A GUIDE TO ENERGY MASTER PLANNING OF HIGH-PERFORMANCE DISTRICTS AND COMMUNITIES

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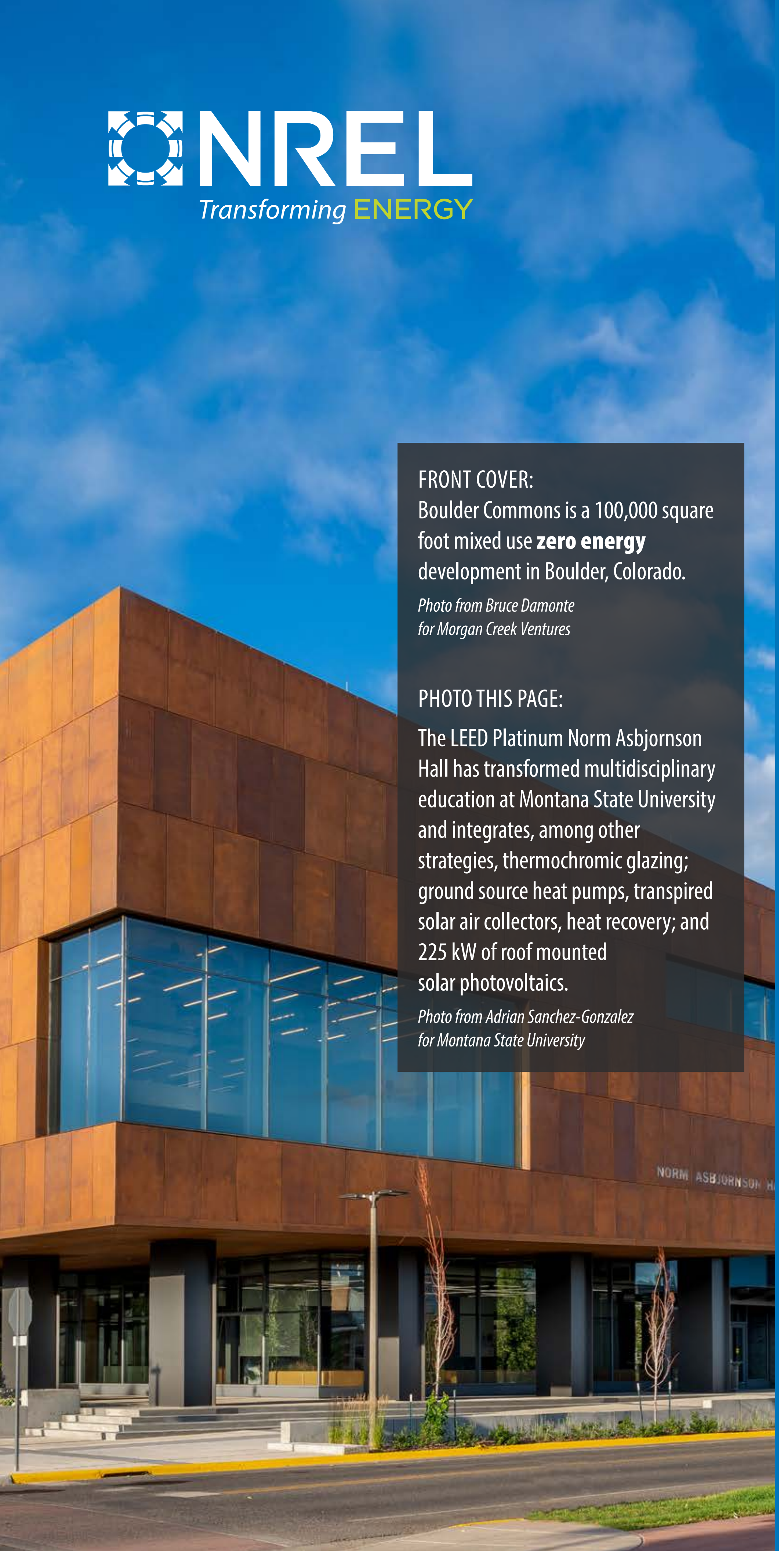

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FRONT COVER:
Boulder Commons is a 100,000 square foot mixed use **zero energy** development in Boulder, Colorado.
Photo from Bruce Damonte for Morgan Creek Ventures

PHOTO THIS PAGE:
The LEED Platinum Norm Asbjornson Hall has transformed multidisciplinary education at Montana State University and integrates, among other strategies, thermochromic glazing; ground source heat pumps, transpired solar air collectors, heat recovery; and 225 kW of roof mounted solar photovoltaics.
Photo from Adrian Sanchez-Gonzalez for Montana State University

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ACRONYMS

DOE	U.S. Department of Energy
EUI	energy use intensity
EV	electric vehicle
EVSE	electric vehicle supply equipment
FEMA	Federal Emergency Management Agency
HP	high performance
HPD	high-performance district
HVAC	heating, ventilating, and air conditioning
IESP	integrated energy services provider
NREL	National Renewable Energy Laboratory
POLB	Port of Long Beach
PV	solar photovoltaics
TOU	time-of-use
ZE	zero energy

GLOSSARY

ambient loop
Two-stage heating and cooling network that distributes low- or ambient-temperature heat between buildings or floors of buildings to provide heating and cooling, supplemented by individual heat pumps that ensure occupant comfort.[1]

behind the meter
Positioned on-site, on the customer (energy user) side of the meter.

business improvement district
Area within which businesses and property owners pay an additional tax or levy to fund projects and services beyond government offerings.[2]

charrette (or design charrette)
Meeting in which all stakeholders in a project gather to resolve conflicts and map solutions collaboratively.

combined heat and power
Simultaneous production of electricity and heat from a single fuel source in a way that captures and uses some of "waste" heat typically lost in the conversion process.[3]

community solar
Distributed solar energy deployment model that allows customers to buy or lease part of a larger, off-site shared solar photovoltaic system.

construction phasing
Building out a district or development in several scheduled construction phases rather than all at once.

demand-side management
Electric utility planning, implementing, and monitoring activities designed to encourage consumers to modify their level and pattern of electricity usage.[4]

development program
Description of the building area, densities, range of building types, and construction phasing plans for the overall development.

electric vehicle
Vehicles that operate on electricity.

energy balancing
Using the diversity of energy loads and load profiles, building types, renewable energy sources, and other considerations to cost-effectively optimize district energy use by balancing energy consumption and production.

energy positive
Building or district that produces more energy from renewable sources than it consumes.

energy use intensity
Measure of energy consumption per square foot per year (in the United States), expressed as kBtu/ft^2·yr, and typically referred to as EUI.

greenfield
A vacant site with a minimum of constraints, in contrast with, for example, a brownfield site contaminated from industrial or other uses.[5]

1 www.energistuk.co.uk/gla-are-ambient-loop-heating-systems-the-future/
2 www.pps.org/article/bid-2
3 www.eesi.org/topics/combined-heat-and-power/description
4 www.eia.gov/electricity/data/eia861/dsm/
5 hmcarchitects.com/news/what-is-a-greenfield-project-advantages-brownfield-project-2019-04-03/

horizontal developer
Entity responsible for roads, bridges, water and wastewater pipes, railways, landfills, water and wastewater treatment plants, power transmission lines, sidewalks, public spaces, etc.

integrated energy services provider
An entity charged with managing district energy-related operations; acts as a multipurpose developer, financier, operator, and administrator for district energy systems.[6]

integrated energy solution
Energy plan that integrates energy efficiency to reduce energy consumption, energy production from renewable sources to meet on-site energy loads, and sometimes energy storage to provide energy services during power outages.

interconnection
Systems synchronized to the utility grid at the point of coupling to allow seamless interaction.

internal rate of return
Interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero.

Islanding
Act of physically disconnecting a defined group of electric circuits from a utility system and operating them independently; islanding capabilities are fundamental to the function of a microgrid.

land entitlements
Part of the legal process a developer must go through to get approval; entitlements dictate permissible uses and thus define what a developer can or cannot do at a site.

microgrid
Small energy system capable of balancing supply and demand resources to maintain stable service within a defined boundary. Most are grid-connected but capable of disconnecting and operating autonomously (islanding).

net present value
Indicator of the value an investment or project adds; compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account (a positive net present value indicates a profitable project).

off-grid microgrid
Microgrid not interconnected with a local utility network.

payback period
Length of time required for an investment to recover its initial outlay in terms of profits or savings.

peak demand
The maximum load during a specified period of time.[7]

performance-based
Focus on measurable performance outcomes rather than prescriptive solutions to design problems; for example, describing how a building will perform by establishing a maximum annual energy use intensity rather than what it will be (an energy-efficient or high-performance building).

ramp rate
Rate of grid net load changes; for example, when the sun sets, solar photovoltaic production decreases but in cases where building loads remain constant or increase due to air-conditioning loads, the grid net load can increase sharply.

renewable energy certificate
A market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation.[8]

resilience
Ability of a system, community, business, etc., to mitigate damage, respond effectively to power and other disruptions, and rebound quickly after a crisis or disaster.

smart grid
An energy system characterized by two-way communications and distributed sensors, automation, and supervisory control systems.

solar ready
Design that includes shade-free roof areas and building structures to support solar photovoltaic loads so that solar can be added cost-effectively in the future.

summer peaking
Highest summer electricity demand when warmer weather increases use of energy-intensive air conditioning.

value engineering
Practice intended to ensure optimum value for the owner in commercial design and construction that can have the unintended consequence of stripping energy efficiency measures that are deemed to be too costly up front.

vertical developer
Entity responsible for the design and construction of buildings.

zero energy
Building or district that produces as much energy from renewable sources as it consumes over the course of a full year.

6 www.naiop.org/Research-and-Publications/Magazine/2016/Winter-2016-2017/Development-Ownership/Net-Zero-Districts-Finding-the-Quadruple-Bottom-Line
7 emp.lbl.gov/publications/peak-demand-impacts-electricity
8 www.epa.gov/greenpower/renewable-energy-certificates-recs

Photovoltaics on Denver Water's new administration building and parking garage move the project closer to its aspirational goal of **zero energy**.

Photo from Frank Ooms for Denver Water

OVERVIEW

Achieving deep energy savings in the U.S. building stock requires a bolder and more strategic approach than addressing energy efficiency and renewable energy one building at a time.

This guide was developed with partners throughout the United States to demonstrate how implementing district-scale high-performance strategies can be successful and scalable approaches to achieving deep energy savings that increase affordability, improve **resilience**, reduce emissions, and foster economic development.

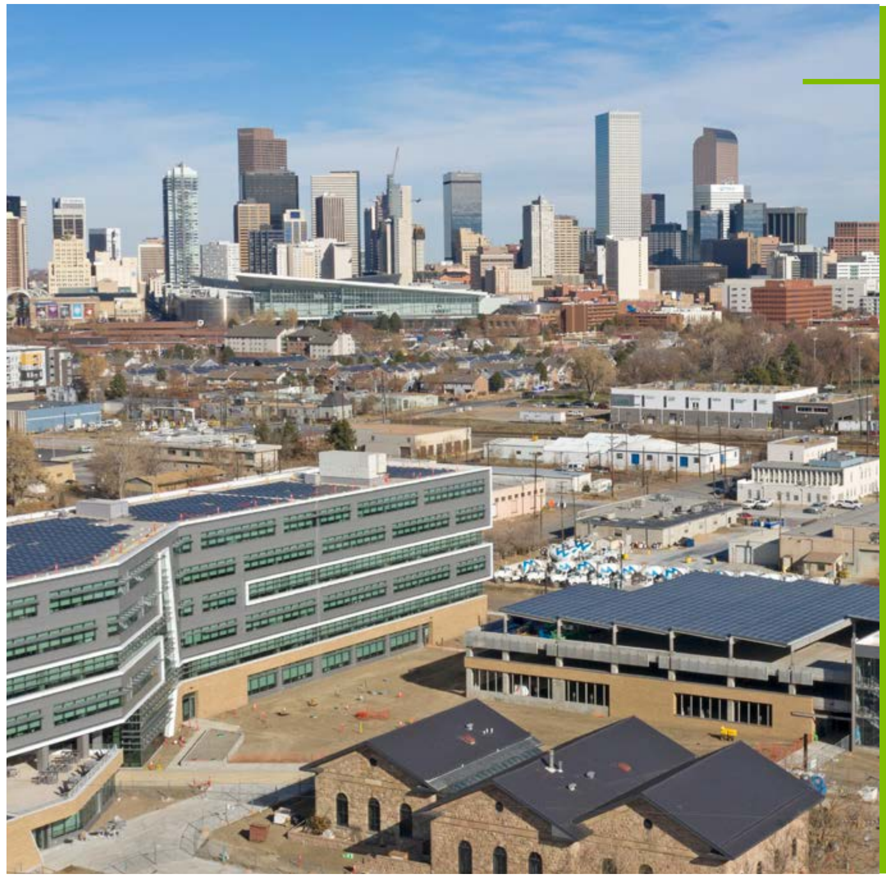
> *High-performance districts…take advantage of the synergies available when energy consumption and production is considered at a district level rather than one building at a time.*

This document serves as a framework for districts, campuses, and communities, illustrating an iterative process of building support for, planning, and implementing high-performance districts by engaging stakeholders, setting aggressive energy goals, completing technical and financial planning, and implementing a high-performance energy master plan. The information in this guide is based on a 3-year U.S. Department of Energy Zero Energy District Accelerator[1] and a range of real-world examples of emerging high-performance districts. It is particularly useful for architects, planners, engineers, local government agencies, and real estate developers in the early phases of planning a district with high-performance or other deep energy goals. For the purposes of this guide, a high-performance district is a multibuilding development that achieves aggressive energy and related goals such as **zero energy**, carbon neutrality, sustainability, ultra-efficiency, etc. High-performance districts optimize energy efficiency to reduce energy loads and use renewable energy resources to meet the remaining loads whenever possible. The Energy Independence and Security Act of 2007 defines a high-performance building as "a building that integrates and optimizes on a life cycle basis all major high-performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations."[2] High-performance districts are collections of such buildings that take advantage of the synergies available when energy consumption and production are considered at a district level rather than one building at a time.

How To Use This Document

This guide is organized so readers can access the information they need regardless of their project role or stage of the development process. The 10 chapters can be read individually or sequentially and are sourced throughout to make it easy to gather more information about a specific topic.

