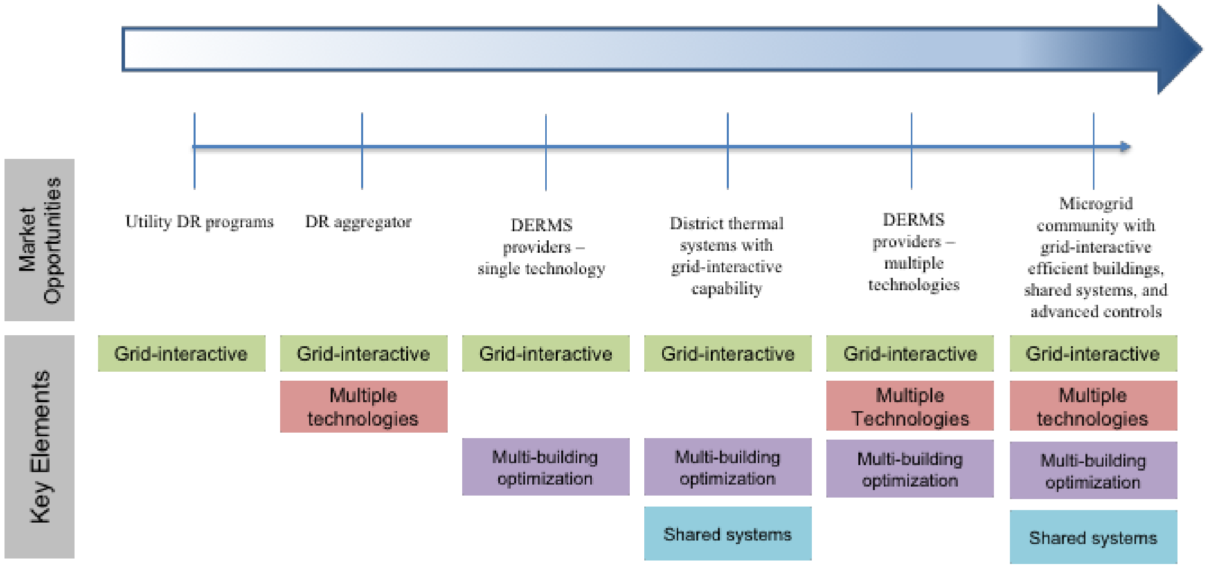

Figure 3: Spectrum of Connected Community Solutions

The market is responding to DERs and capturing the value of integrating these resources through a variety of approaches and business models as depicted in Figure 2. As increased financial incentives from CCs are perceived by project developers, CC projects with greater levels of sophistication are anticipated. In turn, the degree of sophistication and where on the CC spectrum a project falls will impact the levels of potential value that the project is able to unlock.

What Determines a Project's Priorities?

Project stakeholders

While each project has unique characteristics, with various stakeholders playing different roles, the following provides a list of typical stakeholders in CC projects.

- ✓ State Energy Commission
- ✓ Cities and Municipalities
- ✓ Utilities
- ✓ Building Owners
- ✓ Local Organizations
- ✓ Project Developers
- ✓ Building Tenants
- ✓ Technology Providers
- ✓ Project Financiers
- ✓ Project Consultants

Figure 4: Stakeholders in Connected Community Projects

A common theme in project development, as identified through stakeholder interviews, is the importance of strong partnerships between the utility and the owner/developer (customer) and often between the owner/developer and third-party vendors as well. However, projects tend to be differentiated by whether they are utility-driven or customer-driven. The distinction between these two scenarios has implications for control of the assets, how they are operated and optimized, and what benefit is conferred by the CC.

The taxonomy of CC business models is summarized in the following table (See Appendices A and B for case examples that fit into this taxonomy).

Table 1: Taxonomy of Connected Community Business Models

Stakeholder/ Ownership	Placement of Assets	Configuration	Benefits
Projects are generally driven by 1 of 3 main stakeholders: 1) Utility 2) Customer 3) Third-party developer The project driver will influence technology selection, placement, and operation of the assets.	Placement of assets may be: 1) In front of the meter 2) Behind the meter 3) Combination of in front and behind the meter	Assets are either: 1) At building level 2) Central and physically shared by multiple buildings In either configuration, a central controls platform manages the assets across multiple buildings.	Value streams and benefits can be categorized as: 1) Customer benefits (i.e., cost savings or revenues realized by consumer) 2) Grid benefits (i.e., benefits to the utility such as reduced peak demand and infrastructure costs, and system operator benefits such as ancillary services) 3) Indirect benefits (i.e., community investment, reduced GHG, etc.)

Both customer and grid benefits can be realized by a CC. In cases where the projects and the investments are driven by the utility, the utility will generally control and install the assets. In these cases, the utility may operate the assets primarily for grid benefits and wholesale price arbitrage.[3] Alternatively, property owners and third-party vendors may drive the project, with assets installed behind the meter and controlled by the property owner, occupant, or third-party vendor.[4]

However, there are many examples of a hybrid between these two approaches described above that result in shared benefits. The goals and interests driving the project ultimately determine the design configuration, how benefits are prioritized and optimized, and how the benefits are allocated among project stakeholders. The partnership among stakeholders may take the form of shared investment, and, in turn, shared benefits. For example, a utility may control an energy storage system (ESS) placed in front of the meter to serve the utility's economic and grid balancing needs, while reserving a portion of the ESS capacity to provide resilience to the community.

Based on the inventory compiled for this study, a variety of stakeholder arrangements have been identified. Due to the nascent stage of development for many of the projects examined, it is

[3] See Appendix A.3 for an example.
[4] See Appendix A.1, A.2, A.4, and A.5 for examples

premature to conclude which are the most promising models; however, a few themes regarding stakeholder arrangements have emerged from the interviews and research:

- Utility-customer partnerships offer a promising pathway for CC implementation.[5]
- Utility-driven CC projects are becoming more prevalent as utilities are recognizing the grid benefits associated with CC projects.[6]
- Single-owner developments (e.g., campuses) can streamline the path to a CC.[7]
- Multi-owner projects with shared resources and shared benefits have been demonstrated.[8] While these projects face inherent challenges around multi-stakeholder alignment, there are advantages to sharing resources such as lowered capital costs and increased resilience (Energy News, 2019) (Boston University, 2018).
- Third party-driven projects are becoming more prevalent as project developers identify business models that share benefits among stakeholders, shield customers from risk, manage market complexity for the customer, and mitigate interoperability challenges for the utility or system operator.[9]
- With or without direct utility involvement in a project, rate design is key to aligning customer and utility interests in CC operation.

Available technologies and strategies

The following graphic and list of technologies and strategies show what may be deployed in various combinations for the CC projects identified in this inventory (see Appendix B):

[5] See Appendix A.4 as an example.
[6] See Appendix A.2 and A.3 for examples.
[7] See Appendix B.1 for an example.
[8] See Appendix A.5 for an example.
[9] See Appendix A.6, B.2, B.3, B.4, and B.5 for examples.

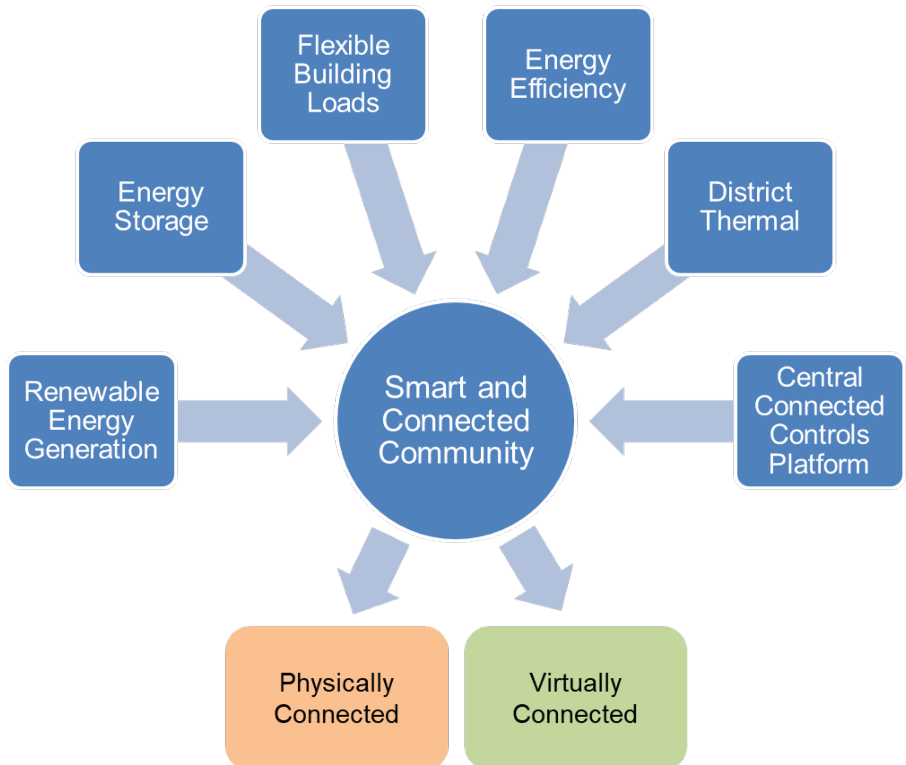

Figure 5: Technologies and Strategies Employed in a Connected Community

1. **Renewable Energy Generation (RE)**: On-site renewable energy generation such as PV, wind, biomass, and small hydropower projects that directly serve the load of the facilities. Installation may be in front of the meter or behind the meter.

2. **Energy Storage Systems (ESS):** Energy storage devices capable of charging and discharging. Examples include chemical batteries, flywheels, and thermal storage (hot and cold). Installation may be in front of the meter or behind the meter. Electric vehicles (EVs) may also be incorporated into ESS strategies when bidirectional EV charger and/or vehicle-to-grid integration (V2G) technologies are implemented.

3. **Flexible Building Loads:** Building subsystems such as HVAC, water heating, clothes washers & dryers, lighting, plug loads, and EV chargers capable of responding to control signals to shed, shift, or modulate load profiles.

4. **Energy Efficiency**: Buildings with integrated design strategies that achieve ongoing reduction in energy use to provide the same or improved functions and services.

5. **District Thermal:** Central thermal plant providing heating, cooling, and/or hot water to multiple buildings. This could also include combined heat and power (CHP) or combined cooling, heat, and power (CCHP). Also included in this category are ambient temperature loop systems, or sometimes referred to as fifth generation district heating and cooling networks, which circulate low-grade heat sourced from the ground, the air, renewable sources or waste heat processes, around a community network of pipes to heat pumps in

buildings and facilities. These heat pumps then upgrade this heat to deliver heating and in reverse, cooling.

6. **Central Connected Controls Platform:** Central controls platform at the multi-building scale capable of two-way communication with the grid, building loads, and other DER technologies within the CC. The controls platform for a CC, which may also be referred to as a DERMS, provides interoperability and intelligence across building systems and other DERs to manage resources in a coordinated and optimized fashion.

7. **Physically Connected CC:** A multi-building electric network that connects loads with energy generation and/or storage devices and one central point of interconnection (POI) to the utility grid. Physically connected CCs include traditional microgrids that are capable of islanding and reconnecting to the utility grid. A District Thermal (Item 5) system is also a physically connected CC (See Table 4).

8. **Virtually Connected CC**: A noncontiguous multi-building network connected via a central controls platform that is capable of remote communication with grid signals and DERs within the CC (See Table 4).

Many of the technologies and strategies listed in Figure 5 overlap with those found in grid-interactive efficient buildings (GEBs), as defined by DOE. In many respects, a CC is a multi-building GEBs network with unique features including:

- The presence of a central energy management and control system operating at the multi-building scale.

- Certain technologies such as renewable energy generation, energy storage, or district thermal systems that may be centrally installed to serve multiple buildings as opposed to the individual building level.

Generally, stakeholders' priorities and values dictate the technologies and strategies that are deployed in a project. However, as more strategies are deployed in tandem with one another, project stakeholders realize more direct financial value as well as drive value with indirect benefits from a CC (See Section *What Determines a Project's Value?* for detailed discussion of value streams). In other words, integration leads to more value; these strategies build on one another synergistically and create a cumulative effect by unlocking additional value streams. Figure 6 below illustrates the level of integration of energy management strategies and the relative associated value streams.

INTEGRATION HIERARCHY / VALUES	CAPEX savings	Energy Bill Savings	Demand Response / Ancillary Services	Resilience	GHG Emissions Reductions
EE (building by building)	○	◔	○	◔	◔
EE+RE (building by building)	○	◑	◔	◑	◑
EE+RE+Storage (building by building)	○	◕	◑	◕	◕
GEB: EE+RE+Storage (DR, Flex, Grid-interactive) (building by building)	○	◕	◕	◕	◕
GEB: EE+RE+Storage (DR, Flex, Grid-interactive) **(multi-building)**	◑	●	●	●	●

○ = Low ● = High (relative within column)

Figure 6: Increasing Levels of Integration Result in More Value

What Determines a Project's Value?

The key question asked in assessing the merits of CCs is: What is the additional value of employing energy strategies that involve multiple buildings? In other words, what can a well-designed, multi-building CC do better to unlock value propositions, compared to a building-by-building approach? The following table summarizes the potential benefits of CCs.

Table 2: Benefits of Connected Communities

Potential Value of CCs (multi-building approach)	
Customer Benefits	**Utility/System Operator Benefits**
• **Capital Expenditures (CAPEX) Savings.** First cost savings with centrally installed systems (e.g., RE, energy storage) are made possible through bulk purchasing, streamlined installation, and reduced total capacity requirements. Also, maintenance savings associated with shared systems from reduced operator costs and reduced maintenance and repairs costs. • **Energy bill savings - Energy efficiency:** Economies of scale with multi-building energy upgrades. District thermal approaches have inherent efficiency advantages.	• **Reduced capacity requirements for generation and transmission and distribution (T&D) infrastructure:** *Deregulated markets*: CCs may enable more shifting of energy use away from peak periods through coordinated market response to price signals, saving suppliers from high spot prices. *All markets*: CCs may enable more shifting of energy use away from peak periods, thus reducing

Potential Value of CCs (multi-building approach)

Customer Benefits	Utility/System Operator Benefits
• **Energy bill savings - Rate switching/arbitrage:** When aggregating load, customers may be able to switch to a more favorable rate schedule. Sophisticated automated controls to enable load flexibility and price arbitrage may be more achievable and cost effective at the community scale. These automated controls can mitigate challenges with behavioral changes and enable value capture beyond manual controls.	investment requirements in generation capacity and T&D infrastructure. • **Streamline EE program delivery:** Energy efficiency campaigns and programs can be scaled more efficiently at the district level through lower customer acquisition costs.
• **Energy bill savings: Demand charge reduction**. Greater load diversity provides opportunity for greater demand reduction per unit of shared DER capacity (i.e., a single DER can reduce peak demand of multiple buildings that have non-coincident peaks). A CC with a master meter may reduce demand charges, because the community peak is typically lower than sum of individual peaks.	
• **Demand response/Ancillary services:** Aggregating load may enable a CC to participate in a wider variety of demand response programs and events, Participating in wholesale markets may augment the value stack of aggregated resources.	• **Increased reliability:** CC aggregated resources can better respond to grid needs at a more meaningful scale (frequency regulation, voltage support, etc.) than individual resources.
• **Resilience:** CCs may enable a larger portion of the building loads within a community to be supported in an islanded state by taking advantage of load diversity and shared assets. Also, when sophisticated controls are leveraged (perhaps more cost-effectively at the multi-building scale), CCs may enable greater islanding capability, and thus the ability to ride out longer duration outages.	Utilities' risks may be mitigated by communities' ability to island during periods of grid stress and the ability of utilities to prioritize responses during grid outages.
• **GHG reduction goals:** Meeting higher percent of annual load per unit installed capacity of on-site renewables may be possible with CCs by taking advantage of load diversity and shared assets. CCs can result in strategies that dispatch aggregated resources to reduce consumption during times of greatest emissions intensity on the grid. By offering on-site, community scale options through aggregating available land, or rooftop resources, CCs may enable more on-site renewable energy projects rather than off-site Power Purchase Agreements (PPAs) or purchasing Renewable Energy Certificates (RECs).	• **GHG reduction goals:** CCs can help meet mandated or voluntary GHG goals.

It should be noted that under the "Prioritized Set of Strategies" column in the table above, central control is a common strategy for all value propositions, allowing systems to be coordinated and optimized across buildings and energy resources.

Leveraging the value stack in multi-building projects

The direct value streams that CCs can capture include energy conservation and avoided cost of grid purchased energy, rate arbitrage, reduced demand charges, demand response and ancillary services to the grid, as well as Capital Expenditures (CAPEX) and Operational Expenditures (OPEX) savings. Indirect value streams of CCs (i.e., value that is not easily captured in ROI calculations), include resilience, GHG reductions, greater investment potential in data infrastructure, community development, and the ability to scale impacts.

Figure 7 presents the drivers or value propositions for the development of CCs.

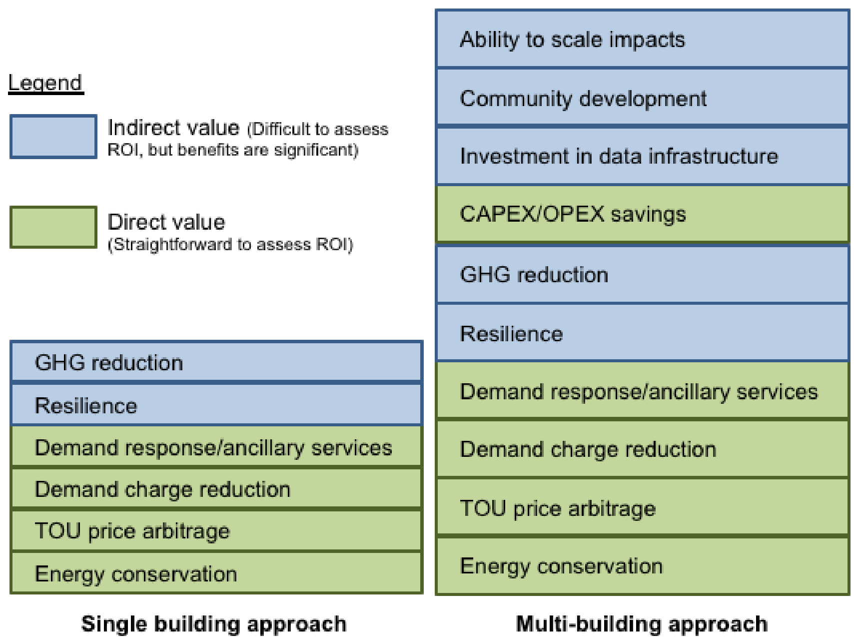

Figure 7: Customer Side Value Stack of Connected Communities

While many of the value propositions listed in Figure 7 are associated with single-building energy management strategies as well as with multi-building CCs, **there is additional value in each of the value streams that can be derived from CC implementation at the multi-building scale**. These opportunities for additional value are described above in Table 2. Figure 7 is intended to be qualitative; the relative additional value of each value stream will depend on the specific project's circumstances.

While the types of assets deployed, their configuration, and their control strategies will largely be determined by the project stakeholders' top priorities, systems that are designed and operated to leverage multiple value streams (i.e., value stacking) will have a better Return on Investment (ROI).

For example, Appendix A.2 describes a multi-technology DERMS provider in Southern California that plans to aggregate solar PV, energy storage, and flexible building loads across the service territory of a community choice aggregator (CCA). In the feasibility analysis for the project, it was found that many of the large commercial customers' peak loads were coincident with wholesale price spikes at the nearest default load aggregation point (DLAP) on the grid. Therefore, using the DERMS platform to mitigate customer demand charges at the building level would also result in greater wholesale cost savings for the CCA, and reduce congestion and potentially the need for infrastructure upgrades for the local utility. Furthermore, peak wholesale prices are likely to be coincident with high GHG emissions intensity, so reducing or shifting energy use away from these times can also advance local and regional GHG goals. While market forces and price signals that shift energy consumption away from peak demand periods do not necessarily correspond to reduced GHG emissions, CCs can potentially be designed to co-optimize dispatch of resources for both GHG reduction and financial considerations. In addition to use of co-optimization, it also leverages value stacking and this example illustrates that CC has the potential to mitigate both grid constraints and GHG emissions.

Indirect value streams

There are multiple value streams associated with CCs that are significant but difficult to capture in the direct ROI analysis. The following serves to enumerate some of the indirect value streams:

Resilience – Resilience is the ability of buildings, campuses, or districts to avoid (i.e., through robustness) or quickly recover from power outages due to weather-related events, cyberattacks, or major utility grid interruptions. While it can be difficult to put a valuation on the ability to keep critical systems up and running, appropriate methodologies are available to facilitate consideration of resilient DERs alongside alternatives for integration into future energy infrastructure and investment planning efforts. These methods include contingent valuation, damage cost, input-output analysis, and defensive behavior (NARUC, 2017). Some of these methods are commonly used to value other non-market goods and thus have associated computer-based tools (NARUC, 2017).

Reduced GHG emissions – CC projects are being employed to assist stakeholders in meeting their GHG emissions reductions goals. The strategies employed by CC projects to reduce GHG emissions include 1) reducing energy consumption through efficient design and upgrades 2) incorporating clean, renewable energy generation into project design, and 3) leveraging intelligent controls to shift load as well as dispatch aggregated resources to reduce consumption during times of greatest emissions intensity on the grid. In some, but not all cases, time-of-use (TOU) utility rates may incentivize load shifting away from high GHG grid intensity periods. In states where an emissions trading system is in place, the cost of emissions can more readily be factored into a project's economic calculations. As carbon pricing mechanisms and GHG policies evolve, the valuation of GHG emissions in project planning may become a more direct and critical factor.

Community development – A CC project can be a community-driven process focused on community and economic development. In some cases, CC projects drive economic revitalization of a community and create the conditions necessary for public and private reinvestment in distressed neighborhoods.[10] Moreover, with revitalization projects that incorporate CC strategies, the benefits of energy efficiency, DERs, and energy management can be shared with lower income households (SVED, 2019) (NYSERDA, 2019).

Investment in data infrastructure – Largely an untapped opportunity, a CC project may be linked with efforts to enhance the data infrastructure of a community, such as physical data storage, fiber-optic cable, as well as servers, routers, and gateways that improve data access. Factoring in the enhanced capability to provide energy services within a community can improve the ROI calculation for the installation of high-speed data infrastructure. Leveraging this synergy between data infrastructure for energy services with data infrastructure to provide other services, could lead to a greater investment potential in data infrastructure and unlock significant value for communities. Additional synergistic services may include increased data access, increased security, better traffic flow, and more efficient public services.

Scaling impacts – Master planning a CC, whether it is for new construction or a retrofit project, results in the capacity to scale sustainability impacts associated with enhanced energy standards, building codes, and control strategies across multiple buildings. Often, a master planned community involves multiple builders, building owners, and various other stakeholders. Engaging these stakeholders in the oversight and planning of a coordinated, multi-building CC can create opportunities for community-wide policies that help unlock the potential value streams associated with the project. For example, stakeholders can agree on connected communications protocols that increase interoperability of controllable devices or set specific energy efficiency targets for buildings in the community. By aligning with community-wide standards, a CC can raise the performance bar across a diverse portfolio of buildings.

The various levers that can be deployed by project stakeholders to realize the value propositions listed in Figure 6 are further described below.

Load diversity and shared systems

A key advantage to deploying DERs at the multi-building scale is that load diversity across buildings can be leveraged to create more economic value per unit of installed capacity. This is especially true for physically connected CCs with shared systems.

A simple example of the advantage gained from load diversity is to consider two buildings subject to high demand charges with peak electric load occurring at different times. One battery can be used to effectively reduce the peak demand of both buildings, whereas in a single-building approach, each building would likely install its own battery to achieve the same benefit. Extending the example to more than two buildings will increase the value of the battery even further. Similarly, in a multi-building complex with a shared central thermal plant, to the extent that the buildings' heating and cooling loads are not coincident with each other, the capacity of the shared plant can be less than the sum of the capacities if each building were to install its own thermal plant. Additionally, district thermal systems have the potential to operate more efficiently than distributed thermal systems (Ontario Tech, 2012). Also, for ambient temperature

[10] See Appendix A.1, and B.4, B.5, B.6, B.7, and B.46 for some examples.

loop systems and fifth generation district heating and cooling networks, heat can be moved from a building that needs cooling to a building that needs heating.

Many metrics exist, but one way to assess load diversity is by examining a diversity factor, defined as:

$$diversity\ factor = \frac{\sum_i^n load_{max,i}}{load_{max,system}}$$

The numerator is the sum of the annual peak loads in individual buildings, and the denominator is the annual peak load of the multi-building community. Thus, a diversity factor of 1 means the peak loads of the individual buildings are perfectly coincident with each other, while a diversity factor of 2 implies that the community peak is half the sum of the individual building peaks. As a general rule, the higher the diversity factor of a set of buildings, the more benefit that can be derived by sharing resources across buildings. It's important to note, for siting considerations, that shared systems could be in the form of central installations connected to multiple buildings or distributed installations that are connected by virtue of being behind the same master meter and POI with the utility grid.

The specific value propositions, identified in Table 2, for which load diversity is a key lever are numerous. On the customer side, additional CAPEX savings (illustrated in Figure 8), demand charge reduction, resilience, and GHG reductions in a CC (as opposed to a single-building approach) are all driven primarily by increased load diversity. First cost savings result from being able to downsize equipment because, typically, the community peak will be lower than the sum of the individual building peaks—which could be true for the shared thermal example described above, as well as for electric loads. Shared solar PV and energy storage installations will be able to meet a higher percentage of community loads in a CC than if the same system, with the same overall capacity, were installed in distributed pieces at individual buildings. For shared systems, the higher the load diversity in the CC, the lower the required system capacity (relative to individual building systems) and the greater the first-cost savings.

Figure 8: Some CCs Take Advantage of Load Diversity to Minimize CAPEX
Credit: NREL-Marj Schott

Increased resilience and GHG reductions result from a similar extension of this principle. Using a resilience metric of the percentage of annual loads that can be met with community resources (generation, storage, and demand flexibility), a CC could be able to achieve any given target level of resilience at lower overall system capacity (and therefore cost) than would an individual-building approach. For GHG reductions, a CC will be able to meet a higher percentage of annual loads with on-site renewables than if the same-capacity system were installed at individual buildings. Because of the load diversity between buildings, solar plus storage installations at the community scale can have higher utilization factors and associated self-consumption ratios than if the same total capacity were installed as numerous, smaller individual systems. An additional benefit of the CC in terms of GHG reductions is the ability to add sophisticated central controls at relatively lower incremental cost, such that targeting periods of low carbon intensity for grid imports (i.e., marginal emissions) becomes more achievable than trying to do this at the individual building level.

There are two ways in which load diversity results in additional demand charge reductions. First is the principle illustrated above, with multiple buildings sharing one battery resource. To the extent that monthly peaks are not coincident across buildings, a shared energy storage asset in a CC will be able to achieve greater demand charge reduction than if the same overall capacity were installed in multiple distributed pieces at individual buildings. Secondly, with a sufficient diversity factor, grouping multiple buildings behind one meter will result in a lower multi-building coincident demand than the sum of the individual building peak demands, which could reduce demand charges without any additional technologies.

In addition to providing demand charge reduction opportunities, a shared controls platform that aggregates building system flexible loads such as lighting, HVAC, water heating, and plug loads, can be leveraged to provide day-ahead, real-time, and fast-response grid services such as voltage regulation and frequency modulation.