1 betterbuildingsinitiative.energy.gov/accelerators/zero-energy-district
2 www.govinfo.gov/content/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf, TITLE IV – Energy Savings in Buildings and Industry SEC. 401. Definitions. (12) HIGH-PERFORMANCE BUILDING

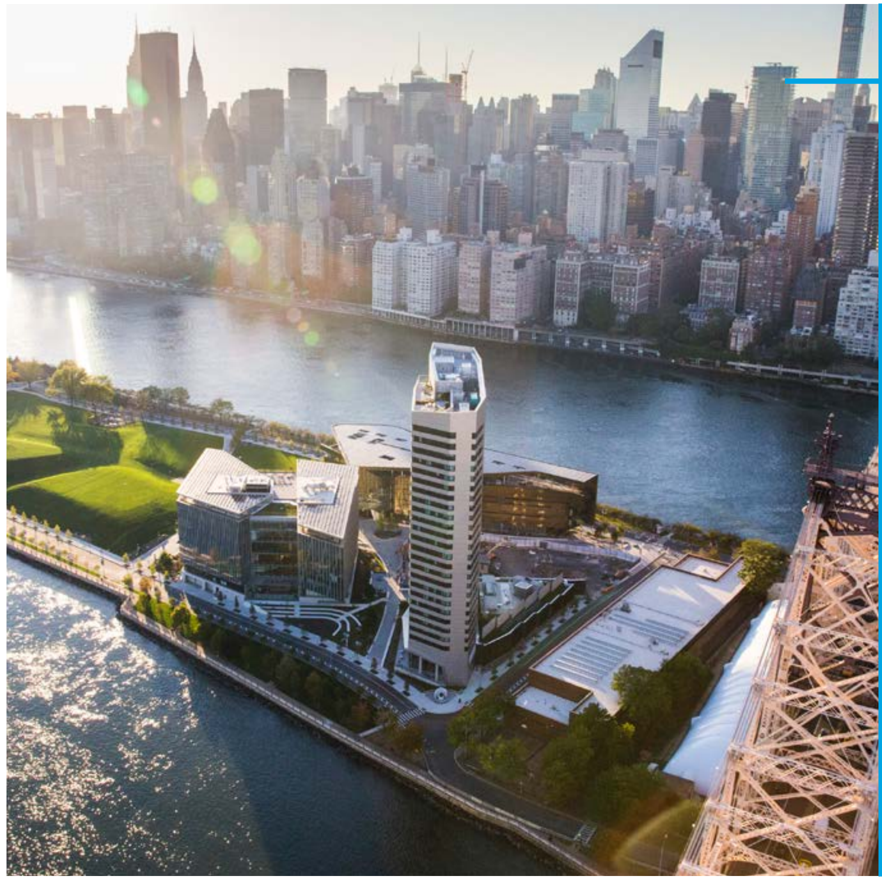


CHAPTER 1

INTRODUCTION defines the high-performance district concept and provides insight into the business case for—as well as the benefits and challenges of developing—a high-performance district.

The new Denver Water Operations Complex uses a large potable water distribution main as a heat source and heat sink, depending on the season.

Photo from Frank Ooms for Denver Water

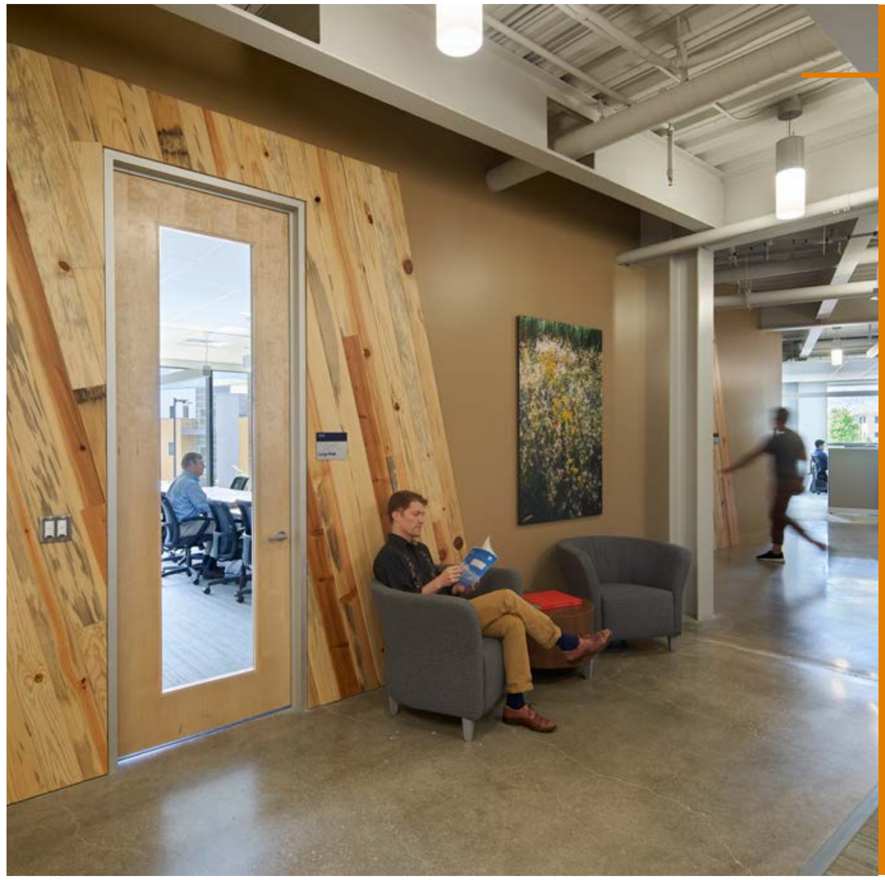


CHAPTER 2

FOSTERING SUPPORT AND ASSEMBLING A TEAM provides detailed guidance into making the high-performance district business case, including identifying and engaging stakeholders and determining project goals.

The Cornell Tech campus is designed to be resilient and sustainable, and one analysis projects it will generate more than $7.5 billion in economic activity and spur $23 billion in overall economic activity in the next 30 years.

Photo from Lucas Blair Simpson for SOM



CHAPTER 3

DEVELOPING FINANCIAL AND BUSINESS MODELS describes the analyses, models, and planning considerations that help the project team develop and execute the business case for a high-performance district.

Boulder Commons developer Morgan Creek Ventures worked with the Rocky Mountain Institute and its counsel to develop the first zero energy lease in the country for a project of this size.

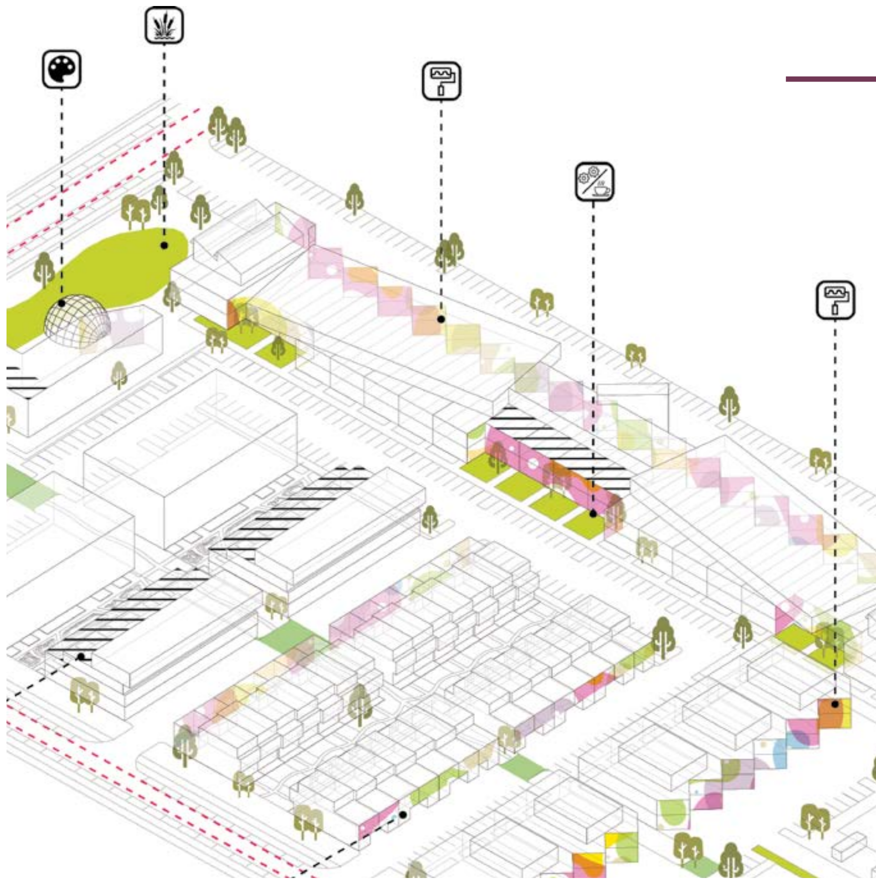
Photo from Bruce Damonte for Morgan Creek Ventures

CHAPTER 4

ENGAGING UTILITIES details what project teams need to know to develop and maintain the critical, collaborative relationships with utilities that are key to the success of a high-performance district.

The National Western Center project team engaged with local utility Xcel Energy and stakeholders to develop an Energy Action Plan for creating a zero energy district.

Rendering from the Mayor's Office of the National Western Center



CHAPTER 5

DEVELOPING AN ENERGY MASTER PLAN establishes the importance of an energy master plan and offers guidance on developing such a plan.

ModernWest will be a 16-acre mixed use development In Longmont, Colorado.

Graphic from ModernWest Ventures Inc.

CHAPTERS 6–9

provide a deep dive into the analysis and planning of a high performance district.

Chapters 6–9 are organized as follows:

A brief overview of why the section is important, how it impacts the high-performance district project, and how it relates to other project elements

Analysis and Approaches. What analyses to run, when and how to run them, example analyses, and available tools; each of chapters 6–9 includes at least one example analysis

Considerations. Factors that impact analysis inputs and outputs and tips to expedite the process

Integration. How to integrate the analysis results to optimize cost-effectiveness.

CHAPTER 6

PLANNING FOR ENERGY DEMAND AND EFFICIENCY discusses the analysis and planning required to reduce energy loads cost-effectively and set appropriate energy targets.

All the structures in the Whisper Valley development in Austin, Texas, will be equipped with solar photovoltaics and a ground source heat pump system.

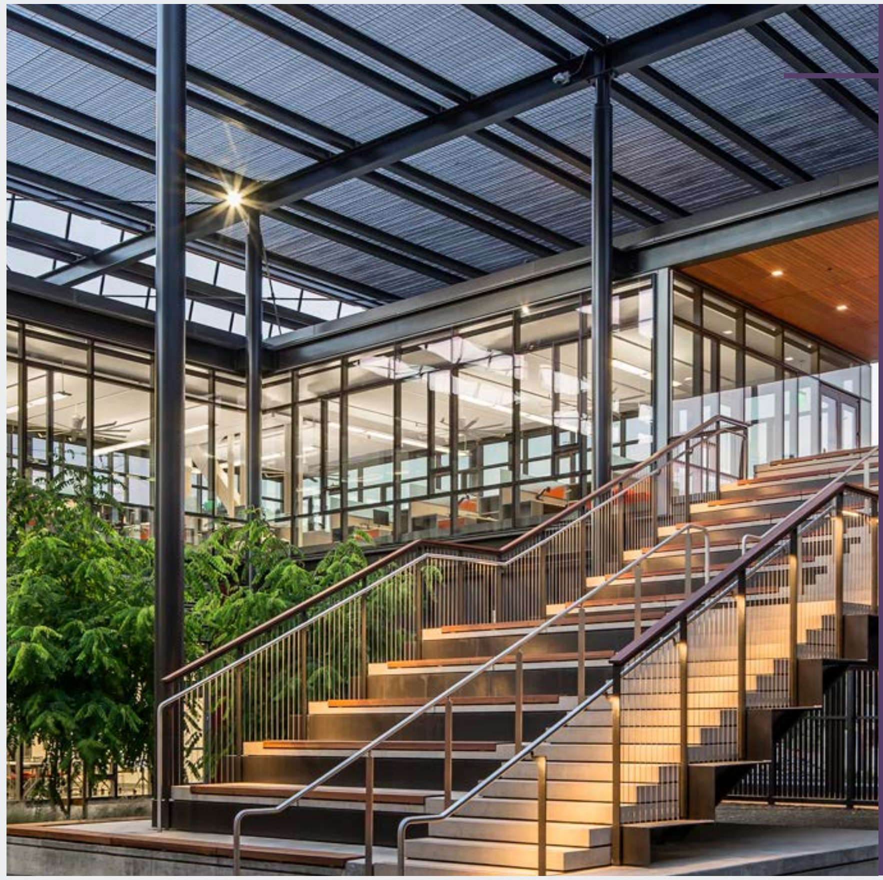
Photo from Rob Aldridge for Whisper Valley

CHAPTER 7

DISTRICT THERMAL ENERGY PLANNING describes the sophisticated district heating and cooling systems that improve the economics of large thermal systems through technology, analysis, and planning.

Montana State University's reduce, reclaim, renewable strategy optimizes building energy efficiency through ground source heat pumps, solar photovoltaics, and infrastructure and energy sharing.

Photo from Adrian Sanchez-Gonzalez for Montana State University



CHAPTER 8

RENEWABLE ENERGY ANALYSIS AND PLANNING details the analysis and other considerations necessary to integrate renewable energy—usually solar photovoltaics—into a district energy system.

Stanford University expects to meet its 100% renewable electricity goal in 2021.

Photo from Robert Canfield

CHAPTER 9

PLANNING FOR GRID INTEGRATION, ENERGY STORAGE, AND ELECTRIC VEHICLES explores the opportunities and technical considerations of integrating district energy systems and electric vehicles with the larger electrical grid.

A Honda FIT electric vehicle charges with electric vehicle supply equipment installed in front of an array of solar photovoltaic panels.

Photo from Capital District Clean Communities Coalition, Albany, New York, NREL 51363

CHAPTER 10

HIGH-PERFORMANCE DISTRICT CASE STUDIES includes a diverse collection of brief emerging high-performance district case studies from around the United States.

The Peña Station NEXT district in Denver, Colorado, is a mixed use community located near Denver International Airport that is targeting a least cost and scalable zero energy development.

Rendering from Fulenwider

CHAPTER 1
INTRODUCTION

Buildings in Geos Neighborhood in Arvada, Colorado, are so energy-efficient that rooftop solar photovoltaic systems provide all the energy needs of the homes and can also charge electric cars as needed.
Photo from Philip Wegener for Geos Neighborhood

High-performance districts (HPDs) are an emerging strategy for fulfilling local, national, and international commitments to energy security, resilience, environmental sustainability, and reduced emissions.