In the case of district thermal systems, there may be inherent efficiency gains associated with larger equipment and decreased operating time at low load. In some cases, district thermal systems have significant energy consumption savings (ASHRAE, 2013).

On the utility side, to the extent that the above customer benefits associated with load diversity encourage a CC to further minimize annual grid purchases, reduce demand peaks, and/or increase islanding capability, the utility will benefit from avoided or deferred costs associated with infrastructure capacity upgrades and generation procurement.

Rate schedules and incentives

Rate schedules play a crucial role in aligning customer and utility-side benefits in the design and operation of a CC. For example, in utility territories with dynamic pricing or TOU pricing[11], the extent to which customers use load shifting strategies and thereby provide utility system benefits (i.e., reduced infrastructure and generation costs) largely depends on 1) how well the TOU periods align with periods of grid stress and 2) the quantity of load that is available to shed or shift on the customer side at the time of grid stress. How much a customer may use load shifting as a strategy also depends on the cost saving opportunity associated with this type of TOU price arbitrage. In other words, for the customer side, rate schedules help create the economic justification for incorporating the technologies and strategies that allow a CC to reduce and shift its load.

Typically, this economic justification will be due to some combination of high energy costs, large TOU price differentials, or high demand charges. A CC has the additional opportunity to create customer benefits by sizing the connected DER to take advantage of the most favorable rate class (by staying above or below a certain demand threshold). And on the utility side, the extent of the customer response to these rate schedules can drive cost savings in infrastructure investment and generation.

In addition to retail rate schedules, a CC may be able to leverage economic value in the wholesale electricity market. For utilities, CCs may create opportunities for cost savings through avoided electricity procurement or revenue through participation in ancillary service markets with the system operator. On the customer side, there has been an increasing trend toward (and

[11] As of 2018, Approximately 45% of U.S. utilities have dynamic pricing available for residential customers, and 64% of utilities have dynamic pricing for commercial customers, based on 2018 EIA-861 data for dynamic pricing.

federal legislation supporting) the participation of behind-the-meter resources in wholesale markets (CCL 2018, FERC 2019). Because wholesale markets often have minimum capacity thresholds, the CCs are in a better position to take advantage of value streams in both retail and wholesale markets than are individual buildings.

Incentives are another key factor in creating economic viability for CCs. Federal, state, and utility incentive programs can help tip the cost-effectiveness scale for a CC today by reducing the effective cost of technologies that enable CC implementation. In turn, incentives may also increase adoption rates of technologies, which then further drives down manufacturing costs as a result of greater market demand, thus enabling innovative technologies and solutions to be more cost-competitive (NREL, 2012).

Economies of scale

There are a number of ways that CCs can help leverage economies of scale to further reduce costs for both building owners and utilities.

- **Group purchasing and procurement.** On the customer side, buildings in a CC can aggregate demand for products and services related to efficient equipment and appliances, efficiency improvements like weather-sealing and window replacements, smart thermostats, grid-interactive controls for water heaters and HVAC system components, and networked lighting systems. By aggregating the procurement across multiple buildings, CC project stakeholders can negotiate lower prices with distributors, manufacturers, installers, and commissioning agencies. This same principle extends to energy efficiency audits as well; a CC could likely negotiate cheaper pricing for a community-wide efficiency audit and retrofit as opposed to numerous discrete audits and retrofits of single buildings. Additionally, solar arrays and energy storage installations will be cheaper, per unit of capacity, than the same equipment procured and installed separately at each building.

- **Efficiency program implementation.** CCs present an opportunity to improve operational effectiveness for utility, federal, state, and local energy efficiency and renewable energy incentive programs. Instead of working building-by-building, program implementers can work with CCs as a whole. The proliferation of larger projects can help make those programs more cost-effective to operate. In addition to the economies of scale that CCs lend to retrofit projects, the ROI of retrofit projects can be further improved by incorporating the CC approach resulting in deeper retrofits at scale.

- **Maintenance.** CCs with central thermal plants, solar PV, and energy storage installations can benefit from lower operation and maintenance costs and higher performance thresholds than distributed systems installed at the individual-building scale. Ease of access to central systems makes them more straightforward to maintain, and due to the more “critical” nature of the central installations (i.e., higher consequences for system failure), these systems may be maintained to higher performance standards than individual-building-scale systems.

Central controls and artificial intelligence

Digital control systems for building energy management and electric power systems have made substantial advances over the last decade. Increased network and processing speeds and advanced analytics have accelerated the development of predictive controls capable of managing complex multi-input, multi-output systems with constraints. Predictive controls can be especially useful for energy management and grid interactivity due to their forecasting capability and ability to optimize across numerous inputs in real time.

The application interface between these control systems is critical to unlocking their value. Generally, each asset type, from solar PV, to energy storage, to building automation systems that reach beyond HVAC, will have its own original equipment manufacturer (OEM) control mechanism. These controls may not be interoperable, and installing an umbrella system that unites the various assets can be cost-prohibitive at the single-building scale. However, at the multi-building scale, a sophisticated control system can be both more cost-effective and necessary to integrate and optimize DERs across buildings. In this way, CCs may be able to increase the effectiveness of grid-interactive resources and offer controls platforms capable of targeting numerous benefits on both the customer and utility side that would otherwise not be realized.

While not an exhaustive list, some examples of such benefits that can be realized by implementing sophisticated controls are shown below in Table 3.

Table 3: Benefits of Advanced Controls in Connected Communities

Customer	Utility/System Operator
Multi-objective optimization (e.g., TOU rate arbitrage, demand charge reduction, and GHG reduction)	Automated forecasts of available demand flexibility and anticipated dispatch capacity
Predictive thermal modeling of anticipated building loads, allowing for optimized pre-cooling/heating	Fast telemetry and streamlined communication with multiple energy resources (e.g., auto-DR, price signals, grid emergencies)

What Determines a Project's Design?

Physical or virtual connection

CCs can be connected either physically or virtually. Contiguous buildings allow for physical connections of the buildings' energy systems—for example, employing a district thermal system or a microgrid, or physically connecting multiple buildings to shared resources such as solar PV or an ESS. Without a physical connection, systems may be connected virtually through a network-based controls platform. Virtually connecting building systems and DERs within a local or regional territory can be operated to provide services to the grid. National portfolios of buildings such as a national portfolio of commercial buildings that are monitored or controlled via a central management system may be considered an aggregation of several virtually connected CCs.

In a retrofit project, the business case for a virtually connected CC may be much stronger than the case for physical connection. Virtually connected CCs, which use wireless communications to control the dispatch of DERs, allow for many of the same value-stacking opportunities as do physically-connected CCs. The table below summarizes the differences in value stream opportunities to the customer between physically connected and virtually connected CCs.

Table 4: Opportunities for CCs that are Physically Connected Versus Virtually Connected [1]

Value Proposition	Physically Connected CC	Virtually Connected CC	Customer Benefit	Utility/System Operator Benefit
CAPEX savings due to downsizing shared resources	Y	N	✓	
CAPEX savings due to shared central intelligence platform	Y	Y	✓	
Deferred grid infrastructure costs[2]	Y	Y[3]		✓
Energy bill savings from avoided grid purchases, demand charge reduction, and time of use (TOU) price arbitrage	Y	Y	✓	
Demand response (DR) and ancillary services	Y	Y	✓	✓
Resilience	Y	N[4]	✓	
GHG reduction	Y	Y[5]	✓	

[1] Opportunities are presented as additional benefits above those of a single building approach.
[2] Primarily a benefit to the utility, although savings to the utility could potentially be passed onto customers.
[3] Benefit to the utility is derived when virtually connected CC buildings are in same distribution network or service territory.
[4] On-site generation and energy storage systems at the single-building level can provide resilience, but there is no added resilience benefit by connecting these resources across noncontiguous buildings through a cloud-based, virtual network.
[5] With a grid that has a high penetration of solar PV (such as CAISO), a Virtually Connected CC may have limited marginal GHG benefits if midday PV production is exported to the grid. Physically connected CCs with sufficient load diversity can have higher utilization rates of on-site renewables, and thereby greater GHG reduction potential.

Physically Connected Systems for New Construction

Physical connections between buildings are often more feasible for new construction than for retrofit scenarios. In a new construction project, creating the physical infrastructure required to connect electric and thermal systems across buildings is more likely to be a viable option than in a retrofit scenario where these connections do not already exist. A new construction project will already have first costs associated with site preparation and utility infrastructure, and thus the opportunity exists to explore a physical network that connects multiple buildings' electric loads with on-site DERs, and/or a central district thermal plant. Whether or not this kind of configuration will prove to be more cost-effective than individual, building-level systems will depend on a number of factors, including:

- *Electric interconnection* – If the development will be built at the end of an existing distribution feeder, or if an existing distribution feeder will be extended to serve the new development, adding an interconnection switch package to control power flows and configuring for one POI with master metering may have a smaller incremental cost than if the development will be tied to multiple feeders or connected in the middle of an existing feeder.

- *Load diversity between buildings* – As discussed in Section *What Determines a Project's Value?* developments with greater load diversity between buildings will typically see higher returns from sharing electric or thermal resources per unit of installed capacity. Load diversity should be maximized and factored into the design to take advantage of the associated asset-sizing, demand-management, and cost-savings implications.

- *Site considerations* – Conditions at the specific development site, such as building layout and proximity, challenges associated with trenching to lay pipes and conduit, and any existing infrastructure, are important factors that will influence the feasibility and costs associated with establishing electric or thermal connections between buildings.

- *Ownership* – In cases where a multi-building district has one owner (such as a campus), physical connections are often more straightforward than in cases where multiple owners exist. With multiple owners, issues around asset ownership and control may create barriers to the implementation of a connected community with shared resources. Projects with multiple property owners will require stakeholders to align with the master plan, building standards, and energy management system protocols.

Physically Connected Systems for Retrofits

In the case of retrofit projects, while the business case for reconfiguring a distribution grid to physically connect multiple buildings and associated energy resources and/or to develop a microgrid may prove more challenging, some project stakeholders may still opt for this strategy for the following reasons:

- *Increased resilience* – In cases of power outages, microgrids can provide CCs with islanding capability and the ability to leverage DERs, such as solar plus storage, to supply power for critical loads when the microgrid is decoupled from the grid. In some retrofit cases, where resilience is crucial, project stakeholders may opt to develop a microgrid for a subset of critical facilities within a community. In these CC cases, a subset of buildings such as hospitals, fire stations, or schools could be physically connected by a microgrid, while a broader set of multiple buildings may still be virtually connected.

- *Streamlined energy services* – Aggregation of loads and integration of DERs through reconfiguring electric distribution infrastructure to allow for a single point of interconnection with the grid, enables streamlined communication and control. Appendix B.11 describes an example of a project that has opted for this approach, which enables the community's energy to be master metered and managed by a third party.

Virtually Connected Systems for Retrofits

For existing buildings that are noncontiguous or where a physical connection is cost-prohibitive, central control systems can integrate and aggregate DERs to form a virtually connected CC. These control platforms, sometimes referred to as virtual power plants (VPPs) or DERMS, are most commonly implemented by third-party entities such as DERMS vendors and demand response (DR) aggregators. The most evolved systems are capable of integrating with BASs, RE, ESS, and microgrid controllers, as well as grid-integrated EV chargers. Generally, resources are optimized for demand management and price arbitrage, employing analytics that factor day-ahead weather, demand forecasts, and price signals.

Currently, in the commercial sector, VPPs often incorporate ESSs, which are deployed to reduce on-bill demand charges, but which can also be bid into retail and wholesale demand response and ancillary services markets. In the residential sector, opportunities exist to aggregate smart home devices such as thermostats, water heaters, and residential ESSs to form a VPP that can respond to grid signals in aggregate.

Challenges associated with software integration across multiple OEM control interfaces have proven to be a barrier to integrating more resources onto these VPP platforms. As these barriers are overcome, and more DERs are deployed, this represents considerable market potential for integrating a larger percentage of the existing building stock into virtually connected CCs.

Building types

Variations in CC strategies are predicated on building use types. While examples of CCs exist for many building types, including residential communities, commercial building portfolios, and mixed-use districts, careful consideration of the building types, spatial constraints, load shapes, rate structures, and regulatory restrictions is required to optimize the design of a CC.

Mixed-use developments and their associated load diversity present opportunity for more efficient use of DERs. For example, a residential development will generally have peak loads in the morning and in the evenings. A commercial development load shape, however, will be complementary to residential loads in some ways, with peaks generally occurring earlier in the day. By physically or virtually connecting the energy systems of buildings with greater load diversity within a CC, designers can make more efficient and cost-effective use of any shared DERs.

In addition to allowing for more efficient use of DERs, the higher load diversity associated with mixed-use developments also leads to more load shedding and load flexibility opportunities and the enhanced ability to respond to demand response events. More specifically, load diversity spreads the opportunities for (or abilities to perform) load shedding and load flexibility out across time (days, day of week, seasons). As the load diversity of a CC increases, the likelihood of resource availability in the form of reserve capacity or load flexibility also increases. A mixed-use CC will therefore be able to provide more effective demand response and ancillary grid services (see Section *What Determines a Project's Value?* for more discussion on load diversity). Finally, if a district consists entirely of the same, or similar building type that peaks coincidentally with grid peaks, then the total opportunity for load shedding/shifting during grid peaks may be higher for that monolithic district.

Energy efficiency

The axiom "energy efficiency first" holds true when it comes to CCs. Energy efficiency measures that are incorporated into multi-building design and multi-building retrofits to reduce energy consumption can often achieve economies of scale and very often have favorable returns on investment. No matter the type of building, energy efficiency is decisively one of the most cost-effective approaches for energy cost savings.

Identifying the point of convergence between the energy efficiency cost curve and the DERs cost curve will assist in achieving more optimal design of new-build and retrofit multi-building projects. However, to accurately identify the convergence point, designers should make efforts to value the hidden and indirect benefits of energy efficiency. For example, in the case of residential developments, the evening ramp of energy load can substantially impact the grid. With higher levels of energy efficiency incorporated into the building design, the load curve is often smoother, with less ramp and lower peak demand, underscoring the role of energy efficiency in providing grid benefits (EPRI, 2017). Grid benefits have direct impact on the utilities' costs, which thereby reduce rates for customers. Furthermore, designers should consider the additive effects of integrative design and the potential for "tunneling through the cost barrier," (Lovins, 1984) in which incorporating aggressive energy efficiency measures results in additional benefits such as reducing the size of the HVAC systems, RE systems, and ESS required to offset and balance loads. In turn, reducing PV and storage size allows for more flexibility in lot orientation, floor plan, and elevations (EPRI, 2017).

What Determines a Project's Size?

There are three key considerations that help determine the size of a CC: 1) The number of buildings and owners, 2) the sizing of technologies deployed in the CC, and 3) the size of the connected load.

Number of buildings

The number of buildings in a CC will depend on a variety of factors including: project design and scope, the number of building owners, the geography and layout of buildings as they relate to utility distribution feeders, and whether the CC will be physically or virtually connected. Because of the value of load diversity discussed above, the economic case for a CC will likely improve as building types and number of buildings are selected to maximize diversity factor. In new construction, the number of buildings is commonly dictated by the size of the development.[12] In a retrofit application, where there is utility interest in grid infrastructure deferral, multiple owners may be able to come together to form a virtually connected CC that coordinates response to local grid conditions.[13] In the case of large campuses, having one owner makes a physically connected CC with a large number of buildings more straightforward.[14]

Technology selection and optimal sizing

The initial technology selection and sizing of energy assets in a CC will depend on the use case and ownership structure and will typically revolve around a primary value proposition identified by stakeholders in the development. In a customer-side project, this process will usually involve analyses incorporating several factors, such as building load profiles and characteristics, utility rate schedules and demand response programs, and any available incentives. In a utility-side project, building load profiles, capacity constraints, and grid services are likely to be among the

[12] See Appendix A.3 for an example.
[13] See Appendix A.5 for an example.
[14] See Appendix B.1 for an example.

primary factors considered in the analysis. The table below outlines the key technologies and their sizing considerations by value proposition.

Table 5: Sizing Considerations for Key Technologies by Value Proposition

Value Proposition	Key Technologies	Sizing Considerations
CAPEX savings	Centrally installed, shared systems (RE, district thermal, ESS) and EE	Maximizing cost-effective EE and size down by connecting multiple buildings with sufficient load diversity.
Deferred grid infrastructure costs	EE, RE, ESS, GEBs	Maximize cost-effective EE and then size to keep loads within capacity constraints of current grid infrastructure.
Energy bill savings	EE, RE, ESS, GEBs	Maximize cost-effective EE and size to optimize demand charge reduction, energy price arbitrage, and avoided grid purchases based on building load profiles. Typically diminishing returns for RE capacity beyond net zero.
Demand response and ancillary services	ESS, GEBs	Size based on parameters of DR or wholesale market program and building load profiles (customer side). Size based on grid constraints and needs (utility side).
Resilience	Microgrid, EE, ESS, RE	Maximize cost-effective EE and size to meet targeted off-grid capability (i.e., can meet critical loads for specified hours or days for average or worst-case conditions).
GHG reduction	EE, RE, ESS, GEBs	Maximize cost-effective EE and size to displace energy consumption at periods with highest grid emissions intensity with on-site renewable generation and/or demand flexibility.

The relative magnitude of each of these value propositions and any opportunities to "stack" value streams will depend on the local retail and wholesale energy market conditions. In order to take advantage of multiple value streams, the sizing (i.e., capacity) of technologies in a CC may need to be adjusted from what is identified in early analysis of the primary value proposition. Identifying additional market opportunities and adjusting system sizing accordingly can help to improve the ROI of the overall development.

An illustrative example of the iterative process described above is the case of a virtually connected CC consisting of energy storage and integrated BASs across a portfolio of commercial noncontiguous buildings, where a common primary value proposition is demand charge mitigation. By oversizing the energy storage and maximizing load shed opportunities to account for additional market opportunities and to allow for "reserve capacity" beyond what is needed for demand charge mitigation, these CCs can create additional value from demand response and/or ancillary services markets.[15] While the ROI of these secondary strategies may not be as high as what is delivered by demand charge mitigation, the *overall project ROI* may be increased by adding capacity to allow for value stacking opportunities.

Total connected load matters

Total connected load is often a bigger driver of project size than number of buildings. This is primarily due to two factors. The first is that greater connected load generally correlates to more load diversity and more resource capacity for load shedding, shifting, and modulating (see Section *Load Diversity and Shared Systems*). The second factor, which is related to the first, is that opportunities to take advantage of multiple value streams may depend on meeting certain minimum capacity thresholds for market participation.

In California, for example, retail demand response programs that are run by utilities are often geared toward single building (residential or commercial) participation. The system operator (CAISO), however, has a minimum capacity requirement of 100 kW to participate in wholesale energy markets, and a 500-kW capacity requirement to participate in ancillary services markets (CAISO, 2019). Given that one of the key value propositions on the customer side for connecting energy resources from multiple buildings is the possibility of generating value from both retail and wholesale markets, ensuring aggregation of sufficient capacity to meet these wholesale market thresholds will be a key driver of project size. In certain markets, customers may meet these capacity thresholds with a combination of traditional demand response measures (HVAC and lighting system load-shed) and energy storage dispatch.

Federal Energy Regulatory Commission (FERC) Order 841 aims to break down market barriers to energy storage. While the specific rules within each territory are still being finalized, the ruling likely allows for a retail/wholesale value stack to become available in every state. Thus, sizing considerations for customer side CCs should weigh both market opportunities, and size demand response and energy storage resources accordingly.

Opportunities at the city and regional scale

City or regional programs designed to aggregate resources across the built environment can result in scaling the benefits of CCs. At the city or regional level, programs can be rolled out with partnerships between and among cities and municipalities, utilities, and, in many cases, third-party, private-sector entities such as technology manufacturers and aggregators. City-scale programs that have proven to be successful include disseminating smart thermostats and smart appliances such as networked water heaters, implementing demand response programs that allow utilities to periodically control end-use devices, and installing EV charging stations with managed charging and vehicle-to-grid (V2G) capabilities.[16]

Market and Technical Challenges

This report indicates that CCs have significant value potential beyond a building-by-building approach. However, as noted by the collection of projects in the inventory (see Appendix B), few

[15] See Appendix A.6 for an example.
[16] See Appendix B.15 and B.43 for examples.

projects are currently leveraging the full extent of value described in this report. In part, this shortfall is because the CC approach is still relatively novel and market conditions (as well as regulatory regimes) are not fully aligned to support high levels of connectedness in retrofit or new construction projects. Additionally, specific technical challenges still exist, such as interoperability of DER technologies. Some of the challenges associated with CCs are also challenges to integrating more grid-interactive approaches at the single-building level. However, as outlined in this report, the additional value potential of CCs suggests that overcoming these challenges could help unlock a proliferation of projects leveraging multi-building approaches to energy management and not just GEB solutions at individual buildings. The following enumerates some of the barriers and challenges:

Market challenges

Utility rates and incentives

As utility rates and incentives are evolving, becoming more granular and more accurately reflecting the time-varying actual costs of energy, investing in CC approaches to realize value for both customers and utilities becomes more feasible. However, in many cases, rates and incentives are not yet dynamic enough to fully reflect needs and constraints on the electric grid, thereby truncating the economic value that CCs may be able to offer.

Regulatory landscape

Regulations in the energy sector, such as the ability for demand-side resources to participate in wholesale energy markets or be properly compensated for their services in vertically integrated markets varies by region and/or state. In some cases, regulations are more conducive to CCs, while in other states regulations are hindering the adoption of CC practices.

In addition, variation across the U.S. regulatory landscape governing interconnection of distributed generation and storage, and the ability for third-parties to provide energy services, presents challenges to some businesses and necessitates tailored business models according to state regulations.

Multiple owners

When multiple building owners are involved in a CC project, there may be challenges associated with organizing, coordinating, and aligning the value proposition across stakeholders. Allocating costs and benefits of the project among multiple stakeholders is significantly more challenging than a single owner scenario, such as a campus or portfolio of noncontiguous buildings.

Valuation of indirect value streams

Building owners face challenges in quantifying and assessing the indirect value streams of CCs such as GHG reductions, increased resilience, and others (see *What Determines a Project's Value?*). Furthermore, project owners and planners face challenges in weighing the various objectives and benefits of CC projects. For example, CC projects in general, and especially those with microgrids, provide energy resilience benefits (Utility Dive, 2018). However, a lack of standardized approaches to identify and value energy resilience investments in conjunction with the other benefits hinders the ability of decision makers to perform meaningful cost benefit analyses to inform decision making and incorporate resilience into the design process (NARUC, 2017).

Capital cost of shared systems

Physically connecting energy systems to leverage benefits of shared systems such as shared storage, may require costly infrastructure and logistical planning that can be prohibitive for projects. Physically connecting energy systems is especially challenging in retrofits, where the infrastructure is already in place.

In addition, while district thermal systems present opportunities for CCs to benefit from inherent efficiencies, economies of scale, and load flexibility, the capital costs of such systems are often a significant hurdle, especially in a retrofit scenario. Furthermore, the proximity of buildings in the thermal distribution network, subsurface conditions where piping is installed, the production cost of thermal energy, and customer connection costs are key drivers of cost effectiveness that vary project to project (Ontario Tech, 2012). Note that capital costs, financing, operations and maintenance expenses, and cost recovery are often distributed very differently across land and building owners, utility companies, third-party energy companies, etc. depending on the individual building and CC approach, which makes capital cost and total cost of ownership comparisons complex (e.g., split incentive effects, first costs vs. total costs of ownership).

Market awareness of CC approach

Adoption of the CC approach by stakeholders may be hindered by a lack of familiarity with the concepts. Many of the concepts presented in this report associated with CCs represent changes to the way building systems are managed and operated. Until awareness of these concepts and approaches becomes more commonplace, stakeholders may be reluctant to adopt changes that are not fully vetted or well understood by their personnel.

Technical challenges

Interoperability of systems

A key barrier to progress in accelerating the implementation of CCs is a lack of adoption of open data models and protocols for interoperability of systems. In CC project design, control platforms must be able to integrate with BASs and DERs, such as solar inverters and storage systems, as well as be able to receive and respond to utility signals, in order to deploy resources accordingly. Legacy building automation systems remain ubiquitous in existing building stock, resulting in integration challenges with many buildings.[17] The challenge of legacy BASs is compounded by the slow adoption of open protocols for DERs and standard data protocols by utilities (IREC, 2018). To overcome this interoperability challenge, standard protocols for grid interconnection and interoperability of DERs, such as IEEE 1547 and IEEE 2030, will need to be universally embraced by manufacturers and mandated by codes and standards. Finally, standards such as Open Charge Point Protocol, CTA-2045 and OpenADR that enable fast, reliable and

[17] Though the building automation control industry is moving toward open data models, such as Project Haystack and Brick Schema and protocols such as BACnet, Modbus, retrofit CC projects will still have to contend with the additional cost and challenges related to converting or integrating with older, proprietary building control systems.

secure demand response, or demand flexibility requests to customer-installed equipment will need to be taken up uniformly by utilities.

Multi-objective analysis and design

Multi-objective analysis and design, such as planning a CC project to take advantage of the full value stack, is a complex endeavor. While an integrative design approach enables CC project stakeholders to leverage greater value, designing to optimize across multiple value streams including energy cost savings, GHG reductions, resilience, and perhaps others is technically and logistically challenging.

For example, an integrative design approach to energy efficiency can result in energy cost savings as well as GHG reduction (See Section *What Determines a Project's Design*?). In addition, these energy efficiency measures can support resilience goals of a CC by decreasing backup generation needed and associated capital costs, reducing size requirements of renewables and storage needed to supply power for critical loads, as well as reducing dependence on external fuel sources (RMI, 2018). Designing to optimize across multiple value streams is not always straightforward. Greater emphasis, additional exploration, as well as effective design tools are required to streamline the assessment and foster a deeper understanding of the synergistic relationships and the potential of integrative design to support multiple value streams of CC projects.

Cybersecurity

Cybersecurity, ensuring that networked solutions for multi-building energy management are secure from cyberattack, poses significant challenges. Increasing sophistication of data network systems (including higher levels of integration, interconnectedness, and data exchange that are required in CC projects) creates cyber risk and vulnerabilities in the systems to malicious actors and cyberattacks. In order to mitigate the cybersecurity challenges and in turn realize the potential benefits of CCs, project planners will need to develop integrated cybersecurity strategies, perform detailed cyber impact and risk assessments, develop comprehensive data governance protocols, and build strategic partnerships to enhance cyber capabilities (Deloitte, 2019).

Subsurface piping installation

With district thermal and central thermal storage systems, there can be technical challenges associated with piping installation in some subsurface conditions, as well as efficiency losses from transporting thermal energy over long distances. Although, so called, ambient temperature loop systems, also referred to as fifth generation district heating and cooling networks, overcome heat loss challenges.

Summary of Findings

Based on the research and interviews conducted across a diverse set of CCs, the following inferences were derived:

1. CC projects can provide solutions that enable grid flexibility for reliability and efficiency and help meet GHG emissions reduction goals. Some individual projects have realized fractions of the total value that CCs may enable but, to a large extent, this potential is untapped across the country.

2. The CC approach can unlock greater value than a building-by-building approach. In other words, with the CC approach, the whole may be greater than the sum of its parts.

3. There are multiple value streams including customer value (e.g., CAPEX cost savings, energy bill reductions, and revenue streams from grid services) as well as utility system operational value (e.g., reduced capacity requirements, deferred or averted grid infrastructure costs, and increased reliability) to be accessed by various stakeholders, through developing CC projects for both new and existing developments.