HPDs comprise diverse types of energy-efficient buildings and use a variety of district-scale approaches to optimize energy use. Typically, HPDs use cost-effective energy efficiency in buildings to reduce overall energy consumption and renewable energy sources, usually solar photovoltaics (PV), to meet the remaining loads. Approaches include setting district-scale energy and sustainability requirements for individual buildings as well as using next-generation district heating and cooling systems, **microgrid** technologies, district-scale renewable energy generation sources, energy storage, and other strategies to aggregate loads, leverage economies of scale, and share infrastructure. HPDs can be mixed use developments, corporate and university campuses, and other geographically contiguous groups of buildings that share infrastructure and optimize energy use.

> *Each high-performance district establishes specific energy and other goals early in the development process.*

Ideally, each district has a commonality that allows for ease of governance, organization, and financing. That commonality can range from ownership of the land and buildings to a **business improvement district**, special tax district, or redevelopment planning area. An HPD can balance energy loads between new and existing buildings to achieve a combined high-performance (HP) profile and provide opportunities for dramatically reduced energy consumption, grid-coordinated design and demand management, water conservation, integrated stormwater management, zero waste, and alternative transportation systems. Engaging stakeholders, especially local utilities, is important and should start at the beginning of the planning process (see **Engaging Stakeholders on page 23** and **Engaging Utilities on page 44**.

HPDs are gaining traction in the market (see **CHAPTER 10 on page 114** for examples of emerging HPDs). Currently, however, HPDs represent a small fraction of commercial and residential building developments and working definitions of what makes a district "high performance" vary. Given the complexities of designing and developing an HPD; variations in local building code, zoning, and other regulations; disparities in the quality and availability of renewable resources; and differences in the HPD goals of a specific district, developing an HPD definition for a project can be challenging.

What Is a High-Performance District?

For the purposes of this guide, an HPD is a multibuilding project in which the buildings as well as the district as a whole integrate and optimize, on a life cycle basis, "all major high-performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations."[1] In addition, HPDs often incorporate resilience (see **Resilience Planning on page 55**).

Each HPD establishes specific energy and other goals early in the development process. These goals can range from a percent improvement beyond business as usual to a **zero energy** (ZE), carbon neutral, or even **energy positive** district. A ZE district generates as much energy as it uses on an annual basis from renewable energy sources. A carbon neutral[2] district's operations result in no net CO_2 emissions on an annual basis. An **energy positive** district generates more energy than it uses and either stores the excess for use during outages or **peak demand** periods or sends it back to the electric grid. The U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) have developed definitions for ZE buildings as well as campuses, portfolios, and communities.[3] In each case, the level of energy efficiency is such that "on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."[4] In addition, the Districts & Communities section of NREL's Zero Energy Buildings Resource Hub[5] offers suggestions and resources for HPDs.

Energy efficiency, a proven and cost-effective strategy,[6] is optimized in an HPD to reduce energy loads as much as economically feasible. The project team then identifies opportunities to further reduce energy loads and/or satisfy thermal loads by using, for example, waste heat from neighboring data centers, buildings, or sewer lines. Renewable energy resources within the district boundaries can then meet some or all of the remaining loads. Off-site renewable energy is often used as well. Each project team will choose the renewable energy resource approach most appropriate for its goals.

1 www.govinfo.gov/content/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf, TITLE IV – Energy Savings in Buildings and Industry SEC. 401. Definitions. (12) HIGH-PERFORMANCE BUILDING
2 architecture2030.org/zero-code/
3 www.energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf
4 zeroenergy.org/project-types/districts-communities/
5 zeroenergy.org
6 emp.lbl.gov/news/energy-efficiency-continues-be-cheaper

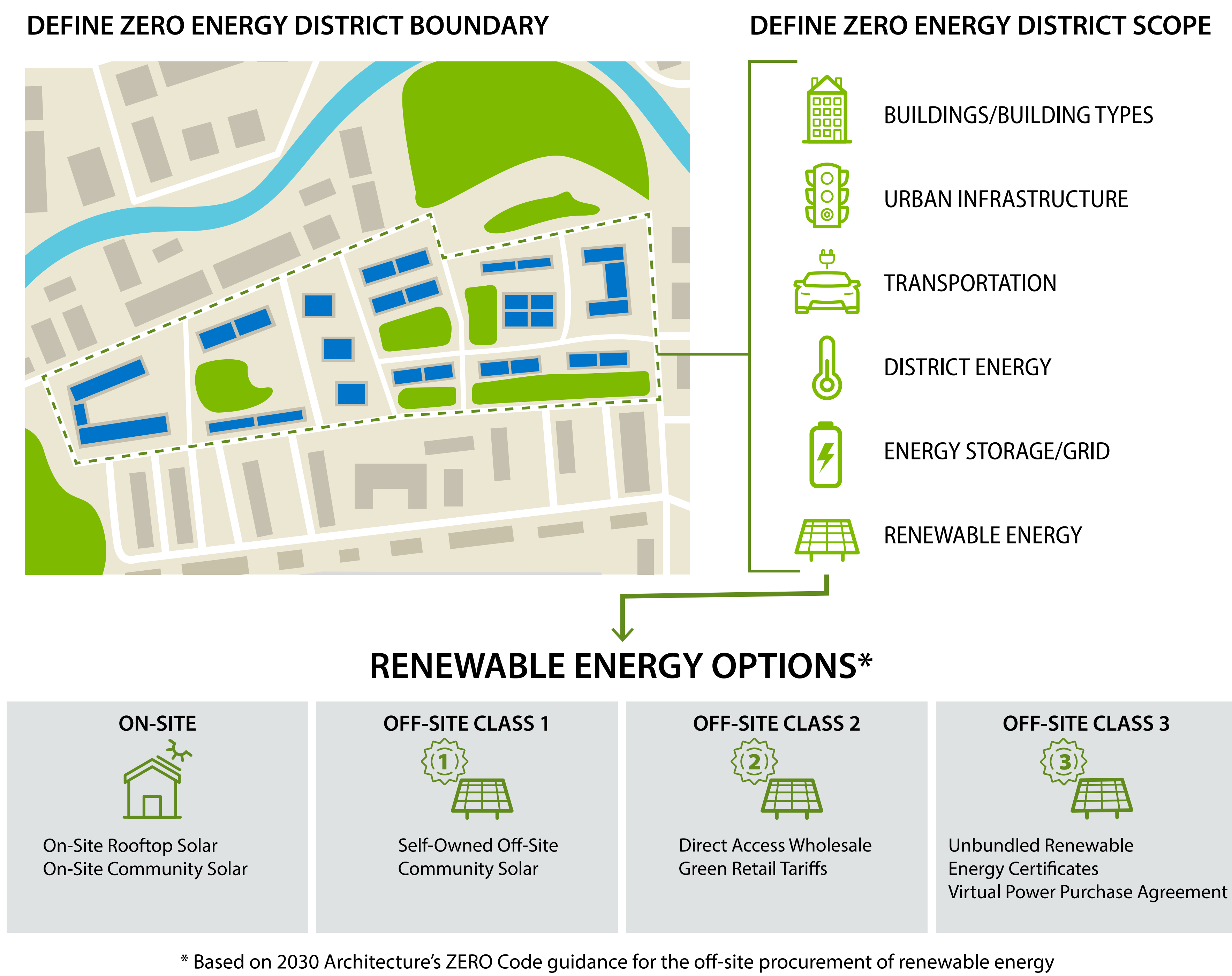


FIGURE 1. Zero energy district definition framework based on Architecture 2030's ZERO Code standard

Energy efficiency, a proven and cost-effective strategy, is optimized in a high-performance district to reduce energy loads as much as economically feasible.

FIGURE 1 illustrates one framework for this process. For others, see **Setting Project Goals and Principles on page 28.**

What Is the Value Proposition and Business Case for a High-Performance District?

HPDs are a new phenomenon in the marketplace. Whether the HPD consists of new construction, existing buildings, or a combination and whether the owners and developers are nonprofit or for-profit affects the economics, goals, and configuration of a district. HPDs offer unique opportunities and benefits for key stakeholders because of the superior performance of individual buildings as well as the synergies that can be achieved across a well-designed HPD. The goals of an HPD project determine the process followed and the stakeholders involved. When the HP goal is established early in the design process, owners, developers, and local governments can take full advantage of these benefits.

Benefits of High-Performance Buildings

Individual HP buildings provide owners and occupants a number of benefits, including:

- **Optimized energy use.** Adopting an energy optimization goal from the outset can reduce both first costs and ongoing energy costs during the decades-long life of a building.
- **Reduced operating costs.** Optimizing energy use can reduce operating costs, most obviously by reducing utility bills. Experience has also shown that HP buildings often have simpler systems that are less expensive and time-consuming to operate and maintain.
- **Increased occupant productivity and wellness.** Good indoor air quality, adequate ventilation, and well-designed daylighting, among other features, account for the increased productivity and enhanced occupant satisfaction in HP buildings.
- **Decreased emissions and climate impacts.** Reducing energy loads and using renewable energy to meet some or all of the remaining loads results in fewer emissions and climate impacts compared with a standard efficiency building.
- **Improved resilience.** Reduced energy loads met with on-site renewable energy production and local energy storage can allow a building to continue to function during power outages. HP buildings may also serve as community refuges during power disruptions because on-site energy systems can continue to supply electricity, heating, and cooling. In addition, superior building envelopes maintain comfortable temperatures and daylighting strategies provide daytime lighting.

Peña Station NEXT in Denver, Colorado, is a transit-oriented development, a type of planned community comprising housing, office, retail, and/or other amenities integrated into a walkable neighborhood and located within a half mile of public transportation.

Rendering from Fulenwider

Benefits of High-Performance Districts

Aggregating HP buildings into an HPD amplifies individual building benefits by taking advantage of the scale and diversity of district buildings. Some of these HPD benefits include:

- **Economies of scale.** HPDs provide economies of scale for on-site renewables, energy storage, and other district-scale energy systems. Investments in these technologies may not be feasible for an individual building owner but can be feasible when shared among many parties in a district. Economies of scale can also drive down the unit costs of energy efficiency technologies, professional services (see CHAPTER 8 on page 80), and thermal installations (see CHAPTER 7 on page 68).
- **Building and energy load diversity.** Analysis of different buildings' energy usage can reveal different peak loads and timing, resulting in district-level heating, cooling, or electricity peaks significantly lower than the sum of all building peaks (see Heating and Cooling Load Analysis on page 70).
- **Higher market profile.** Developers can improve the business case and raise the public profile of an HPD by emphasizing the financial, environmental, social, resilience, and other HP benefits in marketing and outreach communications.
- **Accessibility to new business models.** HPDs can offer alternatives to traditional energy delivery and business models. For example, building owners and district stakeholders may become producers of energy, selling electricity back to the grid. Renewable energy providers or waste heat suppliers can also benefit from the new business models.
- **Future-focused design.** HPDs are developed with advanced technologies and strategies to address resilience, energy, water, waste, and transportation. This protects the investments made today so that the district will not become quickly outdated; rather, it will maintain its durability and high quality into the future.

Cornell Tech on Roosevelt Island in New York City is designed to be resilient and sustainable, with on-site energy generation and buildings built to LEED, Passive House, and **zero energy** standards.

Photo from Iwan Baan for SOM

- **Grid interactivity.** Given their scale, HPDs can provide grid services while adjusting their loads in response to grid needs to help utilities and grid operators better assess and manage distribution networks.
- **Resilience.** The reduced downtime and increased business continuity possible when HP buildings are aggregated into an HPD—especially if energy storage and islandable **microgrid**s provide uninterrupted power during power outages—are attributes that can attract businesses and residents to the district.

Achieving High Performance at District Scale

The benefits of building energy efficiency are well understood and have been integrated into many local and international building codes. In addition, renewable energy installations are becoming commonplace and evidence of their economic, health, environmental, **resilience**, and other benefits[7, 8] is readily available. Optimizing energy efficiency and renewable energy generation across a large development, however, is a paradigm shift for most real estate developers, owners, and professionals.

As **FIGURE 2** shows, HPD developments require an iterative, multidisciplinary planning process to develop a comprehensive energy master plan (see **Detailed Energy Master Plan on page 54**) that balances and optimizes the building types, energy loads, types of energy sources, and locations of those sources while achieving project and financial goals. Careful energy master planning ensures that energy is considered early and often throughout the district-scale design and development process and can also reveal cost-effective paths to HP. Without this type of integrated and iterative process, it is difficult and costly to establish optimal district thermal systems, smart electrical distribution systems, large PV and battery storage systems, **microgrids**, and best-in-class energy efficiency strategies.

> *Aggregating high-performance buildings into a high-performance district amplifies individual building benefits by taking advantage of the scale and diversity of district buildings.*

Thanks to early adopters (see **CHAPTER 10 on page 114**), the advantages of improved energy efficiency and on-site renewable energy generation at a district scale are now being documented. As the emerging case studies in this guide demonstrate, one key to a successful HPD is to include a variety of building types and energy uses.