4. Central control systems that are designed to optimize the operations of DERs such as PV and ESS in conjunction with buildings' operations are a critical component of CCs in order to provide maximum benefits to building owners, occupants, and the grid. A central control system in this context means a multi-building-scale control system, but not a large region-scale control system like an Independent System Operator (ISO) control center. However, an ISO control center in a hierarchal controls topology could influence the multi-building-scale control system.

5. In general, projects that connect more buildings of various types and greater load diversity (e.g., mixed-use developments) and a broad array of integrated technologies (DERs), are better able to leverage multiple value streams.

6. Where feasible, shared assets that are physically connected to multiple buildings (e.g., shared on-site generation, energy storage, and thermal systems) may have better life-cycle costs than individual building level systems due to potentially lower first costs, lower O&M costs, and/or higher utilization, more optimization pathways per unit installed capacity.

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Appendix A. Connected Communities, Case Studies

The following case studies are provided to illustrate a variety of CCs and their associated configurations and project types:

A.1 Seasons at Ontario

Project Type: Multifamily Residential, Retrofit
Location: Ontario, California
Phase: Operational since 2018
Unique Characteristics:

- Affordable housing
- Building owner/customer driven
- Shared benefits between building owner and tenants.

Photo Source: LINC Housing

Seasons at Ontario is an 80-unit, low-income senior community housing development with five buildings that underwent an energy retrofit in 2017. Project partners, including LINC Housing Corporation, an organization focused on creating affordable housing, and Electric Power Research Institute (EPRI) retrofitted the buildings to incorporate advanced energy technologies to demonstrate the financial practicality of such systems in low-income communities. When the development was up for tax credit re-syndication, the owner seized the opportunity to rehabilitate the property. The primary motivations for the retrofit project were to demonstrate how a near-ZE retrofit that incorporates DERs including solar, energy efficiency, and demand response can reduce tenant energy bills as well as reduce the owners' operating expenses.

The project incorporates a controls platform to perform integrated demand side management (IDSM), taking price signals including time of use, day ahead pricing, and demand response signals to control the smart thermostats in the units. Such controls are designed to streamline the monitoring and optimization of the systems for the end user and manage the complexity of the data inputs automatically, in order to benefit the customer. The system aggregates the resources and controls the community of devices to provide grid services.

The project also includes rooftop solar, which is allocated to the common area, and then to the tenants through a virtual net metering program. Virtual net metering is critical in a multifamily tenant scenario to make it possible for individual tenants to see financial returns and a reduction in their energy bills. The retrofit incorporated a number of energy conservation measures, such as heat pump water heaters, and resulted in total electrification of the development. Also, while the Seasons at Ontario project does not include energy storage, some LINC Housing projects are incorporating battery energy storage supported through grants. These projects are taking DC output from inverters and powering DC loads in the common areas to reduce efficiency losses. The primary use cases for these multifamily solar + storage projects are rate arbitrage, shifting the solar production to peak demand times for the end users, and providing backup power for resilience.

A.2 Lancaster Virtual Power Plant

Project Type: Mixed-use, noncontiguous, new construction and retrofit
Location: Lancaster, California
Phase: Under Development
Unique Characteristics:

- Project has regional footprint
- Community choice aggregator driven
- Combines both VPP and microgrids
- Wholesale market participation with excess capacity.

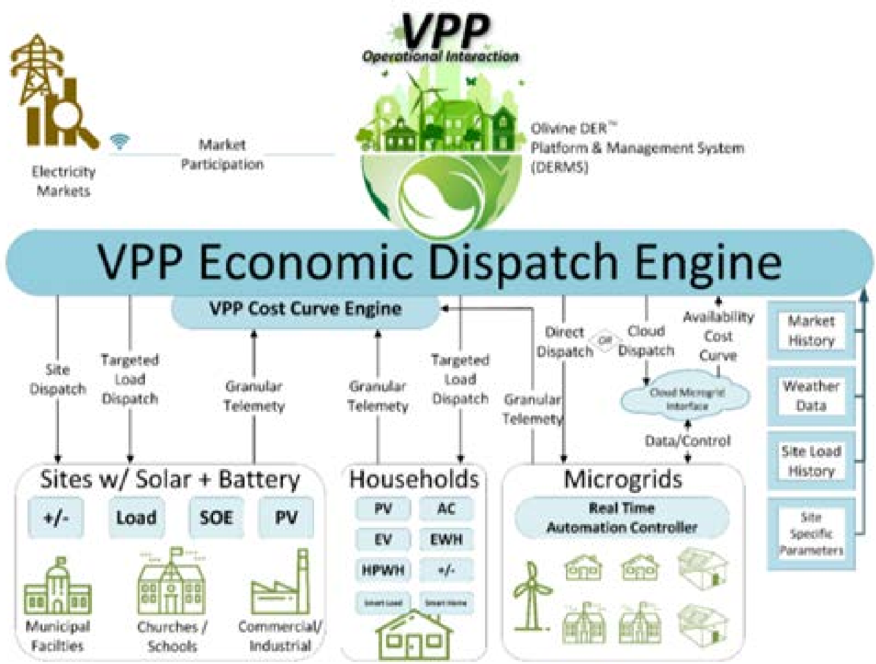

Figure A-1: Lancaster VPP Schematic

The Lancaster Virtual Power Plant (VPP) is a network-based aggregation of DERs within the service territory of Lancaster Choice Energy (LCE), a community choice aggregator (CCA), in Southern California. The Lancaster VPP is targeting to aggregate 10 MW of solar, 5 MW of energy storage, and 10 MW of flexible load capacity across a diverse set of developments:

- Three retrofit resilient school microgrids with solar and storage resources, as well as EV charging.
- Two new residential ZE microgrids, one 78 homes, the other 164 homes. Both are planned to have solar and battery resources and EV charging at each home. The larger development will have a 125 kW/500 kWh flywheel installation that will serve as a dedicated VPP resource.
- Thirteen additional schools with solar plus storage resources as well as EV charging.
- Five City of Lancaster facilities with solar and storage.

Over time, Lancaster VPP plans to add additional flexible load and dispatch through a commercial energy storage program run by LCE, as well as integration with smart household devices (e.g., water heaters, thermostats), and commercial buildings' energy management and control systems.

Olivine, a third-party integrator and demand response provider, will operate the VPP on behalf of LCE. Customer-sited resources will be controlled to benefit the customer first, and reserve capacity will be used to reduce costs for LCE (which, in turn, can further reduce customer costs). Olivine is a registered demand response provider with the California Independent System Operator (CAISO), allowing the VPP to participate directly in wholesale energy markets. Through a sophisticated controls platform, the VPP will optimize which resource is dispatched when, in order to maximize value. After customer-side value streams are maximized, the VPP's reserve capacity will be used primarily to avoid high wholesale procurement costs (e.g., the spot market during peak periods) and to maintain enough demand response capacity to count toward LCE's resource adequacy. The figure above is a schematic representation of how the VPP works.

A.3 Reynolds Landing

Project Type: Residential, New Construction
Location: Birmingham, Alabama
Phase: Operational as of 2017
Project Size: 62 single family homes
Unique Characteristics:

- Utility-driven project
- Shared resources for grid services, customer bill savings, and resilience
- Integration of building level and central controls

Photo Source: Green Tech Media

Housing developer Signature Homes partnered with Alabama Power to develop this newly constructed neighborhood of 62 single-family homes, located just outside Birmingham, Alabama. The community is supported by DERs, which can operate in conjunction with or disconnected from the existing electric grid. The partners saw the project as an opportunity to develop the future of homebuilding, to better understand interactions between buildings and the grid, and to evaluate the potential for non-wired alternatives to infrastructure upgrades.

The homes are designed and built to a high standard of energy efficiency and rated 45 on the HERS scale. The homes are constructed with 2x6 exterior walls with R24 blown-in fiberglass. Panasonic energy recovery ventilators (ERVs) are installed as standalone systems from the HVAC. Each home comes with a Wi-Fi integrated, variable-capacity heat pump system rated at 20 SEER, triple-pane windows, and LED lighting. While electric vehicle (EV) adoption is currently relatively low in Alabama, the homes are prewired and ready for EV charging with a NEMA 1450 plug in each garage.

Alabama Power owns the 330-kW solar PV array, a 600-kWh battery storage system, and a 400-kW natural gas generator. These distributed generation assets, located at the end of the distribution line, with the neighborhood in the middle of the line, form the microgrid, which is operated by the utility in front of the meter via the microgrid controller, CSEISMIC. This project is testing the technical challenges and economics of small-scale, utility-owned sites. The DERs connected to the microgrid could be sized for resilience with the battery, solar PV, and generator sized at the anticipated peak load.

The microgrid controller is integrated with each home's energy management system. The homes' energy management system is called VOLTRONN™, which was developed by the U.S. Department of Energy's Pacific Northwest National Laboratory. Homeowner control of their smart thermostat and appliances and can override commands from the microgrid, because the microgrid and home energy management controllers are designed to integrate seamlessly and manage a very complex set of determinants for the homeowner. The microgrid controller can facilitate load shifting and demand response with precooling as well as moving setpoints 2 degrees up or down HVAC and up to 140ºF in each home or a subset of homes in response to outdoor air temperature, price, and demand signals from the utility. In addition, each home is sub-metered down to the circuit level in an effort by the utility to better understand usage patterns.

The solar and storage assets are operated to provide overlapping benefits to both the utility in the form of grid services and to the customers in the form of energy performance. The utility is testing various strategies for optimizing the dispatch of the battery. Economics are considered by feeding the algorithms transmission price signals, charging the battery at low price times, and discharging when prices are high. Resilience is enhanced by reserving a percentage of the battery charge for islanding. In addition, grid balancing with the solar plus storage combination is being tested, using the battery as a flexible load for solar smoothing and capacity firming as well as to facilitate load matching between the solar production and residential demand.

A.4 Peña Station NEXT

Project Type: Mixed-use, New Construction
Location: Denver, Colorado
Phase: Operational as of 2016
Unique Characteristics:

- Customer-utility partnership
- Utility controlled battery, customer owned solar PV
- Assets operated for both customer and grid benefits
- Integration of building load flexibility and energy storage for increased resilience

Photo Source: Peña Station NEXT

Peña Station NEXT, upon all construction phases completed, a planned 382-acre mixed-use community situated on the first train stop from Denver International Airport (DEN), is designed to have a "portfolio microgrid" that would enable multiple stakeholders to share the assets as well as the benefits and services of the solar + battery energy storage system. The primary partners include Panasonic, currently the sole end-user on the microgrid and an equity partner in the development, and Xcel Energy, the distribution utility company. The project benefits Panasonic, as the microgrid enhances the resilience of their 24/7 operations, while Xcel Energy benefits by averting infrastructure costs of an already-constrained distribution grid through use of the battery for demand response as well as voltage and frequency regulation capabilities.

The microgrid is comprised of a 1 MW, 2 MWh battery that sits in front of the meter and is owned and operated by Xcel Energy to provide demand response as well as frequency and voltage regulation. A 259-kW rooftop solar array owned by Panasonic provides power to the Panasonic facility and is also coupled with the battery. The project also includes a 1.6-MWdc solar carport system that is not part of the microgrid but that is owned by Xcel Energy and connected directly to the distribution grid. Denver Airport covered the cost of the steel, as the carport provides covered parking for airport patrons. A reserve capacity of 25% of the battery is maintained to provide resilience to the Panasonic facility, a 24/7 operation. The microgrid is capable of islanding, at which time the building management system of the Panasonic facility monitors the state of charge (SOC) of the battery and sheds noncritical loads starting with lighting, changing HVAC setpoints, and then turning the HVAC system off.

A.5 FortZED

Project Type: Mixed-use, Noncontiguous, Retrofit
Location: Fort Collins, Colorado
Phase: Operational in 2012, but no longer operational
Unique Characteristics:

- Multi-owner partnership
- Strategic control to manage peak load and DER dispatch on one distribution feeder
- Successful example of multi-stakeholder relationship building and coordination

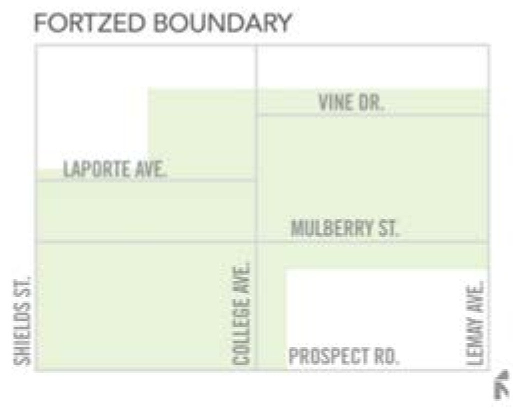

Figure Source: Fort Collins Government

The Fort Collins Zero Energy District (FortZED) was a pioneering effort that started with the goal of making Fort Collins a zero-net-energy district and evolved into a demonstration of DER integration for peak load management. Encompassing approximately two square miles, the project involved a number of partners including the city of Fort Collins, Fort Collins Utilities, Larimer County, Colorado State University, New Belgium Brewing Co., the technology company Spirae, and others. Loads under management included a total of 4 MW of generation such as PV, CHP, and conventional generators. In addition, a total of 760 kW demand-side management, load shed resources were under management. A central controls platform for the project enabled distributed energy resources to be automatically dispatched for demand reduction.

Through the Renewable and Distributed Systems Integration (RSDI) initiative, the FortZED project was successful in demonstrating the use of a standardized controls platform to manage multiple buildings and a diverse set of DER assets for demand management. The demonstration project enabled a 20-30 percent peak electric demand load reduction on the two feeders. With a district scale project of this magnitude involving multiple buildings and stakeholders, the relationship building, communication, and partnership development were critical to getting participants' cooperation for the central control platform and to achieving results.