Energy modeling and simulation are also critical to the success of an HPD. To determine the optimal mix of buildings and energy loads and to mitigate the risks of adopting a novel development approach, project teams use building energy models specific to the site to run simulations of various building types, massing configurations, energy sources and placements, and other HPD

7 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Measuring-the-Economics_2016.pdf
8 www.epa.gov/statelocalenergy/public-health-benefits-kwh-energy-efficiency-and-renewable-energy-united-states

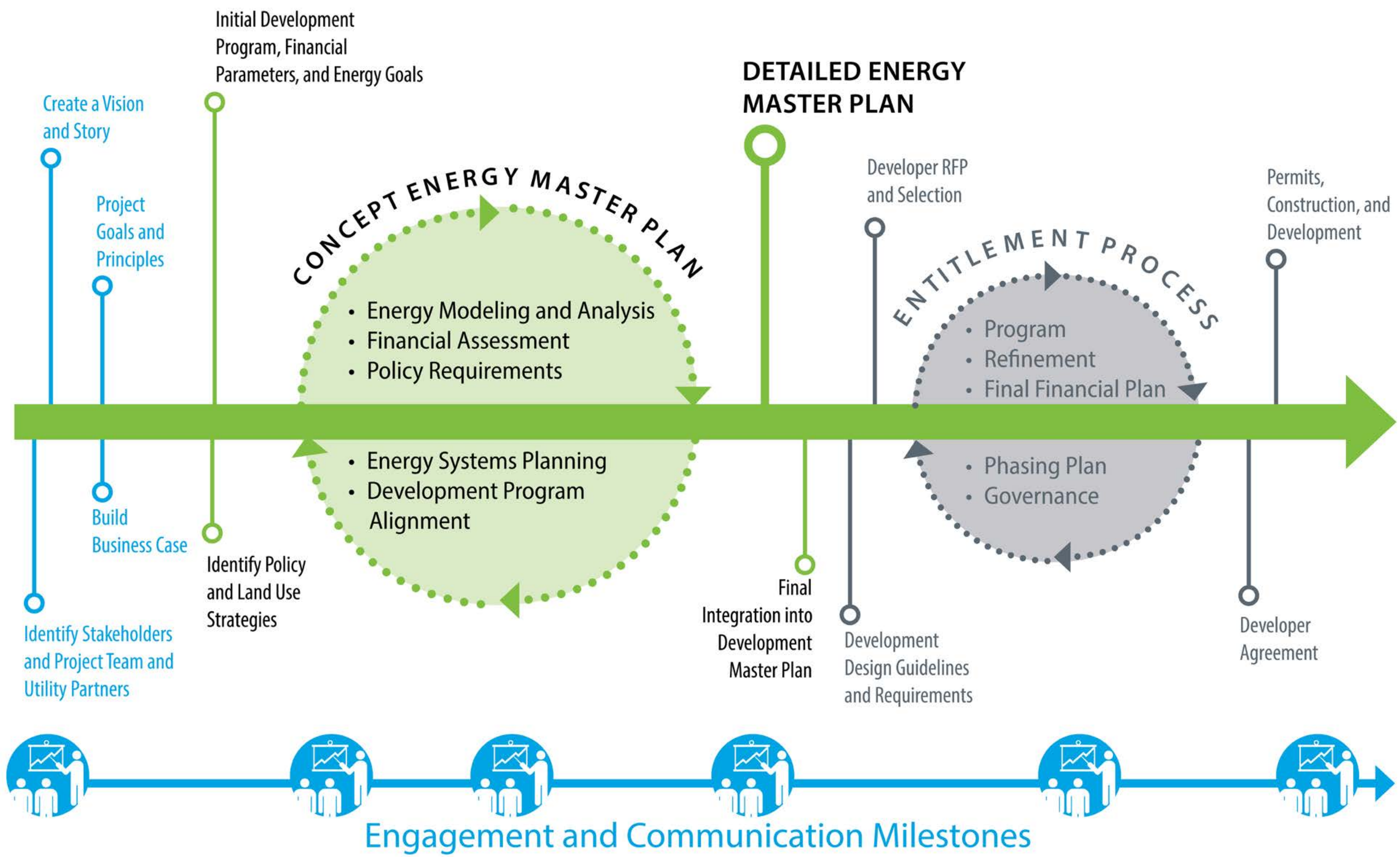


FIGURE 2. High-performance district development process

elements. Ideally, this testing and refinement process starts at the beginning of the design process (see **Planning for Energy Demand and Efficiency on page 58**). Careful attention to the process of balancing energy use and renewable energy production (see **Balancing Energy Consumption and Production on page 61**) enables some developments to reach the aspirational goal of a ZE or even an **energy positive** district.

All-electric construction also provides benefits at a district level. Notably, it can cost less to build, improves indoor air quality, increases public safety, and—in most locations—reduces utility bills.[9] Adding PV and storage enhances district **resilience** and reduces exposure to future energy price increases.

Challenges of High-Performance Districts

Although HPDs offer communities and developers many benefits, there are critical barriers to consider and address as the project team develops a master plan. The following are some of the most important, but there may be others unique to a location:

- **Complexity.** Creating an HPD is more involved than a standard development and requires consideration of financing, planning, design, and operations early in the process as well as constant balancing of objectives to avoid unintended consequences and keep costs down (see **CHAPTER 5 on page 52**)
- **Utility engagement.** A utility can be a powerful and important ally and partner in the development of an HPD or it can derail the project. Soliciting utility support from the outset is essential (see **CHAPTER 4 on page 44**).
- **Novelty.** HPDs are a new concept, with few examples for developers or local governments to use as models. Risk aversion among real estate developers and some local governments can be a serious obstacle to sustaining the long-term momentum required to meet aggressive energy goals.
- **Business models.** Many developers and energy providers use established business models and may resist a longer HPD path to return on investment (e.g., 20–30 years, rather than 5–10 years).
- **Governance.** Financing and managing an HPD's novel energy systems can be challenging for the parties involved in the district. Although new energy controls, metering technology, ownership models, and payment tools will mitigate this challenge over time, these issues should be considered from early in the project.
- **Up-front costs.** HPDs typically cost more initially than conventional developments, and the project team must identify the additional up-front costs (district-scale system and infrastructure investments, phasing costs, etc.) and balance them with the long-term benefits (lower operating costs, reduced emissions, higher rents/property values, etc.).
- **Inadequate energy master planning.** In the absence of a strategic and informed master plan, aggressive energy goals can be more costly and difficult to achieve. Energy master planning should be integrated into the overall land use development master plan, providing sufficient detail to cost, phase, and understand energy system options related to the building program, other infrastructure improvements, and landscaping.

9 fossilfreebuildings.org/ElectricMFGuide.pdf

The cost of **zero energy** homes at Geos Neighborhood in Arvada, Colorado, is comparable to conventional homes.

Photo from Geos Neighborhood

CHAPTER 2

FOSTERING SUPPORT AND ASSEMBLING A TEAM

Oak View, a low-income community in Huntington Beach, California, is exploring the use of energy efficiency, renewable energy, and **microgrid** technologies to improve the environmental performance and resiliency of the local electric infrastructure.

Photo from Dr. Laura Novoa, University of California, Irvine

HPDs are a new, complex, cutting-edge approach to achieving energy goals in large developments or on campuses. This added complexity compared to a standard project requires strong communication and engagement strategies from the inception of the project through occupancy and operation.

Communication is critical for developing understanding and building support with decision makers within development companies and local government agencies; creating clarity and buy-in from financial/grant partners; establishing and maintaining good relations with the utility; ensuring the planning, design, and construction team delivers the vision; and establishing trust and working relationships with external stakeholders, including community groups, environmental groups, state and regional agencies, and others. An effective communications and outreach effort builds local support for the project, which in turn can help strengthen the project's business case.

Engaging Stakeholders

The complexity and novelty of an HPD project can make it a more challenging concept for stakeholders to understand than other large development projects. Focusing on this complexity and the benefits of the energy system are common mistakes when trying to involve decision makers and laypeople in the project. All stakeholders do not need to know all the details of the proposed energy system; the key to a successful project is a compelling, accessible story focused on the benefits that will accrue to different community groups if the project is successful. This primary tenet should be central to all stakeholder engagement efforts—project team members must connect the dots between stakeholders' interests and values and the relevant HPD characteristics and benefits.

Although community and stakeholder involvement has long been a mainstay in development projects, there is evidence that many local government jurisdictions and developers are concerned about the engagement process and potential barriers such as the extended timelines for engaging the community, opportunities for misunderstanding and derailment by a vocal few, and overall uncertainty about how the community process will inform and shape the final product. This concern is compounded by the reality that often the same small group of engaged citizens shows up over and over. Further, the need to involve disadvantaged and historically underserved communities provides additional challenges that can make effective and authentic community and stakeholder involvement elusive.

> *Project team members must connect the dots between stakeholders' interests and values and the relevant high-performance district characteristics and benefits.*

Initially, the idea of pursuing an HPD might be the brainchild of an individual or small group of people, but a successful project will require buy-in from all levels of the owner's team, project team, and a range of stakeholders. The first cost of an HPD can be higher than a standard development and a persuasive case must be made from the outset that the return on investment justifies the increased cost. The HPD will require steadfast support to ensure that early choices support the HP goal and that the owners, stakeholders, and project team members understand the vision in terms of money, time, risk, and effort from the beginning.

For the ownership team, this may mean developing an economic model that illustrates the incremental costs, the cost savings over time, the benefits of market differentiation, and the attractive long-term return on investment. For a government entity, it means linking existing local plans, goals, and initiatives to the project, including economic development, sustainability, **resilience**, and emission reductions, among other community benefits.

For specific stakeholders, the vision needs to be communicated and discussed within the framework of each group's agenda. For the local utility—a key stakeholder in every HPD—sharing the details of the project and developing a close, collaborative relationship from the outset will help all parties identify opportunities and avoid roadblocks (see **CHAPTER 4 on page 44**). For the larger community, that could mean communicating benefits in a simple and transparent way that resonates with local needs. Interactive workshops, visioning exercises, and focus groups are all effective ways to engage stakeholders in the discussion and build support. Communication tools such as well designed and produced websites, print materials, and videos are also useful. These initial relationships and support structures need to be fostered and maintained throughout the effort.

Toward that end, district leaders should focus from the start on:

- Identifying the full spectrum of key stakeholders (see **FIGURE 3**) and determining what their roles might be in the adoption, implementation, and operation of the project
- Listening to and learning about what matters to stakeholders
- Mapping the type and interest(s) of stakeholders to key project benefits (see **Benefits of High-Performance Districts on page 17**) and creating effective communication materials to convey that information through multiple channels
- Building trust through a range of engagement activities from beginning to end that involve stakeholders in ongoing conversations
- Sustaining stakeholder engagement by linking stakeholders' interests and concerns with the successful implementation of the project.

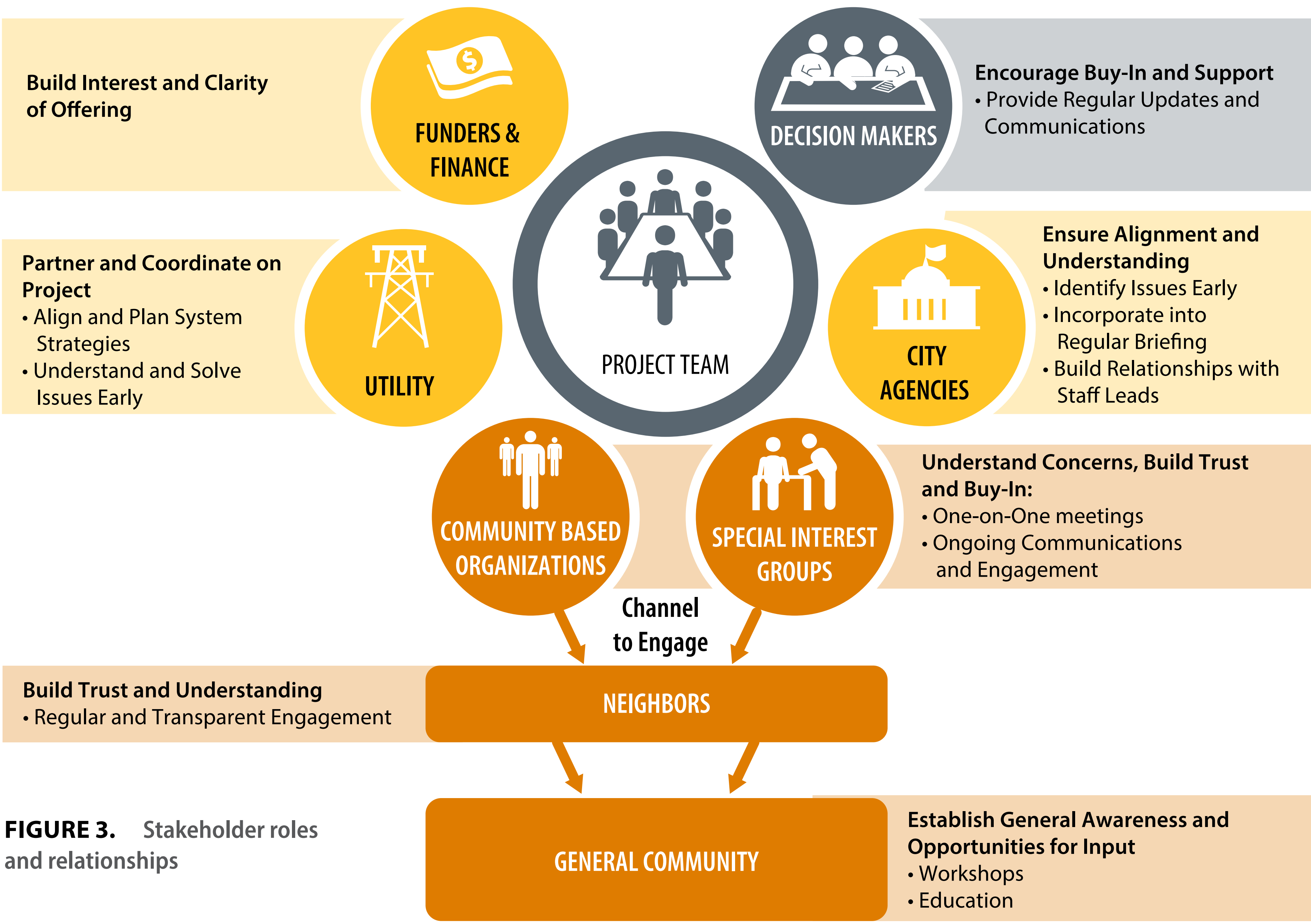


FIGURE 3. Stakeholder roles and relationships

Adding HP goals across an entire development requires a different planning team composition. It may also involve new stakeholders and enhanced roles for standard project stakeholders (see **FIGURE 4 on page 25**).

Stakeholders can be supporters or detractors. In some cases, detractors need to be a higher priority, especially if they can be transformed into supporters or are central to project approval processes. Stakeholders can include:

- **Local government employees and officials.** If the local government is not the project lead, it will need to approve the project and issue permits for any construction. It is critical to develop strong relationships with multiple government departments, including, but not limited to, planning, public works, building and zoning, and sustainability, as well as the city council or similar decision-making body.
- **Elected officials (mayors, city council members, legislators, etc.).** These stakeholders can be difficult to engage, but their ability to affect progress and outcomes makes them central to any outreach strategy. Often their time is limited, their interest in and understanding of specific details is minimal, and the project team's only contact with them is at formal approval meetings. A more successful strategy is to bring them in early and update them in less formal settings along the entire timeline. Project tours, study sessions, one-on-one meetings, and project briefings can be useful strategies.
- **Local utilities.** A productive and cooperative working relationship with local electric, water, sewer, and other utilities from the outset of the project is critical to the success of an HPD. Contacting local utilities early in the process, understanding their concerns and sensitivities, and developing relationships with key personnel will smooth the process of achieving a HP goal in a large development.

- **Special interest groups.** Each project will have characteristics that attract groups with special interests, and these groups can help extend the project's outreach through their newsletters, email lists, or meetings. These groups include, but are not limited to, local businesses, community-based organizations, neighbors, environmental groups, justice and equity communities, and real estate professionals.
- **Funders and financing partners.** Although many financial partners may not be involved with the project until later phases, identifying and developing relationships with potential funders, foundations, and private lenders should happen early in the process. These partners can be instrumental in guiding project development and determining the building mix. They should be briefed on potential risks and should buy in to the overall vision of the HPD. They can also offer valuable insights about how to make the project more attractive to lenders, funders, and investors.
- **General community.** Depending on the project, community-wide engagement may be desirable or even required. To engage the entire community, begin with the groups listed above and add additional communications, outreach events, and engagement approaches to the outreach plan that can apply to everyone in the area (see **FIGURE 5 on page 27**). Understanding the specific goals for involving this audience will be important in determining the level of outreach and engagement. A community-wide program requires careful planning to ensure that resources and time are well spent, and that each step is achieving the outreach goals (see **Engaging Stakeholders on page 23**).
- **Additional key stakeholders.** For some projects, state and transportation agencies may also be important stakeholders.

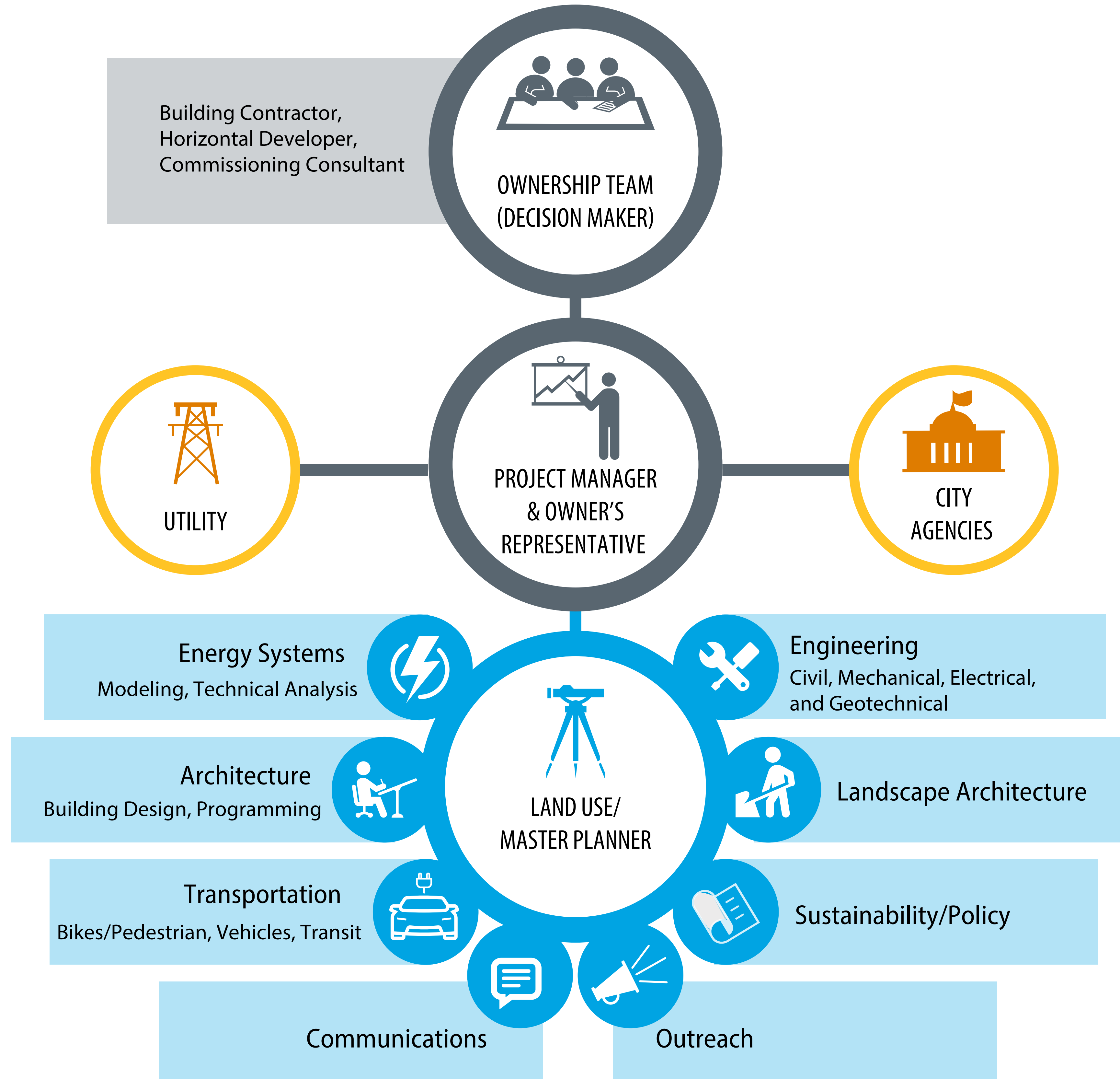


FIGURE 4. Makeup of the project team for a high-performance district

Developing clear outreach goals (separate from project goals) and creating an outreach plan for the stakeholder process is essential to ensuring the project effectively engages the groups mentioned above. Stakeholder engagement goals can help focus messaging, choose venues, shape communication materials, and indicate specific engagement activities. Different communities can have vastly different characteristics that need to be considered in order to develop an appropriate and effective engagement process.

Developing a Technical Advisory Team and/or Community Advisory Committees

One of the greatest challenges in large projects is the extended timeline and the complex issues that are difficult to explore in a typical meeting. An approach that has proven successful is to establish dedicated committees with carefully chosen members willing to commit to these longer time frames and complexities.

Two types of committees can be useful to get stakeholders involved. The first is a technical committee comprising individuals with detailed technical knowledge related to the project, including, but not limited to, energy, sustainability, urban planning, environmental regulations, finance, and real estate. Members of this committee must be able and willing to deeply explore and advise on technical aspects of the project. The committee may meet most frequently during the early planning phases but will likely be used throughout the project; participation requires a serious commitment.

The second is a community advisory committee made up of laypeople from various community groups. These committee members are able to devote time and attention to learning about and providing input on the project at key milestones. They are also able to network and serve as project advocates during broader community meetings as well as discussions with decision makers. Members of the community advisory group should commit to the process and agree to attend at least three or more meetings before joining the committee.

Stakeholder Engagement Resources

International Association of Public Participation

A wide range of resources and tools for effective community and stakeholder outreach.[1]

Center for Community Action and Environmental Justice

The Center for Community Action and Environmental Justice is a progressive, base-building, nonprofit organization that convenes people on cooperative community processes to improve social and environmental planning. See *Transforming Toxic Hot Spots into Thriving Communities*.[2]

Regional Resilience Toolkit: 5 Steps to Build Large-Scale Resilience to Natural Disasters[3]

From 2013 to 2018, the Federal Emergency Management Agency (FEMA) and U.S. Environmental Protection Agency (EPA) helped three California regions take large-scale action to improve disaster resilience.

Based on these technical assistance projects, FEMA and EPA partnered with the Metropolitan Transportation Commission/Association of Bay Area Governments (MTC/ABAG) to create a toolkit that helps regions plan for disasters by working across multiple jurisdictions and with nongovernmental partners.

Creating a Vision and Telling the Story

People gravitate to good stories—especially ones with a new and innovative vision—and crafting and telling a district's HP story are important to its success. The story will develop and evolve as the project moves through planning, implementation, and operation, but telling the HP story early can attract influential stakeholders to the project. During the planning process, the story can help build public support and turn community members into advocates. This can ease the regulatory process and even make the project more marketable. The HP story can also be part of an effective marketing campaign to attract building owners and tenants to the district. During operation, the story can help ensure ongoing engagement with and education of district building occupants so that the importance of the HP goal is communicated to current and new occupants. The story can also be a tool to familiarize real estate brokers with the value of HPD features as they sell and lease space to prospective buyers and tenants.

> *People gravitate to good stories—especially ones with a new and innovative vision—and crafting and telling a district's high-performance story are important to its success.*

At the same time, the story must resonate with a broad range of project stakeholders. To be effective, it should be multifaceted and illustrate how an HPD can promote economic development, reduce costs, increase **resilience**, and enhance community wellness, among other key elements specific to the development.

1 www.iap2.org/page/resources
2 healthyplacesindex.org/wp-content/uploads/2018/01/ccaej_transforming_toxic_hot_spots_thriving_communities.pdf
3 www.epa.gov/smartgrowth/regional-resilience-toolkit

An HPD project can be initiated by a developer, private building or landowner, government entity, or other community group. Because HPDs are a new development strategy, it is likely that a broader range of "owners" will emerge over time than those present in the current market and described in the case studies in this document (see **CHAPTER 10 on page 114**).

Regardless of who the owners are, before the HPD is planned, the project lead must articulate its underlying vision and purpose. This visioning phase is the optimal time to integrate HP into the district's story. A well-developed vision statement helps articulate—briefly, clearly, and to a range of audiences—the essence of the project. A vision statement may not include a reference to HP if that characterization doesn't resonate with key audiences and instead must embody the specific benefits and needs that are most important to those audiences. (It must, however, be included in the project goals.)

Once the reasons for and benefits and challenges of an HPD approach are understood in the context of the particular project and the stakeholders have been identified, it is important to integrate them into the overall vision and story. HP can have strong synergies with other economic, environmental, and social project objectives. For example, solutions can align with:

- A credible business case
- Local government incentives for improved energy efficiency and other green building features
- 100% renewable energy or carbon emission reduction goals
- Innovative and cutting-edge development approaches
- Healthy building goals; an HPD's low-energy building systems enhance indoor air quality and thermal comfort
- Community **resilience**.

FIGURE 5. **Outreach materials accessible to both English and Spanish speakers developed for an Advanced Energy Community demonstration project in Oak View, a low-income community in Huntington Beach, California.**
See the Huntington Beach case study on page130.

Handouts from Kirsten Graham and Noemi Luna-Ochoa.

HP is also a key aspect of many comprehensive third-party green rating systems for projects comprising multiple buildings. One of the most exciting aspects of an HPD is its leadership potential to define a new and better way of building. HPDs are creating the next generation of built environment and therefore defining the future. Enthusiasm for an HPD can raise the profile of a community, campus, or district and attract the attention of top-tier developers, builders, designers, businesses, tenants, employees, and customers. It can also help build public and regulatory support, because all communities have a keen interest in building for a better future.

Investment in quality messaging material and highly visual graphic content that clarifies and illuminates a district's HP vision is important from the beginning and should include a website, social media presence, and coverage in appropriate media outlets to help disseminate the story.

Setting Project Goals and Principles

The vision should capture the imagination and generate excitement, while the goals should articulate the vision and provide measurable steps to realize it. Project goals should be clear, simple, and meaningful and express the vision in ways that can be easily translated into policies. This may include goals for **resilience**, sustainability, affordability, equity, economic development, energy performance, carbon emission reduction, and the like. Goals can range from broad policy statements to specific objectives to key principles. Goals from community plans, especially from the land use/general plan or plans specific to the HPD, should be reviewed and aligned with the HPD goals. A large development project such as an HPD can build on existing plan goals, tailoring them or adding only goals that relate to the project. Once drafted, project goals along with the vision should help guide the project team's conversations and direct decisions.

> *The vision should capture the imagination and generate excitement, while the goals should articulate the vision and provide measurable steps to realize it.*

Project goals are refined from the master developer's original vision. The goal setting process involves the planning team and other key players and can also involve community and special interest groups. HPD needs are integrated into clear, measurable, and achievable goals.

In an HPD, the project team must define the energy goal for the district, determine how it will be measured (often a specific **energy use intensity** [EUI] expressed as kBtu/ft^2·yr), and establish district boundaries. The energy goal will include energy use targets for each building as well as renewable energy generation targets, often based on the building roofs, parking canopies, and other areas available for PV installations (see **What Is a High-Performance District? on page 15**, and **Photovoltaics and Solar Access Planning on page 85**).

Energy-related goals and principles should be embedded in the master plan and carried forward into the implementation process. This is particularly important if developers other than the master developer will be responsible for the vertical development (buildings). One way to accomplish this is to include energy goals in the design guidelines, development covenants, and requests for proposal for building developers. The energy goals could also address potential challenges and opportunities related to the grid **interconnection** with the local utility and could include a set of grid optimized energy management metrics.[4] In addition, third-party certification might be a project goal. This could include certification for individual buildings and/or certification for the district as a whole. Certification goals should be identified early because those choices will determine the metrics measured for compliance.

The project team develops design and planning principles in response to the project's vision, goals, program, and other specific drivers. These principles serve as design and decision-making guides throughout the process and should include energy-related principles specific to the vision of and approach to the HPD. Examples include requiring all-electric buildings, emphasizing energy efficiency, mandating passive design strategies, and optimizing roofs for PV (see **Locating Photovoltaics on page 85**).

While developing goals, it may become clear that the team will need to understand the existing policy barriers or opportunities that will enable the project to move forward with the HP vision intact. For the Highland Bridge Ford site in Saint Paul, Minnesota, two policies were critical enablers—the city's Sustainable Building Policy[5] and Minnesota's SB2030[6] law based on Architecture 2030's limits for buildings.[7] Saint Paul has been able to use these policies to ensure the developer will achieve high levels of energy efficiency and will use solar to balance costs and meet sustainability goals. One of the lessons learned from that effort is that had team members realized the importance of the city's policy in developer negotiations, they would have amended their proposal to apply more clearly to large developments or to a district.

4 newbuildings.org/resource/gridoptimal/
5 www.stpaul.gov/sites/default/files/Media%20Root/Planning%20%26%20Economic%20Development/Ford%20Site%20Zoning%20and%20Public%20Realm%20Master%20Plan%20FINAL.pdf
6 www.b3mn.org/2030energystandard/
7 architecture2030.org/zero-code/

Highland Bridge Civic Square is part of the planned redevelopment of the site that was the former home of Ford Motor Companies' Twin Cities Assembly Plant in Saint Paul, Minnesota

Rendering from Ryan Companies.

Other HP projects have had to advocate for new innovations. For example, a large campus developed by United Therapeutics in Silver Spring, Maryland, had to amend local drilling rules to allow ground source heat pump wells to be drilled under a multistory office building.[8] Similarly, the project team for the **Hazelwood Green** district in Pittsburgh, Pennsylvania, ensured that sustainability was written into the zoning code for the project so that future developers would have to adhere to the project vision.