Considered a lofty goal at the time of inception in 2007, the FortZED project did not actually achieve its goal of a zero-energy district before the project was disbanded in 2017 due to regulatory aspects, historic practices for energy distribution and natural project lifespan (~10 years)[18]. However, the project in many respects is considered a success and is credited with initiating critical dialogue and moving stakeholders towards accomplishing much of what the project set out to do. For example, the City of Fort Collins developed its ambitious Climate Action Plan, and Colorado State University has pledged to be powered by 100 percent renewable electricity by 2030. The FortZED projects resulted in many technical advancements around demand response, load control, and load flexibility for the companies and partners involved. Furthermore, an important outcome of the FortZED project has been to market Fort Collins as an innovation hub.

[18] https://www.coloradoan.com/story/news/2017/09/10/fort-collins-zero-energy-district-powers-down/646429001/

A.6 Virtual Power Plants

Project Type: Commercial, non-contiguous
Location: Multiple
Phase: Operational
Unique Characteristics:

- Mostly third party-driven
- Shared benefits between customer and third-party developer
- Varying models and degrees of sophistication, from deploying storage to reduce peak demand, to controls systems capable of integrating with building level systems.

Through wholesale and retail demand response and ancillary services markets, utilities and grid operators are rolling out programs to leverage a wider range of resources to help balance the grid and manage demand. In addition, electric utilities are creating more granular rate structures with time of use and demand charges.

These programs and tariffs, designed to more accurately account for the true cost of energy, are unlocking value streams associated with building portfolio energy management. To tap into these value streams, project developers and aggregators, as well as technology and controls companies, are developing strategies to aggregate building-level assets across large portfolios. These connected systems are often referred to as Virtual Power Plants.

A wave of projects in California has demonstrated that by installing energy storage systems in noncontiguous buildings, and aggregating these systems across a service territory, several value streams can be allocated among project stakeholders. Commonly among project developers and DERMS vendors, the business model entails third-party investors that finance the assets such as ESS. The customer or building owner does not put down any upfront investment but benefits from on-bill demand charge reduction as a result of the placement of the asset at their site. The investor benefits from revenues generated from wholesale and retail grid services markets, and the project developer or DERMS vendor may take a management fee and a portion of the revenues generated through grid services. A company called Stem is rolling out its storage as a service model, working with large enterprise customers such as JC Penney, AMC Theatres, Whole Foods, and Home Depot, and has deployed a total of 550 lithium-ion battery energy storage systems. Another company, Advanced Microgrid Solutions (AMS), has deployed energy storage systems at 21 commercial buildings owned by Irvine Company, several Walmart sites, and others, for a total of over 30 MW of battery storage capacity. A batch of Whole Foods stores in Northern California with a company called Axiom Energy uses tanks of salt water to store thermal energy and discharge the cooling to the refrigeration systems.

These energy storage strategies work by employing central control systems to monitor the buildings' energy demands in conjunction with tracking real-time energy prices. When prices are low, the energy storage systems are charged by the grid, and when prices are high, the storage is discharged. Value is generated by these systems through energy bill savings from reduced demand charges and energy arbitrage. In addition, revenues are generated by aggregating resources to participate in wholesale and retail demand response markets. Often the design of the storage systems incorporates excess capacity beyond the buildings' peak demand, in order to respond to utilities' demand response events.

Appendix B. Example Connected Communities

The following map and associated list present example CC projects in the United States in two categories. Although the authors made best attempts within the project constraints, it should be considered a partial inventory. The information presented below is summarized from project websites and publicly available information.

The projects highlighted in green are CC projects that align to a large extent with the definition of a CC provided in the Introduction and generally incorporate the four key elements. The projects highlighted in yellow do not fully align with this definition of a CC, but rather incorporate some of the key aspects of the definition and are therefore on the spectrum of CC projects as indicated in Figure B-1. Projects that currently do not fully align could undergo future changes to achieve a strong alignment with the provided CC definition.

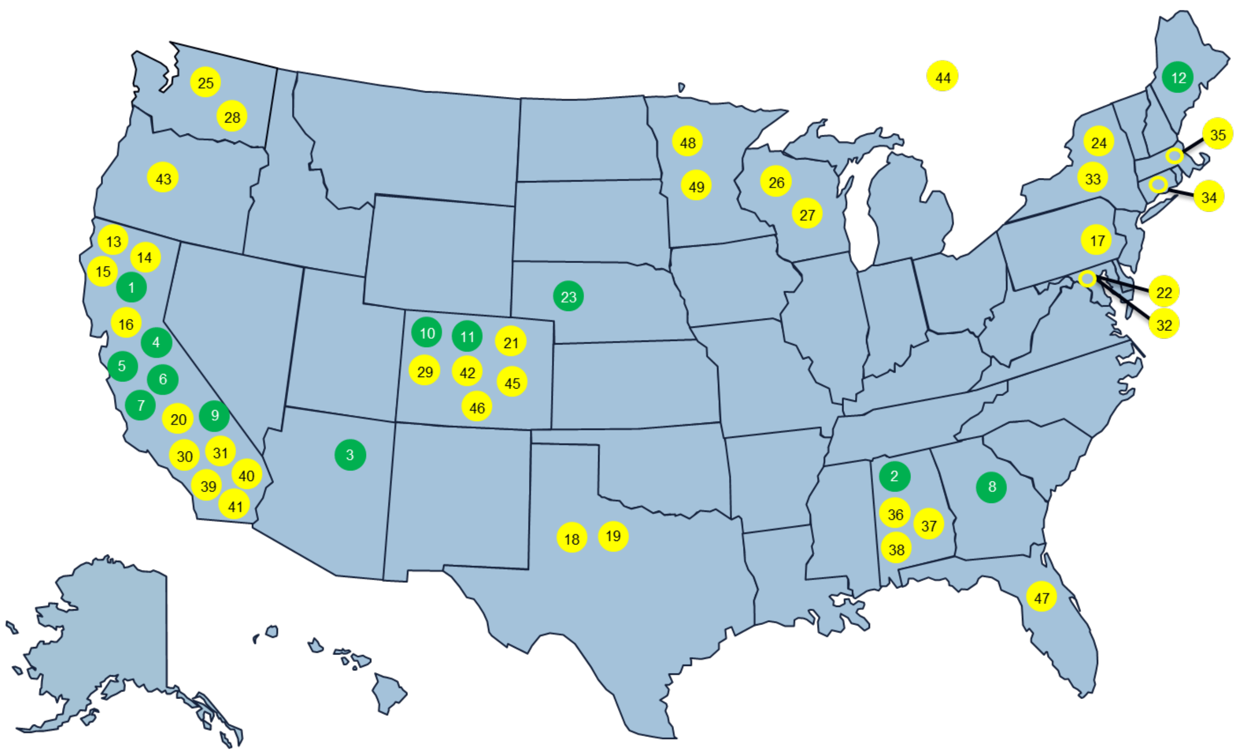

Figure B-1: Example Projects with Different Extents of Alignment with Report CC Definition

1	**Project:** Leap / Distributed Energy eXchange (DEX) **Project Type:** Commercial, Noncontiguous **Size of Project:** Unknown **Location:** Various cities in Northern California **Phase:** Under development

A company called Leap successfully bid on contracts to deliver 90 megawatts of commercial-industrial load reduction capacity under California's Demand Response Auction Mechanism (DRAM) program. The company has developed its Distributed Energy eXchange (DEX) API, a technology platform that communicates and integrates with HVAC systems, EV chargers, building automation systems, DER controllers and other resources that provide load shedding and load flexibility grid services. Leap is aggregating demand response resources by working with companies like Whole Foods, Axiom and others. Whole Foods is deploying refrigeration battery storage systems supplied by Axiom.

2	**Project:** Reynolds Landing **Project Type:** Residential **Size of Project:** 62 single-family homes **Location:** Birmingham, Alabama **Phase:** Operational as of 2017

Reynolds Landing is a newly constructed, single-family home residential community development. The project is a partnership between Southern Company subsidiary Alabama Power and homebuilder Signature Homes. The project incorporates efficient homes and a microgrid with 800 kW of on-site generation and 600 kWh of storage. The microgrid controller is operated by the utility company and is integrated with the home energy management system.

3	**Project:** Jasper in Prescott Valley **Project Type:** Residential **Size of Project:** 2,900 homes **Location:** Prescott Valley, Arizona **Phase:** Under development

Builder Mandalay Homes is partnering with Sonnen, an energy storage system company, to build Jasper, a single-family home development in Prescott Valley, Arizona. The design would equip each home with 3.9 kW of solar panels and an 8 kWh Sonnen battery. Through the SonnenCommunity central control system, the project would aggregate the battery storage capacity (11.6 MW and nearly 23 MWh) and enable it to be operated as a virtual power plant and to provide grid services. Various ownership and lease models are being explored for the building level assets.

4	**Project:** Mosaic Gardens at Pomona **Project Type:** Residential **Size of Project:** 46 apartment units **Location:** Pomona, California **Phase:** Operational as of 2016

An affordable housing community, Mosaic Gardens at Pomona, is a newly-build project focused on energy efficiency that earned a LEED Platinum certification. The project includes a central controller developed by Oak Ridge National Laboratory that manages the solar plus battery storage system, of sizes 33.6 kW DC and 61.37 kWh, respectively. The solar is allocated to the common areas in the community. The added measures are implemented to decrease tenant bills as well as operating expenses. An energy dashboard for the tenants is designed to motivate behavior-based energy reductions and allow for research on how low-income multifamily energy use differs from that of single-family homes.

5	**Project:** Seasons at Ontario **Project Type:** Residential **Size of Project:** 80 units **Location:** Ontario, California **Phase:** Operational as of 2018

Seasons at Ontario is a senior housing development owned and managed by LINC Housing. In partnership with EPRI, a retrofit project was conducted to bring the development into compliance with California Title 24. Measures such as smart thermostats and a 140-kW solar PV array were implemented, and advanced controls were developed by Oak Ridge National Laboratory. The project was designed to demonstrate Efficient Retrofit Packages (ERP) with Integrated Demand Side Management (IDSM) capabilities. The goal is to learn about customer comfort and behavior from energy usage patterns as well as the grid impacts of the energy retrofit measures.

6	**Project:** Oakland EcoBlock **Project Type:** Residential **Size of Project:** Block of 30 to 40 adjoining residences **Location:** Oakland, California **Phase:** Under development

Oakland EcoBlock is a proposed residential energy and water retrofit project led by UC Berkeley, with assistance from Lawrence Berkeley National Laboratory. The proposed project is at the block scale level and will connect the community to a microgrid with rooftop solar, block-level flywheel energy storage, and EV charging stations. The project enables grid-islanding capabilities. Furthermore, the project team is exploring the possibility of managing the DERs and grid services through an Integrated Energy Service Provider (IESP), whereby the private project developer would own the assets and the residents pay the microgrid utility costs to the IESP rather than to the local utility.

7	**Project:** Mosaic Gardens at Willowbrook **Project Type:** Residential **Size of Project:** 61 units **Location:** Los Angeles, California **Phase:** Under development

Mosaic Gardens at Willowbrook, a low-income housing development, is undergoing a retrofit project. The retrofit is designed to demonstrate a system of cost-effective and sustainable energy technologies for disadvantaged communities to ensure equal benefits to energy innovations. The project plan includes solar PV panels, a community-shared battery energy storage unit, DC lighting retrofits, and an automated intelligent controls system.

8	**Project:** Altus at The Quarter **Project Type:** Residential **Size of Project:** 46 units **Location:** Atlanta, Georgia **Phase:** Pre-development

Altus at The Quarter is a residential community with smart and sustainable features. The distributed energy resources, including rooftop solar and battery pack energy storage, are deployed at the building level. The battery storage is controlled by the home energy management system. The batteries receive signals from the utility, Southern Company, which may result in influencing operation of the battery but does directly command/control the battery. Also, the project includes managing devices (HVAC - standard heat pump and a mini-split, heat pump water heater, and EV charger) in conjunction with the battery and solar to understand their respective technical and cost advantages. The goals of the project include testing the ability of rooftop solar PV with battery storage and thermostats, heat pump water heaters, and EV charging working together to improve load balancing, leveraging data collection to determine how to improve customer energy bill savings, and better understanding how to align energy efficiency features to improve customer comfort.

9	**Project:** Lancaster Virtual Power Plant **Project Type:** Mixed Use, Noncontiguous **Size of Project:** City Scale **Location:** Lancaster, California **Phase:** Under development

Lancaster, CA is taking advantage of a virtual power plant approach to optimize DERs for cost savings, revenue generation, and grid resilience and to maximize DER value. Included in the project are two residential microgrids, with a demonstration of a flywheel energy storage system, and three renewable energy microgrids at local schools. The model in which the battery storage assets are to be deployed is a public-private partnership. The aggregation of all these resources allows the city to participate in the CAISO wholesale energy market.

10	**Project:** Peña Station NEXT **Project Type:** Mixed Use, Contiguous **Size of Project:** 100-buildings, 382-acre **Location:** Denver, Colorado **Phase:** Operational as of 2016

Peña Station NEXT is a new, planned 100-building, mixed-use district with its initial phase operational. To mitigate power system impacts and grid infrastructure investment associated with the district masterplan, Peña Station incorporated a microgrid design with islanding capability as well as solar PV and energy storage assets. The battery energy storage system is installed in front of the meter, is owned and controlled by Xcel Energy, and is operated to meet the utility's voltage regulation, frequency modulation, and peak demand requirements. A percentage of the battery capacity is reserved to provide resilience to Panasonic, the primary end-user currently connected to the microgrid.