8 Presentation at the 2019 DOE Better Buildings Conference. Details and case study are available at www.utunisphere.com. Details about getting the wells approved in statute are available at www.sourceofthespring.com/business/united-therapeutics-continues-work/.

Selecting a Developer and Navigating Land Entitlements

Developer Request for Proposal

If the project lead is not a developer, typically the lead local government agency or the site owner will issue a request for proposal to solicit developers to direct the design and construction of the project. During this process, the vision and reality can collide if local stakeholders are not aligned with the vision and the project team has not made a compelling business case. This happens in particular if the financial pro forma has not been completed or is inaccurate, if the modeling and program development has not considered market issues, or if the overall expectations for the project are drastically out of line with what developers are willing to undertake.

The **Hazelwood Green** team wrote sustainability into the project's zoning code to ensure future developers would adhere to the vision

Photo from Ashley Koltonski, Cushman & Wakefield/Grant Street Associates, Inc.

The latter scenario occurred early in the development of a ZE district in **Erie County, New York**—the development market was not ready to embrace the vision the owners developed. The market has evolved, however, and in 2019 the project began moving forward (see **FIGURE 6 on page 31**).

The request for proposal is an important tool for conveying the specifics about what the lead agency/owner expects and clarifying for the developer what is required and what is negotiable. Coordinating and communicating the expected outcomes, goals, and unique elements of the project with the owner's purchasing department and selection committee is important at this point. Ideally, they have been engaged much earlier and are well aware of the project and its intent. At a minimum, the request for proposal should include:

- Project description
- Project vision, goals, and principles (including energy and sustainability performance goals):
  - Tiered goals[9]
    - Must have/mission critical goals
    - Highly desirable/important
    - If possible, wish list.
  - Clear definition of project outcomes—the more precise the goals and definition, the more likely the vision will be realized
  - Achievable and reasonable mission critical goals.
- Description of relevant ordinances, guiding policies, and required certifications
- Planned building and program mix as well as stipulations related to affordability or use limitations
- City, state, or other regulatory requirements
- Links to existing studies and models if available
- Initial concept and site plans
- Expected **land entitlement** process including stakeholder engagement, approval process, and timeline
- Phasing plans if available.

Land Entitlements

Land entitlements are part of the legal process a developer must go through to get approvals for a development. Entitlements dictate what uses are allowed on the property and define what a developer can or cannot do. The process can be complex, time-consuming, and costly.

The entitlement phase is an important juncture to reconnect to stakeholders, remind decision makers of the vision, and update individuals new to the project about what the development is intended to achieve. Bringing the key parties up to date and back into the conversation can help ensure the project will proceed as envisioned. This phase is also an opportunity to update and refresh communication tools, reengage with the press, and reach out again to the community.

For major land developments that require entitlements, the local jurisdiction has the opportunity and need to embed the master plan vision into **land entitlement** requirements. Quantifiable performance goals established during the master planning process will be updated and refined to ensure that the developer meets the requirements and understands the vision of the project.

Typical **land entitlement** processes require community engagement. This is an opportunity to leverage project advocates and community members who have been involved from the beginning to continue to advocate and ensure the project vision is captured in the entitlement. Entitlements can cover, among other things:

- Zoning updates or variances
- Use permits
- Utility approvals
- Transportation and parking approvals
- Landscaping, open space, and park requirements
- Sustainability and performance requirements.

Getting the First Project Right

A critical step in realizing district HP goals is ensuring that the first building project in the district reflects the energy efficiency, renewable energy, and design expectations for the rest of the development. This project sets the design standard and provides inspiration and guidance for future development. It also serves as a model, proving to local stakeholders and industry professionals that it can be done and directly addressing concerns about meeting energy and sustainability requirements in the master plan and design guidelines.

In addition, ownership and lease models can be tested in this showcase project. For example, the managers of the Boulder Commons office building in Boulder, Colorado, piloted an innovative design and operations model with their tenants and developed a ZE lease structure model.[10]

The first district project is an opportunity to define the "starter thermal network" for a phased district thermal energy system, setting the stage for future buildings to connect to the district energy system. Often this project has a heating, ventilating, and air-conditioning (HVAC) system designed in parallel with the district system infrastructure that can easily connect into the district energy system once it becomes available.

9 www1.eere.energy.gov/buildings/publications/pdfs/rsf/performance_based_how_to_guide.pdf, pages 31–32
10 rmi.org/news/boulder-commons-sets-new-standard-net-zero-leases/

For the Western New York Commercial and Manufacturing Demonstration Project in **Erie County, New York**, local officials and the developer plan to use the first building to set the district standard by establishing EUI targets, using ground source heat pumps, requiring **solar ready** rooftop design, and including HP lease language for future development.[11] The initial building will serve as a model for this brownfield redevelopment district.

FIGURE 6. A **zero energy** light industrial manufacturing and commercial facility designed to achieve zero or better in several sustainability categories: energy, carbon, water, waste, materials, and value on an Erie County (New York) brownfield site

Graphic from HGA, ELEMENTA, and C&S Compa

11 www.ecidany.com/documents/z7%20flyer042617.pdf

CHAPTER 3

DEVELOPING FINANCIAL AND BUSINESS MODELS

Managers of the Boulder Commons office building in Boulder, Colorado, piloted an innovative design and operations model with their tenants and developed a **zero energy** lease structure that ensures the buildings operate as they were designed to.
Photo from Bruce Damonte for Morgan Creek Ventures

The business case for an HPD can make or break a project, even when there is a sound technical pathway to HP.

Understanding the up-front costs as well as the significant operational cost savings available during the life cycle of the district can reveal attractive financial models that enable HP, reduce the up-front cost to developers, decrease energy costs for consumers, and deliver returns to investors. The crux of any HPD financial plan is that an up-front capital investment in energy efficiency and district-level energy infrastructure will yield substantial long-term operational cost savings in the form of reduced energy use, operations and maintenance costs, and equipment replacement expenses. Although initial costs can be higher than traditional development, HPDs can reduce costs over the life of the district for master developers, building owners, and tenants while delivering profits to the energy developer.

HPD economics rely on a long-term outlook (see **FIGURE 7**)—often as long as 50 years for investors focused on energy infrastructure—that can drive substantial returns while reducing energy use and emissions. This long-term approach may not work for every developer, particularly traditional commercial real estate developers with a shorter-term time horizon and greater risk tolerance.

> *Key players can realize their long-term visions if they're able to connect with more patient sources of capital such as investors with experience working with large, long-term infrastructure projects.*

Other real estate investors, especially those that focus on infrastructure (roads, bridges, thermal energy systems, **microgrids**, etc.), however, are comfortable with lower returns coupled with lower risk. Infrastructure projects are secure and predictable, and although steady long-term paybacks are a disincentive to some developers, they can be an incentive to others.

Local government project leads need to understand the specifics of this business case and integrate the long-term investment horizon into their development RFPs.

Interested master developers need to also contemplate how to align this long-term model with investment expectations. These key players can realize their long-term visions if they're able to connect with more patient sources of capital such as investors with experience working with large, long-term infrastructure projects. If HPD projects are executed effectively, the benefits can be significant.

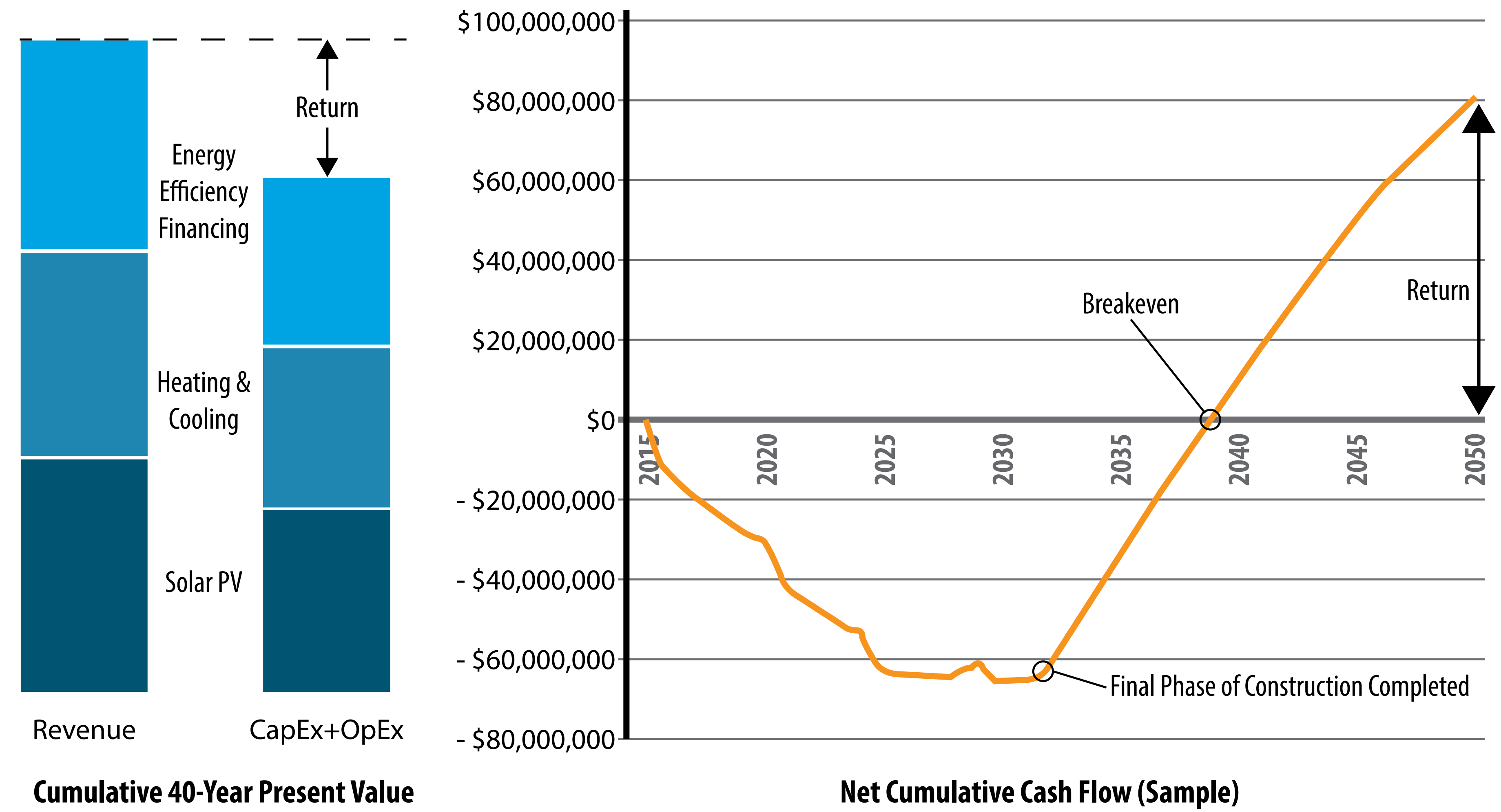


FIGURE 7. Financially attractive investment opportunities

Elements of a Robust Financial Analysis

This section outlines critical concepts to consider when formulating a district business plan, which should be developed as early as possible in the process. A robust financial analysis focuses on a balance of up-front capital costs, long-term energy and operating costs, and other key values that the development team might consider. Financial analysis should be closely coordinated with the thought process and considerations of the design team, so the energy and financial plans can be improved iteratively and based on a comparison of findings.

Cost Analysis: Balancing Up-Front with Long-Term Operations Costs

The first step in performing a financial analysis is understanding the up-front capital costs and the potential long-term cost savings of the technical scenarios considered by the design team. In a typical district-level development, the site owner or developer is working to procure a commodity (buildings that match urban planning requirements) rather than outcomes (a district that produces more energy through renewable resources than it consumes). Costing for a commodity-based approach typically leads to rules of thumb around the construction cost per unit area (typically $/ft^2) that conform to an expected market rate based on the anticipated finish quality of the space. Costing based on outcomes typically leads the design team not only to consider that higher up-front costs might be warranted for higher levels of performance, but also that a value analysis should incorporate life cycle energy, operations, maintenance, and equipment replacement costs.

Many of these developments will exist 50, 75, or 100+ years down the road, so project owners, developers, and building owners should consider scenarios that provide the greatest long-term value. For projects initiated by a local government entity, it is important to align financial goals and the final business plan with the overall vision and project goals to ensure ongoing support by stakeholders and decision makers.

> *Many of these developments will exist 50, 75, or 100+ years down the road, so project owners, developers, and building owners should consider scenarios that provide the greatest long-term value.*

Scenario Analysis

An HPD analysis typically includes multiple scenarios, which allow the design team to understand the tradeoffs in up-front cost, long-term costs, and other values among the various options. Even if up-front costs are higher for HPDs, the long-term value is typically much higher than that of a conventional development. In other words, over a longer time horizon, the HPD will deliver greater financial returns while anticipating future code changes.[1]

After analyzing each of these scenarios, they can be compared based on energy performance, **net present value**[2] (an indicator of how much value an investment or project adds) of any investment beyond business as usual, and alignment with project goals, including energy and sustainability goals. A focus on **net present value** or other long-term economic variables is crucial, because many investments with the lowest up-front costs deliver less value over time and could result in substantially higher energy costs, operating costs, and emissions. **FIGURE 8** shows that the long-term energy, operations, maintenance, and other costs far outweigh the up-front capital costs of a building. It is therefore important to leverage variables that include both short- and long-term costs to make the best investments and to develop a business plan that can leverage these long-term savings.

An Iterative and Holistic Approach to Considering Costs

A successful financial analysis is developed with the design team rather than after the design team has completed its work. In a traditional arrangement, the design team might leverage established rules of thumb to develop a building that is code-compliant, invests minimally in energy efficiency measures, and only seeks premium features when considering the desired finish quality of the development.

There might be a round of **value engineering**—a practice intended to ensure optimum value for the owner. Unfortunately, **value engineering** can have the unintended consequence of stripping energy efficiency measures that are deemed to be too costly up front. The value engineer may be unaware that these measures are good investments, saving energy and money over the life of the building or development.[3]

In an HP planning process, the project team recalculates costs, energy performance, and ongoing operating costs for each of the scenarios outlined above. The HPD scenario is then fine-tuned, and multiple iterations might be considered to weigh the benefits and drawbacks of

1 rmi.org/wp-content/uploads/2017/03/Insight-brief_Net-zero-energy8_2.pdf
2 www.solar-estimate.org/solar-panels-101/what-is-net-present-value
3 labs21.lbl.gov/DPM/Assets/procurement_aesvcs.pdf, page 30

various building efficiency measures, district heating and cooling systems, renewable energy options, and other areas for which there may be trade-offs between the economic and energy goals of the district.

Key Considerations for High-Performance District Scenarios

HPD or building scenarios typically include several concepts that help make a district more cost-effective and energy-efficient, including:

- **Establishing the technical potential and implementable minimum** Involves first considering the most "technical potential"—the energy efficiency scenario that could be achieved on the site by leveraging advanced building construction techniques, very energy-efficient technologies, and a low energy district heating and cooling system, regardless of cost and other constraints. Then layer in the district's goals and financial constraints to devise the "implementable minimum"—the lowest feasible energy use scenario. Engaging stakeholders, especially local utilities, is important and should start at the beginning of the planning process (see **Engaging Stakeholders on page 23** and **Engaging Utilities on page 44**. Often the implementable minimum is still far more energy-efficient and thoughtfully designed than the solution that a design team would have created using a traditional process, and allows the planner to include other benefits such as right-sized equipment.
- **Focusing on the life cycle costs** of the investment rather than the up-front costs as is common in traditional approaches involves considering the trade-offs related to long-term cost savings. Often these long-term cost savings would be realized by building owners and building tenants rather than the development team. In those cases, alternative financing models may be needed for developers to recoup the up-front costs of efficient equipment from the tenants and building owners who realize the cost savings. See **Key Considerations for High-Performance District Scenarios on page 35** for a discussion of how developers can monetize these long-term savings, sharing the economic benefits across all the key players.

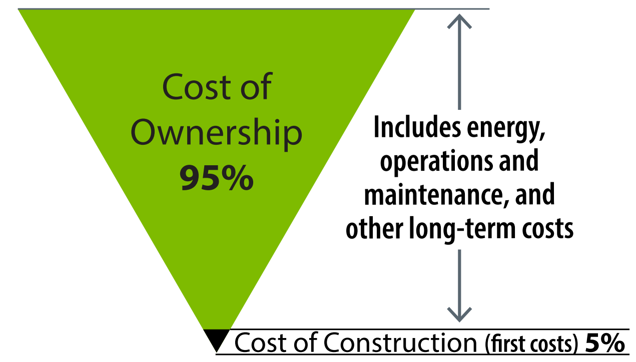


FIGURE 8. When considering the costs of a building, the ongoing costs of ownership far outweigh the up-front cost of construction

Source: U.S. Federal Facilities Council Technical Report No. 142

- **Right-sizing equipment** rather than over sizing equipment (a common practice for a business as usual process) involves sizing equipment to meet code and match the expected outcome (e.g., heating or cooling loads). Often right-sized equipment is key to making a compelling financial case for an HPD because, among other things, right-sizing reduces first costs.
- **Developing a financial analysis** that describes a scenario in which a bigger expense in one area of district energy demand or supply unlocks a large cost savings in another is key to a successful HPD. An example of cost-effective **energy balancing** is an investment in more efficient appliances that produce less heat and use less energy. The reduced internal heat gain makes a smaller, lower-cost cooling system feasible, so spending additional money on efficient appliances unlocks the opportunity to reduce the size and cost of the cooling system.

Value Analysis and Key Metrics

While iterating between the financial and technical plans for the district, costs should be analyzed based on both the incremental capital costs and life cycle costs of each scenario. Incremental capital costs should be considered for the HP and moderate scenarios. This would be the difference between the cost of that scenario and the business as usual scenario. For example, if the business as usual scenario includes a cost of $1 million for a particular building and the HP scenario includes a cost of $1.1 million for that same building, the incremental cost of the HP scenario is $100,000.

The **incremental cost** is an important factor in determining the financial viability of an improvement to the district. In the above HP scenario, a building owner might save $50,000/year in ongoing operating costs as a result of the building's HP status. Comparing this to the total up-front cost of the HPD, the payback would appear to be unjustifiably long (22 years). Comparing this to the incremental cost of $100,000 results in a 2-year payback, illustrating the importance of doing this analysis.

A **life cycle cost analysis** can uncover the scenario that will cost the least to build, own, and operate over the life of the buildings and systems within the district. This is a critical concept to include when developing a financeable business plan that reduces energy consumption and emissions while delivering a return to investors. Even though life cycle cost savings are realized well after the up-front investment has been made, a savvy energy developer, master developer, or **integrated energy services provider** (IESP) can find ways—a long-term on-bill financing program, for example—to redistribute these long-term cost savings among the **vertical developer**s and building owners.[4]

4 rmi.org/wp-content/uploads/2017/03/Insight-brief_Net-zero-energy8_2.pdf

TABLE 1. Nonenergy and Other Benefits of a High-Performance District

Benefit	Description	How to Monetize Benefits
Reduced operating costs	Reduced building operating costs due to lower operations and maintenance requirements, fewer repair and replacement costs, and lower energy costs	Direct cost savings can be quantified or can be converted into a lower net operating income and lower capitalization rate (the ratio of the return on investment to the property value, a metric used by investors to judge a property's financial viability) when commercial building sales are a factor
Employee productivity, wellness, and retention	Enhanced employee productivity in commercial or industrial buildings as a result of green building features; green buildings often have better ventilation, lower levels of volatile organic compounds, more natural light, and other features that can enhance tenant health[5]	Improved productivity, wellness, and retention result in $3,395 of increased profits per year per employee according to one source[6]
Occupant satisfaction	Increased occupant satisfaction due to green building features often leads to better tenant retention, faster lease-up rates, reduced vacancy, and quicker building sales	Faster lease-up, reduced vacancy, and faster building sales have been approximated in Rocky Mountain Institute's "Best Practices for Leased Net-Zero Energy Buildings"[7]
Regional economic development	A new HPD can bring jobs, low-income housing, and workforce development opportunities to a region	Number of sustained jobs created Number of low income housing units included
Resilience	An HPD can serve as a hub for the community during natural disasters, power outages, and other disruptions; on-site renewable energy, efficient buildings, and optional energy storage can allow these districts to include emergency gathering places that can be shared outside of the boundaries of the district	Reduced business downtime
Business continuity	On-site renewable energy systems, optimized energy efficiency, and energy storage (when available) can allow businesses within the district to operate during outages	Continuous operation during outages and emergencies allow businesses to generate revenue
Stable future energy costs	On-site renewable energy systems, optimized energy efficiency, and energy storage (when available) reduce the amount of purchased energy in an HPD as well as mitigate concerns about future utility price hikes	Local PV installations require no fuel and incur no transmission and distribution losses and, if they include storage capacity, can be effective strategies for reducing **peak demand**; this enhances the long-term financial health of an HPD and represents a significant risk reduction for owners and tenants

5 stok.com/research/financial-case-for-high-performance-buildings
6 Attema, Jeremy E., Simon J. Fowell, Matt J. Macko, and Warren C. Neilson. 2018. The Financial Case for High Performance Buildings. San Francisco: stok, LLC. stok.com/wp-content/uploads/2018/10/stok_report_financial-case-for-high-performance-buildings.pdf.
7 Carmichael, Cara, and Alisa Petersen. Best Practices for Leased Net-Zero Energy Buildings: An actionable guide explaining the business case and process for developers and landlords to pursue net-zero energy leased buildings. Rocky Mountain Institute, 2018. info.rmi.org/NZE_Lease_Guide.

Making technical decisions based on technical feasibility, impact on energy goals, and life cycle costs will ensure that the end product achieves its goals while delivering the greatest financial returns, indicating greater market viability and a higher likelihood that an IESP or other entity would be willing to finance the energy components of the district.

Additional Benefits

There are a number of nonenergy and "soft" benefits that can be monetized but are not acceptable in every financial pro forma included in a district-level master planning effort. Energy master planners should engage in conversations with site owners, utilities, developers, the IESP, and other interested parties before deciding whether or not to incorporate them into the financial pro forma.

Energy Development Models

Development can follow a number of different implementation and financial models, depending on the technical requirements, the mixture of new and existing buildings on site, the financial concerns, and the risk tolerance of the parties involved in a specific district-level development.

The IESP approach is an integrated and holistic strategy that places the responsibility for all energy services with one entity. Doing this aligns economic incentives between the IESP, real estate developers, building owners, and tenants, while including sufficient scale to generate a profitable business model for the IESP.[8]

The IESP model is similar to the energy services company model, which is typically leveraged for turnkey building retrofit or new construction projects. The IESP model also includes elements of the design, build, own, operate, maintain (DBOOM) model. As the name suggests, the IESP or energy developer would be responsible for all elements of the district's energy systems from design through operations and maintenance (see **FIGURE 9**).

Although the IESP model is promising as a model for developing HPDs, there are other options. A case can be made for many different business models depending on ownership structure, utility and regulatory structure, and other considerations.

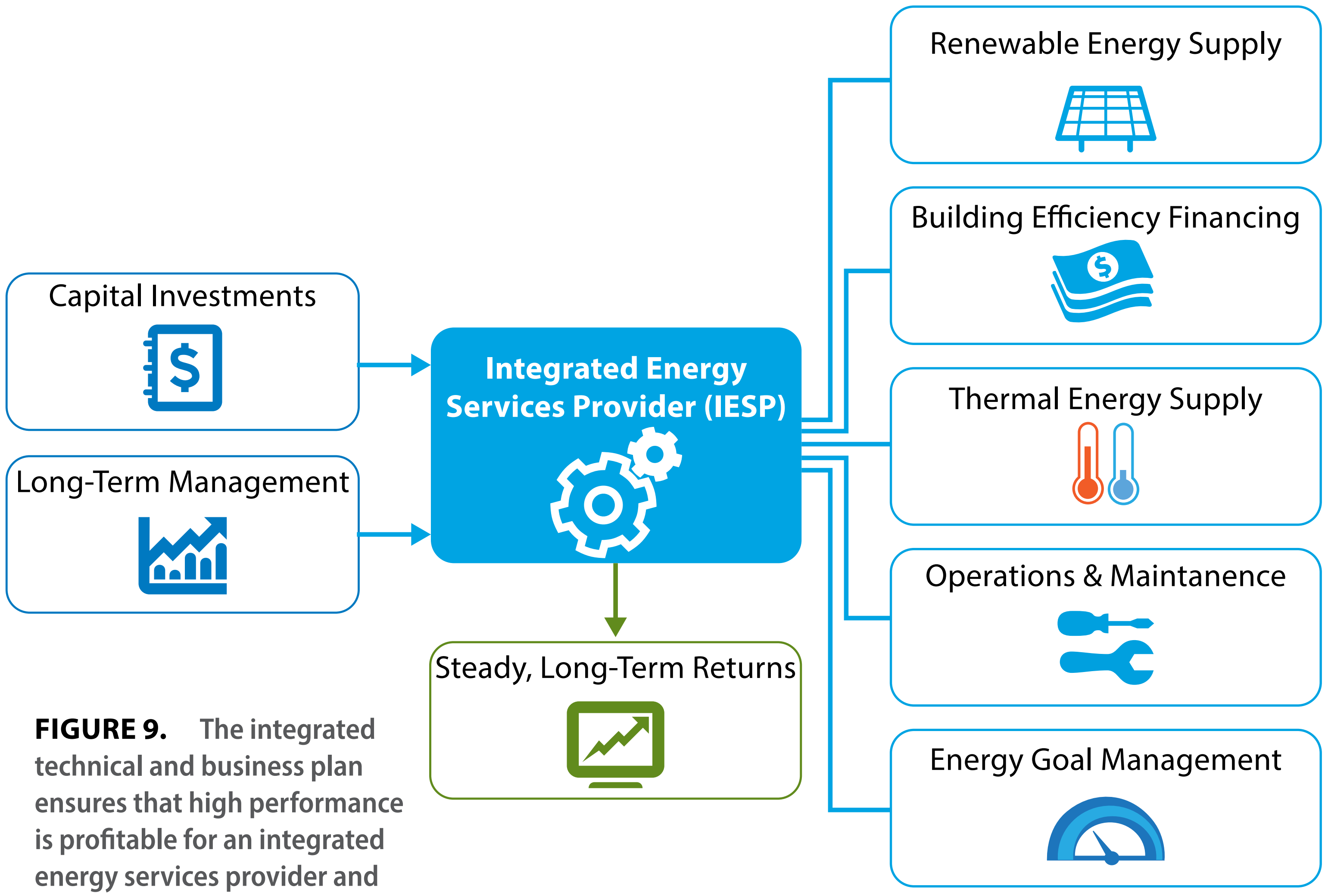
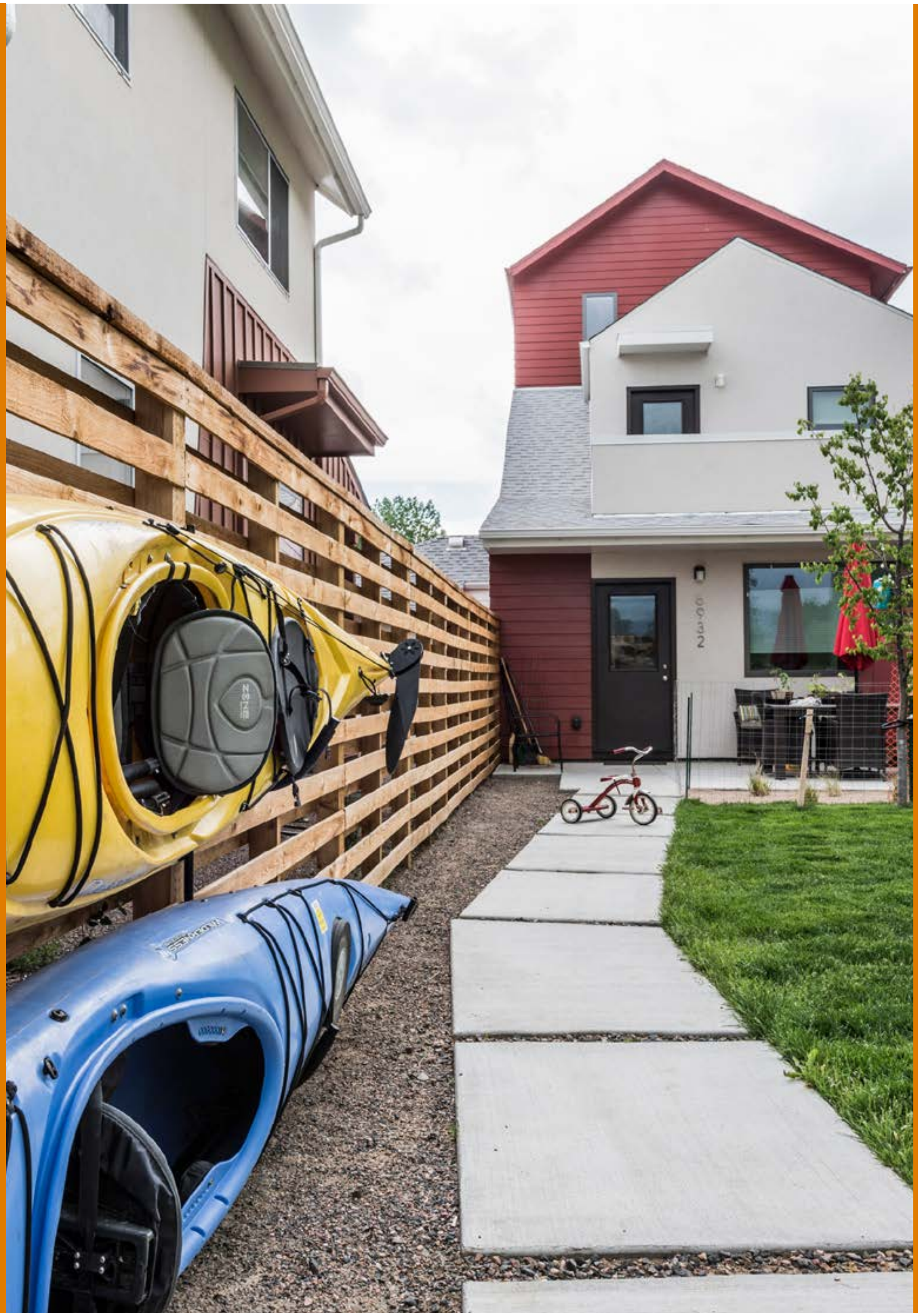


FIGURE 9. The integrated technical and business plan ensures that high performance is profitable for an integrated energy services provider and attractive to **vertical developers** and tenants

8 rmi.org/wp-content/uploads/2017/03/Insight-brief_Net-zero-energy8_2.pdf



Geos Neighborhood is a high density **zero energy** mixed use development in Arvada, Colorado.