11	**Project:** Fort Collins Zero Energy District (FortZED) **Project Type:** Mixed Use, Noncontiguous **Size of Project:** Downtown area scale **Location:** Fort Collins, Colorado **Phase:** Operational as of 2012

The FortZED project brought together five major building owners who wanted to help places of business regulate their energy usage to reduce load spikes in the grid during high demand periods. A large section of the grid served by two feeders provides energy savings and demand reduction potential. The buildings and DERs are connected together virtually with a central controls platform that enables communications between the distributed generation systems as well as the building automation systems associated with load shedding and flexible demand capacity.

12	**Project:** Isle au Haut **Project Type:** Mixed Use, Contiguous **Size of Project:** 140 participant meters **Location:** Gulf of Maine, Maine **Phase:** Under development

Off the coast of Maine, Isle au Haut is preparing for the risk of loss of an aging six-mile electric cable connected to the mainland. This project offers an alternative, lower-cost solution to the residents who own the island's utility company. It includes plans for a microgrid to mitigate possible power failures, keep the cost of energy low, and avoid price spikes. The microgrid involves a 250-kW solar array, a 1,000-kWh energy storage system, a diesel generator, a microgrid controller, and six air-to-water heat pumps with thermal storage. The project also includes plans to use a blockchain-based energy valuation network and metering system.

13 **Project:** University of California San Diego Microgrid
Project Type: Campus
Size of Project: 450 hectare, 761 buildings
Location: San Diego, California
Phase: Operational as of 2011

UCSD's goal to reduce costs of energy for the campus and reduce GHG emissions has resulted in a campus microgrid project that incorporates on-site generation, battery energy storage, two district thermal plants, and thermal storage tanks. The campus has undertaken an energy efficiency upgrade program since 2008, runs demand management of building loads in response to calls from the local utility, and manages the control of the DERs on campus through a central control platform. The university is considering installing a high-end master controller-Paladin which will control all generation, storage, and loads with hourly computing to optimize operating conditions. The project will continue to evolve towards more electrification as California's cap-and-trade program disincentivizes fossil fuel use by 2030.

14 **Project:** Irvine Co Hybrid Electric Buildings
Project Type: Commercial, Noncontiguous
Size of Project: 21 high-rise office buildings
Location: Various cities in California
Phase: Operational as of 2018

To reduce demand charges, Irvine Company, in partnership with Advanced Microgrid Solutions, has deployed distributed energy storage systems to 21 high-rise office buildings. The commercial portfolio leverages advanced energy management systems with building-level controls for energy demand that can shift the buildings to battery power. A cloud-based, virtual optimization software continuously monitors grid conditions and coordinates demand reductions across the portfolio to provide electric grid services to Southern California Edison.

15 **Project:** JCPenney
Project Type: Commercial, Noncontiguous
Size of Project: 26 stores
Location: Various cities in California
Phase: Operational as of 2015

The retail chain JCPenney is deploying on-site energy storage at multiple stores in partnership with the company Stem. Stem's software-enabled batteries operate the system and identify the demand management opportunities for savings. The stores have better control of the timing of energy use resulting in lowering demand charges, avoiding peak times, and protecting against future rate increases. The individual site optimizations benefit local customers through demand charge reductions, while the aggregated resources across multiple sites and managed through central controls by Stem, leverage wholesale markets and ancillary services as well.

16 **Project:** Ice Energy District Deployment
Project Type: Commercial, Noncontiguous
Size of Project: 1,200 units installed in SCE territory. Deployment in other states
Location: Various cities in California, and other states
Phase: Under development

Ice Energy is in the process of distributing thermal energy storage units to businesses to develop a distributed thermal energy storage system project. The units are designed to make ice during low-priced electricity hours and then use the ice to cool the air conditioners when electricity prices are otherwise high. The idea is to marry peak electricity demand with cheap overnight electricity prices. The first phase of the project deployed 100 icemakers, equivalent to 1.9 MW, while future plans include deploying over 1,200 icemakers at a number of businesses and industrial facilities across Southern California Edison's (SCE) territory. Many contracts are also implemented in other states.

17	**Project:** Philly Navy Yard **Project Type:** Commercial, Noncontiguous **Size of Project:** 7.5 million SF occupied, 10.5 million additional SF possible, 1,200 acres **Location:** Philadelphia, PA **Phase:** Operational as of 2013

The Navy Yard in Philadelphia leverages a district energy plan in which several smaller microgrids sync together. This plan seeks to reduce the city's carbon intensity and allows the city to participate in demand response. The on-site grid incorporates 1 MW solar PV, a 600-kW fuel cell, and a 6 MW natural gas peaking plant. The project supports grid resilience, emissions reduction, and system energy efficiency.

18	**Project:** Whisper Valley **Project Type:** Residential **Size of Project:** 2,000 acres, 7,500 homes **Location:** Austin, Texas **Phase:** Under development

Whisper Valley is a single-family home residential community under development that includes an integrated geothermal loop and central chiller plant. All homes are to be equipped with efficient appliances, nest thermostats, and (at the option of the homeowner) rooftop solar PV. For this new construction project, the developer is installing geothermal boreholes on each single-family property for geothermal heat pumps and integrating the piping with a central chiller plant for back-up during extreme heat events, which is an example of an ambient temperature loop systems and fifth generation district heating and cooling network.

19	**Project:** Pecan Street Inc. in Austin **Project Type:** Residential **Size of Project:** 1,115 active homes and businesses, 250 solar homes and 65 electric vehicle owners **Location:** Austin, Texas **Phase:** Under development

Pecan Street Inc., located in Austin, Texas, is a test bed for water- and energy-related products for the residential and small-scale commercial markets. The purpose of the project is to bridge the gaps between research, industry, and customers. Pecan Street Inc. is working with Austin Energy to test the integration of distributed energy resources (including solar PV, energy storage, and grid-integrated EV) and the associated impacts on grid stability.

20	**Project:** Oak View, Huntington Beach **Project Type:** Mixed Use, **Size of Project:** 660 acres **Location:** Huntington Beach, California **Phase:** Pre-development

The Oak View low-income community in Huntington Beach is planning to maximize cost-effective use of renewable energy sources, reduce emissions within the community, and reduce life-cycle cost of energy consumption for ratepayers. In addition, this retrofit project is geared to mitigating grid constraints and improving grid reliability and resilience. The project integrates on-site renewables and storage into the design.

21	**Project:** National Western Center (NWC) **Project Type:** Campus **Size of Project:** 250 acres **Location:** Denver, Colorado **Phase:** Under development

The National Western Center, a master-planned campus that will double the grounds that have housed the National Western Stock Show, is aiming to be a net-zero-energy campus. Renewable energy as well as district thermal solutions are included in the project. Some of the concepts are high-efficiency HVAC systems within each building, rooftop solar PV, and a wastewater heat recovery system that transfers thermal energy from a City of Denver wastewater pipe running through the property to buildings via a campus piping and heat pump network as an example ambient temperature loop system. Energy storage and/or biofuel generators for campus load management and demand response opportunities are being considered.

22	**Project:** Montgomery County Microgrid / Schneider's Boston One Campuses **Project Type:** Campus **Size of Project:** <10 buildings **Location:** Rockville, Maryland **Phase:** Operational as of 2017

A combination of advanced controls and demand-side management software allows the microgrid at Schneider's Boston One Campus to manage on-site solar, energy storage, EV charging stations, and building HVAC assets more efficiently. Since the investment is going behind the meter, adoption of new utility rate designs is under discussion with the local utility company, Duke Energy. The goal of this project is to mitigate some of the regulatory and technology roadblocks currently associated with microgrids.

23	**Project:** University of Nebraska **Project Type:** Campus **Size of Project:** Multiple buildings **Location:** Lincoln, Nebraska **Phase:** Operational as of 2012

The University of Nebraska in Lincoln has implemented many sustainability efforts, such as a thermal energy storage (TES) tank, water source heat pump loop, and a centralized renewable energy system (CRES). The TES reduces operations costs by utilizing a water storage tank to offset the normal operation of the chiller. The water source heat pump loop allows for a more sustainable way of heating and cooling, while the CRES provides heating and cooling without the use of steam boilers and water chillers.

24	**Project:** Cornell Tech Campus **Project Type:** Campus **Size of Project:** 12 acres, Bloomberg Center is 160,00 SF **Location:** New York City **Phase:** Operational as of 2017

Cornell's Tech Campus is built with cutting-edge sustainability features such as being all-electric and including highly insulated envelopes. The site also incorporates a number of energy options, including ground source geothermal, two solar canopies totaling 800 kW, and hydrodynamic power. In addition, an apartment building within the campus features a Passive House design.

25	**Project:** Microsoft Campus **Project Type:** Campus **Size of Project:** 2.5 million SF new office space, 6.7 million SF of existing renovations **Location:** Redmond, Washington **Phase:** Under development

Powered entirely by hydropower, the Microsoft campus in Washington is pioneering ways to reduce their carbon footprint. New buildings on the Redmond campus will be supplied with a building monitoring system, made by Azure, for optimization of energy usage. The campus also places high emphasis on accessibility and preservation. To stay green on the transportation end, transit options are fully funded for employees and the underground parking structure features smart parking technology. The campus is built for easy access for pedestrians and cyclists alike.

26	**Project:** Gundersen Health **Project Type:** Campus **Size of Project:** 45 buildings **Location:** La Crosse, Wisconsin **Phase:** Operational

Gundersen Health is undertaking a number of renewable energy projects to power its buildings. The campus includes biogas, biomass, geothermal, solar PV, solar hot water, and wind power.

27	**Project:** Epic Campus **Project Type:** Campus **Size of Project:** 25 buildings, 1,100 acres **Location:** Verona, Wisconsin **Phase:** Operational as of 2018

A medical systems software company has created Epic Campus, a space with multiple sustainability features. The campus contains daylighting, PV panels, a geo-exchange field and pond, wind turbines, and 1.6 million SF of green roofs.

28	**Project:** Catalyst Spokane **Project Type:** Commercial **Size of Project:** 2 buildings **Location:** Spokane, Washington **Phase:** Under development

A building in Spokane, Washington, envisioned to be part of a 770-acre University District, is adding several components of sustainable design. Such design parameters include the use of cross-laminated timber material, a gray water system, low-flow fixtures, and a smart building management system to ensure efficient operations and control. This project has the potential to be a model for future developments.

29	**Project:** Westminster Reduced Energy District **Project Type:** Commercial, Noncontiguous **Size of Project:** City scale **Location:** Westminster, Colorado **Phase:** Pre-development

The local utility company, Xcel Energy, is developing programs for the city of Westminster, Colorado, to help facilitate its vision to be a low-carbon and sustainable development. Various energy efficiency programs and renewable energy offerings will set the city on a path toward reducing greenhouse gas and carbon dioxide emissions and achieving electricity savings.

30	**Project:** StoneEdge Microgrid **Project Type:** Commercial, Noncontiguous **Size of Project:** 16 acres including 16 buildings **Location:** Sonoma, California **Phase:** Pre-development

StoneEdge Farm in Sonoma, California, has built a microgrid to serve as a technology demonstration and to provide energy independence in the event of main grid failure. This microgrid will be able to run in parallel to the macro, or main-grid and will also have islanding ability. The assets to be included in the microgrid for distributed energy generation are solar arrays, hydrogen fuel cells, and a microturbine. Meanwhile, for storage, the assets will include batteries and hydrogen. The project is privately owned and is meant to be an open-source platform, setting the stage for any facility, community, or city to replicate.

31	**Project:** Walmart **Project Type:** Commercial, Noncontiguous **Size of Project:** 27 buildings **Location:** Various cities in Southern California **Phase:** Operational

Advanced Microgrid Solutions (AMS) has deployed energy storage batteries at Walmart stores in California. For Walmart, the systems bring the ability to shave expensive peaks, smooth out imbalances in on-site generation and consumption, and help the company meet a goal of powering half of its operations with renewable energy by 2025. AMS will manage Walmart's batteries to lower demand charges and provide demand response revenues by aggregating these resources within a service territory.

32	**Project:** General Motors E-Motor Plant **Project Type:** Commercial, Contiguous **Size of Project:** One building **Location:** White Marsh, Maryland **Phase:** Operational as of 2015

TimberRock Energy Solutions partnered with OnStar and General Motors (GM) to develop a microgrid demonstration project, exploring the next generation of energy infrastructure at large commercial and industrial facilities. The objective of the project was to quantify how a microgrid comprising DERs, such as solar PV, EV charging infrastructure, stationary li-ion storage, and a small fleet of EVs, could deliver an economic "benefit stack" to participating stakeholders.

33	**Project:** Western New York Manufacturing Zero Energy District **Project Type:** Commercial, Noncontiguous **Size of Project:** 148 acres of the 994-acre Bethlehem Steel Redevelopment Area, 93,000 square feet for first building **Location:** Buffalo, New York **Phase:** Pre-development

An old brownfield site will be used to develop a light manufacturing facility and office space in the Buffalo, New York area. The project will be the state's first-ever zero-energy manufacturing facility of its size, at 80,000 SF. The facility will be powered by solar, geothermal, and wind energy. The building is intended to be a “lighthouse project” to attract more buildings like it to the area. It will also become a place for education about sustainable building design, resilience, and innovation for industrial manufacturing.

34	**Project:** Milford Microgrid **Project Type:** Commercial, Noncontiguous **Size of Project:** <10 buildings **Location:** Milford, Connecticut **Phase:** Under development

In Milford, Connecticut, a microgrid is being built to serve a middle school, a senior center, an apartment complex and two town buildings. The microgrid is intended to reduce the cost of electricity and serve as a virtual net metering program. The town will use a tax-exempt lease purchase to finance the costs of the microgrid, while Schneider Electric will design and maintain the equipment.

35	**Project:** Sterling **Project Type:** Commercial, Noncontiguous **Size of Project:** <10 buildings **Location:** Sterling, Massachusetts **Phase:** Operational as of 2018

A community solar plus storage project allows the town of Sterling to island in the event of a power outage. With a PV solar array of 3 MW and a 2 MW lithium-ion battery, the community can be provided emergency backup power. The grid-scale battery system mitigates the cap of commercial solar capacity. The project presents itself as an energy storage demonstration by which the economic case for batteries is being studied.

36	**Project:** Northwoods **Project Type:** Residential **Size of Project:** 51 homes **Location:** Auburn, Alabama **Phase:** Pre-development

Alabama Power is developing a homebuilding program to partner with homebuilders on smart neighborhoods across the state. The aim of the project is to construct energy-efficient homes that feature advanced energy products and home automation systems to benefit both homeowners and the utility company. The energy-efficient construction will feature improved insulation, high-efficiency heat pump and water heater, and Energy Star appliances. Meanwhile, examples of smart products to be installed include Google Home smart speakers for voice control and Nest learning thermostats to help save energy and provide more control over the home's temperature at any time.

37	**Project:** Harris Doyle Homes **Project Type:** Residential **Size of Project:** 55 homes **Location:** Auburn, Alabama **Phase:** Pre-development

A homebuilder, Harris Doyle Homes, and a local utility company, Alabama Power, plan to build new energy-efficient homes. The plan makes use of a wide array of energy-efficient building products, including low-E window panes, radiant-barrier roof decking, tankless water heaters, high-efficiency furnaces, and spray-foam insulation.

38	**Project:** Cedar Rock Farms **Project Type:** Residential **Size of Project:** 21 homes **Location:** Leeds, Alabama **Phase:** Operational as of 2018/2019

The homes at Cedar Rock Farms are high-performance houses, built with enhanced energy efficiency measures that go beyond industry standards. Built in partnership with Alabama Power, the homes include programmable thermostats, improved insulation, and high-efficiency heat pumps, water heaters, and appliances. Homeowners can handle routine tasks through smartphones, tablets, and voice-activation.

39 **Project:** Nightingale at Compton
Project Type: Residential
Size of Project: 30-unit apartment complex
Location: Los Angeles, California
Phase: Under development

EPRI is partnering with LINC Housing to develop a low-income community constructed to combat homelessness in the LA area. The project is designed to improve energy efficiency and reduce energy bills for traditionally underserved markets. Nightingale at Compton seeks to demonstrate the energy-saving potential of an all-electric, net-zero-energy community. Some measures taken are improved central heat pump water heaters, high-efficiency windows and appliances, and 80 kW of rooftop solar PV.

40 **Project:** CitySquare at Irvine
Project Type: Residential
Size of Project: 44 three-floor units
Location: Irvine, California
Phase: Operational as of 2019

Meritage Homes partnered with EPA, SCE, EPRI and the City of Irvine to develop an innovative, all-electric, zero-energy condominium community. The neighborhood demonstrates the energy-saving potential of home electrification while analyzing the performance of the energy improvements. The goal of the project is to use new methods of home construction to reach net-zero-energy status.

41 **Project:** De Young EnVision at Loma Vista
Project Type: Residential
Size of Project: 36 homes, 26 acres
Location: Clovis, California
Phase: Operational as of 2018

The De Young EnVision community is a single-family home development designed to demonstrate the benefits of high-efficiency, high-performance communities. The homes feature rooftop solar PV sized at 3.5-kW, high-efficiency HVAC systems, and Aerobarrier envelope sealing. The community is further exploring how the integration of smart connected devices can be used to reduce carbon footprint and how load balancing is impacted by solar.

42 **Project:** Revive
Project Type: Residential
Size of Project: 86 units
Location: Fort Collins, Colorado
Phase: Operational as of 2017

Revive is a net-zero-carbon-emissions, solar- and geothermal-powered housing development in Fort Collins, Colorado. The homes are rated as negative on the Home Energy Rating System (HERS), which means they produce more energy than they use. The idea behind the project was to create a new standard for energy efficiency, keeping in mind every detail in the home from the solar on the roof to the recycled materials in the carpet. Another energy measure included in the community is geothermal wells underneath each home.

43 **Project:** PGE Smart Grid Test Bed
Project Type: Residential
Size of Project: Three neighborhoods, 20,000 customers
Location: Portland, Oregon
Phase: Pre-development

Portland General Electric plans to build a test bed in three Portland neighborhoods to allow for two-way flow of electricity and information. The utility company hopes to upgrade existing feeders and substations with advanced automation distribution technologies and allow for customers to utilize smart thermostats, smart domestic hot water heaters, and peak time rebates. The test bed will help introduce the energy transition using new technologies, products, and programs while still allowing customers to have control over their comfort in an affordable manner.

44	**Project:** Quayside Waterfront, Toronto **Project Type:** Mixed Use, Contiguous **Size of Project:** 2,500 units for 5,000 residents, and retail, 12 acres **Location:** Toronto, Canada **Phase:** Pre-development

Quayside is a planned new neighborhood in Toronto, Ontario, Canada. The project group is designing for an advanced power grid with batteries, a thermal grid to capture clean energy from the buildings' heating and cooling systems, low-load buildings to minimize heating loads and provide resilience, an active stormwater management, and more. The project aims to create a pathway to climate-positive communities.

45	**Project:** Montava **Project Type:** Mixed, Contiguous **Size of Project:** 4,500 residential units, 860 acres **Location:** Fort Collins, Colorado **Phase:** Pre-development

The idea behind Montava is to bring together an energy-efficient neighborhood consisting of residential homes, retail spaces, schools, and a farm. Mandalay Homes and Thrive Homebuilders, two high-efficiency builders who have implemented net-zero-energy designs in the past, are taking on the challenge to build this sustainable community. The project is intended to demonstrate how a large-scale development can reduce its environmental footprint.

46	**Project:** Sun Valley EcoDistrict (SVED) **Project Type:** Mixed Use, Contiguous **Size of Project:** 100 acres, 1.6 million SF **Location:** Denver, Colorado **Phase:** Under development

A low-income neighborhood in West Denver, Colorado, is undergoing an extensive redevelopment to minimize economic displacement. With a focus on bringing more affordable housing units to the area while integrating them with middle-income homes, the community hopes to spread costs equally among residents. Renewable district energy systems are being co-developed with the Xcel Energy. As part of the planning process, developers are considering how to tie together DERs with both the existing buildings and new properties.

47	**Project:** Babcock Ranch **Project Type:** Mixed use, Contiguous **Size of Project:** 19,500 homes, 6 million square feet of commercial space **Location:** Babcock Ranch, Florida **Phase:** Under development

A solar farm, bought by Babcock Ranch but owned and operated by Florida Power and Light (FPL), is being built to serve Babcock Ranch and its surrounding community with clean, renewable energy. From a financial standpoint, the residents are billed under the same rate structure as other FPL customers, but since the homes in Babcock Ranch are equipped with energy-efficient products and therefore use less energy than most homes, their electric bills are lower. However, the primary goal of the community is not about saving money for tenants, but rather setting the stage for the use of solar for the rest of the country.

Babcock Ranch also includes many other sustainability features such as tree preservation, water efficiency, and sustainable material usage.

48	**Project:** Grand Rapids Solar + Storage **Project Type:** Mixed Use, Contiguous **Size of Project:** Unknown **Location:** Grand Rapids, Minnesota **Phase:** Operational as of 2019

A citizens group, Itasca Clean Energy Team, the municipal utility company, Grand Rapids Public Utilities, and the main utility company, Minnesota Power, are all working together to develop a solar plus storage community in Grand Rapids, Minnesota. The plan calls for a 1 MW solar array and 2 MWh battery system. The goal of the project is to lower demand charges by storing the solar energy in batteries and deploying the batteries during high demand times.

49	**Project:** Morris Dairy Farm **Project Type:** Residential, Agriculture **Size of Project:** Unknown **Location:** Morris, Minnesota **Phase:** Under development

EPRI is working with a dairy farm and a new home community, combining energy efficiency and load balancing to provide grid services and support. The main focus is on understanding the thermal energy flows and opportunities for heat recovery and energy efficiency. The community intends to conduct measurements of energy usage and develop a load shape model using the operating schedules of the dairy farm. They will look at how applications of renewables, both PV and wind generation (currently at the farm and future planned), will impact net load shape and the distribution system.

Appendix C. Interview Template

Interviewee(s):
Organization:

Interviewers:
Date:

Project Background

1. Briefly describe your involvement with the project(s):

2. Provide the following background info

	Name of Project	City, State	GEBs (Y/N)	DER (Type/ MW)	Storage (MW/ MWh)	Microgrid (Y/N)	# of buildings/ building types	Approx. total square footages	Approx. total Connected Load (MW)
1.									

3. Does the project participate in or utilize an energy benchmarking program? Examples include EnergyStar Portfolio Manager, Better Buildings Challenge, GRESB?

   a. Would the appropriate party be willing to share this energy data with us for purposes of the study?
   b. Do you have an idea of the level of efficiency of the buildings in the community? What is the EUI of the building types?
   a. EUI, x % above local code, etc…
   b. What are the building types in the district?
   c. What certifications, if any, does the project have? Examples include LEED, Living Building Challenge, Passive House, EnergyStar for Buildings, etc.

Measure Specifics

Below are some more in-depth questions about the measures in each of the categories described above

Grid Integrated Energy Efficient Buildings

1. Do any of these building systems include connected (or “smart) devices or controls? Please describe. [May include grid-interactive controls]
   i. Envelope measures

ii. Lighting measures
iii. HVAC measures
iv. Other

2. Retail Demand Response: Is the project enrolled in a demand response program? Can you tell us about the program? [specific questions below if needed]
    i. Which program?
    ii. Is the program through a utility or an aggregator?
    iii. Is the DR control automated?
    iv. Is DR enrollment at the building or district level?
    v. What is the approximate annual revenue from DR program participation?

3. Wholesale markets [Only follow up with this if it seems relevant, otherwise skip to #4]: Does the district (or buildings within the district) participate in any wholesale electricity market program? E.g., capacity market, ancillary services (spinning reserves, black start, frequency regulation), demand bidding?
    i. Which program?
    ii. Through an aggregator or directly?
    iii. What is the approximate annual revenue from WS market participation?

Renewable Energy Generation

4. Which, if any, energy generation technologies are present (e.g., Solar, wind, biomass)?
5. Are these resources at the building or community scale? Why has the system been designed in this way (e.g., shared vs building level asset)?
6. Is there EV charging infrastructure?
7. Is EV charging controlled? How?
8. Is there Vehicle->Grid Integration (VGI) capability? If yes, please describe.

Energy Storage

9. What type(s) of energy storage are present? Examples include batteries, flywheels, thermal storage.
10. Are these resources installed in front of the meter or behind? How are they controlled (by the utility, customer, 3rd party)? [questions a-c below only if needed/relevant. Otherwise skip to #11]
    a. Size of customer-controlled resource vs. utility-controlled resource?
    b. If behind the meter, are the resources installed at the building or community level (i.e., shared)?
    c. Describe the charging/dispatch strategy and how this strategy was developed?

Microgrid

11. Is the project a microgrid as defined by a central point of interconnection and the ability to island/reconnect to the larger grid? [If no, skip to #12]
    Y/N

    a. What is the main driver for creating a microgrid?

Advanced Controls and Data Analytics

12. What mechanisms are employed to "connect" the community/district/portfolio [choose as appropriate]
    a. Is data collected/shared across buildings?
    b. Electricity
    c. Thermal connection (e.g., District heating or cooling, central plant serving multiple buildings, cogen facility)
13. Describe your metering and submetering program?
14. Describe any district scale controls that integrate and optimize energy resources and data across multiple buildings?
    a. In the case of multiple buildings with multiple owners, how are BASs connected? What organizing body designs and maintains this system?
    b. What is/are the primary use case(s) for these controls (Rank 1-6, 1 being highest priority) [have them describe and rank if applicable]? Are there attempts at value stacking? Describe?

Energy conservation	
Demand charge management	
Resilience/backup power	
TOU price arbitrage	
Non-wires alternative/ grid infrastructure deferral	
Other: Describe:	

    c. How do these controls interface with district resources? (e.g., Through the BAS at the building level, inverters for storage and DERs) [only if relevant, NA if not]?
    d. How do these controls interface with the utility/system operator (e.g., Virtual end node, telephone) [only if relevant, NA if not]?

Business Model

[send out value stack matrix ahead of time, ask them to fill out and will discuss reasons on call]

15. Describe the drivers of the decision to include “connected” measures from multiple categories? Rank the justifications below [if applicable] (1-4, 1 being highest priority)

Resilience (Due to an unreliable big grid or because of a critical facility)	
Financial returns	
GHG Reduction	
Non-wires alternative / grid infrastructure deferral	
Innovation	
Economic revitalization	
Equity and inclusion	
Other: Describe: XXX	

16. Describe the drivers of the decision to apply these measures at a district scale, across multiple buildings, as oppose to individual buildings? Rank and explain the justifications below [if applicable](1-4, 1 being highest priority)?

Economies of scale, financial impacts	
Increased resiliency	
Higher GHG reduction	
Other: Describe:	

a. What were the key advantages or disadvantages to designing energy management at the multi-building, district level?

b. How did the project being new build or retrofit factor into the energy management design outcome?

c. How did the building usage type (e.g., residential, commercial, mixed use, portfolio, or campus) inform the system design?

17. How were the categories/measures selected? Include all that apply.

(a) Analysis by paid consultant

(b) Grant funding opportunity
    (i) Including statewide incentives
(c) Input from utility
    (i) Including incentive program
(d) Internal analysis
(e) Other?

18. Was the utility involved during the planning phase to give input on type and sizing of energy resources in the district?

19. Please describe the ownership model of the energy assets in the district [reference a. if needed]?

    a. How are operational decisions made?
        i. At the district level?
        ii. At the individual building level?

20. Were the project's economic goals met (ROI/IRR)[only for completed projects, NA if not]?
    - What contributed to achieving/not achieving these goals?

21. Key findings/learnings from development?
    - What has worked well (successes)?
    - What has been challenging?
    - What questions or challenges remain unresolved?