Photo from Philip Wegener for Geos Neighborhood

Key Business Model Considerations

A successful business model for an HPD focuses primarily on transferring long-term value to the site owners and developers who invest the up-front capital to deliver site-wide energy infrastructure, more energy-efficient buildings, and on-site renewable energy. It is important to keep the site owner and developer goals in mind while determining the best ways to distribute the long-term value inherent in any energy efficiency project. By marrying these goals with the financial tolerance of all parties involved, a financial plan for the district can be constructed that enables an energy developer to:

- **Provide up-front capital to** horizontal developers for district heating and cooling infrastructure, **microgrid** technologies, renewable energy, and energy storage
- **Consider the potential savings** of making the project all-electric, if possible, as well as any other energy investment potential to support the local grid (see **CHAPTER 4 on page 44**)
- **Provide up-front capital to** vertical developers to invest in more energy-efficient technologies, such as high-efficiency all-electric appliances, highly insulated building shells, air sealing, and construction methods.
- **Deliver energy bills to building owners and tenants that account for the total cost of the HP solution** and pay back debt on up-front investments over time. Often, the energy bill results in a comparable or lower total cost than the building owner or tenant would typically pay.
- **Provide operations and maintenance on all district-scale systems** (renewable energy and heating and cooling systems)
- **Provide assurance that the HP goals of the district will be met and maintained over time**
- **Maintain any additional site-wide infrastructure that may require a long-term investment**
- **Accept a financial return comparable to a site infrastructure project**; this may require a 50-year investment, with a breakeven point between 10 and 30 years, meriting a large long-term financial gain in exchange for a large amount of short-term capital
- **Balance the risks that the site owner, horizontal and** vertical developers**, and energy developer are willing to take**, so that entities willing to take on more risk are justly compensated.

Many ownership and financing structures are possible when developing an HPD. The final structures depend largely on the financial tolerances and desired ownership structure of the district. The established risk profile, up-front costs, and time horizon for the IESP will ultimately need to be balanced to find the optimum price point for all parties.

It is essential that the business plan move past the typical economic thresholds considered in the development industry, particularly the common focus on meeting market rate $/ft^2 construction costs, making decisions based on a **payback period**[9] or **internal rate of return**,[10] and other characteristics that might compromise a life cycle approach.

TABLE 2 on page 39 summarizes the risks and benefits of three ownership structures.

9 www.lexico.com/definition/payback_period
10 investinganswers.com/dictionary/i/internal-rate-return-irr

TABLE 2. Risks and Benefits of Energy Ownership Structures

Energy Ownership Structure	Key Benefits	Key Risks
District owner owns all energy systems	• District owner retains full control of all energy systems in the district • District owner does not pay premium for financing costs, project management, or long-term maintenance of district systems	• District owner retains full responsibility for district high-performance goals and performance of systems (including service outages and warranty repairs) • District owner may be required to develop expertise outside its typical purview or hire consultants with the requisite skill sets
Parcel owners within the district own energy systems in buildings; energy developer owns district-wide systems	• Parcel owner retains control of building-side equipment, which tenants or other stakeholders interact with directly; less reliance on a third party that is not regularly working in the building • Energy developer does not assume risk related to operation of equipment within the building and is not responsible for user errors	• Responsibility shared between building-level and district-level personnel, leading to more complex problem solving, repair, and replacement issues; encourages finger pointing • Discourages right-sizing of district-scale equipment, because the energy developer has less control over sizing, maintenance, and use of building-side equipment
Energy developer owns district-wide system and energy systems in buildings—could be an energy as a service business model	• Simplifies problem solving and issue resolution, as energy developer is fully in control of all systems that interact with district-level energy systems • Can make energy developer responsible for attaining high-performance goal if written into contracting documents • In certain markets, this will enable the energy developer to engage in utility- or regional-level demand response and grid services programs, providing an additional revenue stream and reducing overall costs • Allowing the energy developer to take over more energy services will likely make their bottom line economics pencil more quickly, reducing costs for all players	• Puts full control in the hands of an entity that does not reside in district buildings • Without proper incentive structure, energy developer may not feel responsible for high-performance goal, occupant comfort, or other potential problem areas that need to be negotiated in its contract • Requires a guarantee of payment for the energy services, granting energy developer first rights to sell district electricity, heating, and cooling to tenants in order to ensure their financial solvency

Choosing an Energy Developer

There are many different ways to work with an energy developer, whether it is an IESP or other entity. The energy developer will lead investment and management of the energy systems on site. In some cases, the horizontal real estate developer assumes this role, in others it could be an energy services company, and still others may choose an arrangement unique to that HPD. A single entity should assume this role as well as the responsibility for the design, construction, and operation of energy systems on the site. In procuring an energy developer, the following considerations are essential:

- **The district's HP goals and the intent of the solicitation should be very clear.** Applicants should be willing to embrace these goals and the intent of the solicitation and commit to maintaining a high—and measurable—level of performance and quality. Developers accustomed to business as usual approaches should clearly understand the ambitious nature of this district's energy goals before applying.
- **The energy developer should be procured in tandem with the real estate horizontal developer.** Procuring both of these entities at the same time unlocks several possibilities and synergies:
  - The procurement process could require that horizontal developers and energy developers form teams prior to final round submissions to ensure collaboration and demonstrate a willingness to share risks and rewards.
  - The procurement process would allow for one entity to apply as both the energy developer and

horizontal developer. Some companies may see taking on both roles as a major risk or as a poor use of their in-house skills. Others may see this as an opportunity to better align the real estate development and energy development processes, reducing costs and risk.

- **Understanding past performance is critical.** Most energy developers will have experience working on ZE or HP districts, and understanding the energy developer's business model, technical approach, and project implementation practices will help paint a clear picture of its capabilities. Other developers may not have worked on a project of this scale yet, which can present benefits in terms of novel approaches, but also risks in terms of a lack of experience, lack of capital, or inability to demonstrate capabilities.
- **The request for information can help better define district needs.** The first stage of a procurement, typically a request for information, can be a tool to uncover some of the larger risks or opportunities for a given HPD project. Further, it might allow the team to ask respondents to help shape the next round of the request for proposal based on their business models, local market realities, or other concerns that the project team might not understand clearly.
- **A multistage request for proposal may be necessary.** A single-stage solicitation might not allow the team to learn enough about an energy developer's role, business model, or risk appetite to make an informed selection. A multistage request will allow the team to improve their approach, which can be informed by the initial stages of an energy developer solicitation as well as the **horizontal developer** solicitation.
- **Build the team early.** Ideally, the energy and **horizontal developers** would come on board in the early stages of site analysis and exploration. A small amount of analysis may be necessary to inform the requests for proposal, but an ideal arrangement would bring the horizontal and energy developers on early to align with the site owner's goals and perform site-wide economic and technical analysis themselves.

Financing Approaches

The financing approach for a given district depends heavily on the balance of new construction and major renovation within the district, the risk tolerance of all parties involved, and the creditworthiness of the site owner. Each of the energy development models listed in **TABLE 2 on page 39** typically includes financing that eliminates up-front capital costs for the district owner or **horizontal developer** by leveraging debt financing that is paid back over time. An energy **performance-based** model, like the energy savings performance contracting model used by energy service companies, typically estimates the monthly or annual debt payment based on the amount of money that is being saved through energy cost savings (see **FIGURE 10**). The IESP model does something similar over a long time frame, which allows the financing of the higher up-front costs of district heating and cooling systems as well as district-wide renewable energy infrastructure like PV. Because building energy efficiency investments need to be made by **vertical developers** on a building by building basis, the cash flow for the IESP may require that they make large up-front payments to energy developers in addition to financing their costs for district-level infrastructure. The repayment for this is typically made through some form of on-bill energy payments by the building owners or tenants.

Procurement at Scale To Reduce First Costs

Procurement at scale has many benefits, particularly in decreasing the first costs of equipment like PV; LED lighting; building-side HVAC systems; and other building components that will be included in all or most buildings. Taking an approach that leverages economies of scale can reduce LED lighting costs by 20%–50% depending on the scale of the installation. Further, a Lawrence Berkeley National Laboratory analysis[11] shows that the installed price of PV systems declines with increasing system size for nonresidential installations (see **FIGURE 11**) for the sample analyzed. Specific installed prices for a project will vary based on many factors, but potential economies of scale for PV systems can be considered in analyses for HPDs.

As the number of district energy system "customers"—the building owners and tenants residing in the district—increases, economies of scale can reduce costs by decreasing risk for the energy developer, IESP, and others who have a stake in the long-term success of the district. A larger number of confirmed customers for the district heating and cooling system and on-site renewable energy generation system will reduce the IESP's risk, which enables it to reduce the cost of delivered energy services and/or decrease the period over which the system needs to be financed.

11 emp.lbl.gov/tracking-the-sun

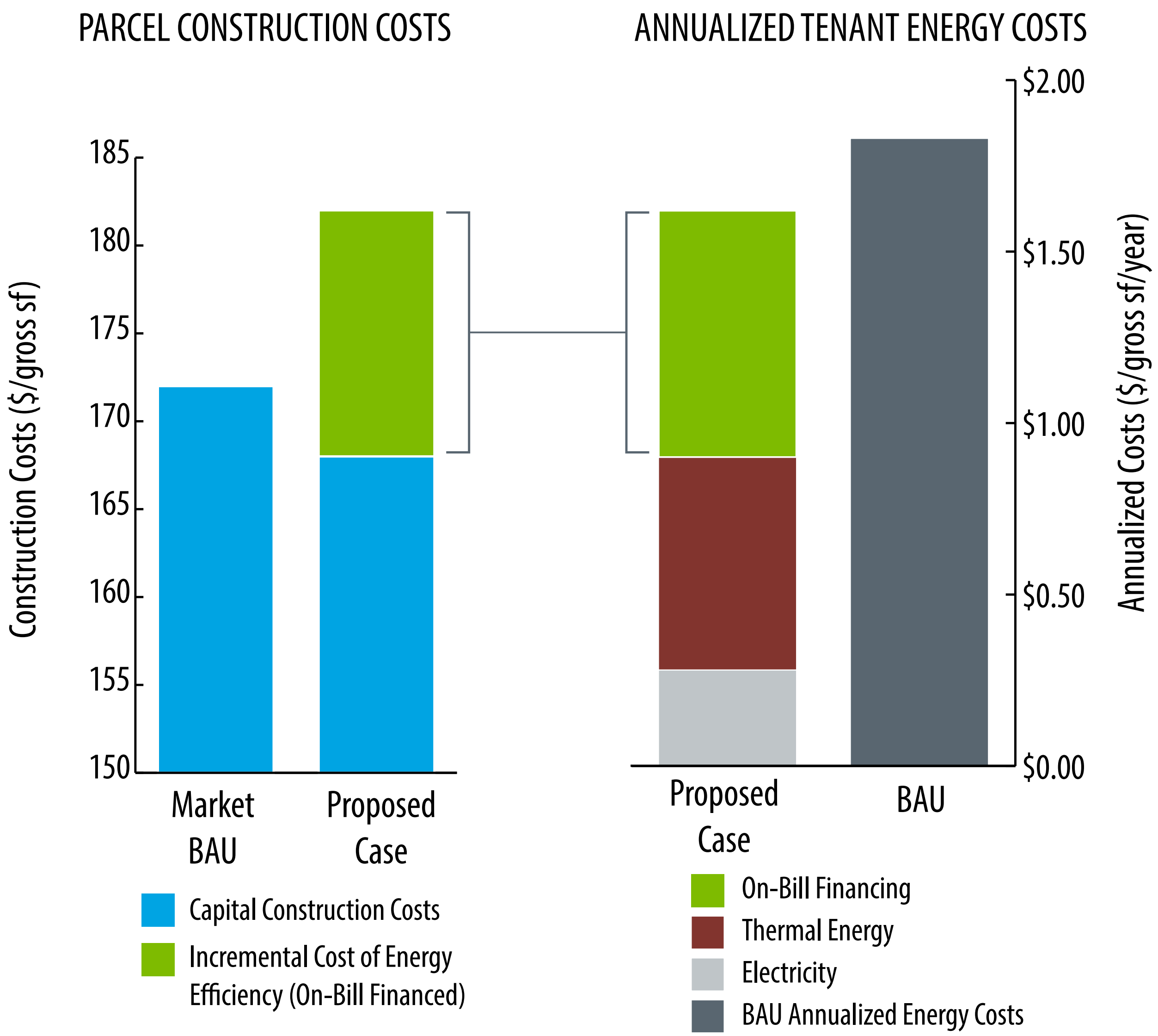


FIGURE 10. The integrated energy services provider model can benefit developers, building owners, and tenants through long-term financing

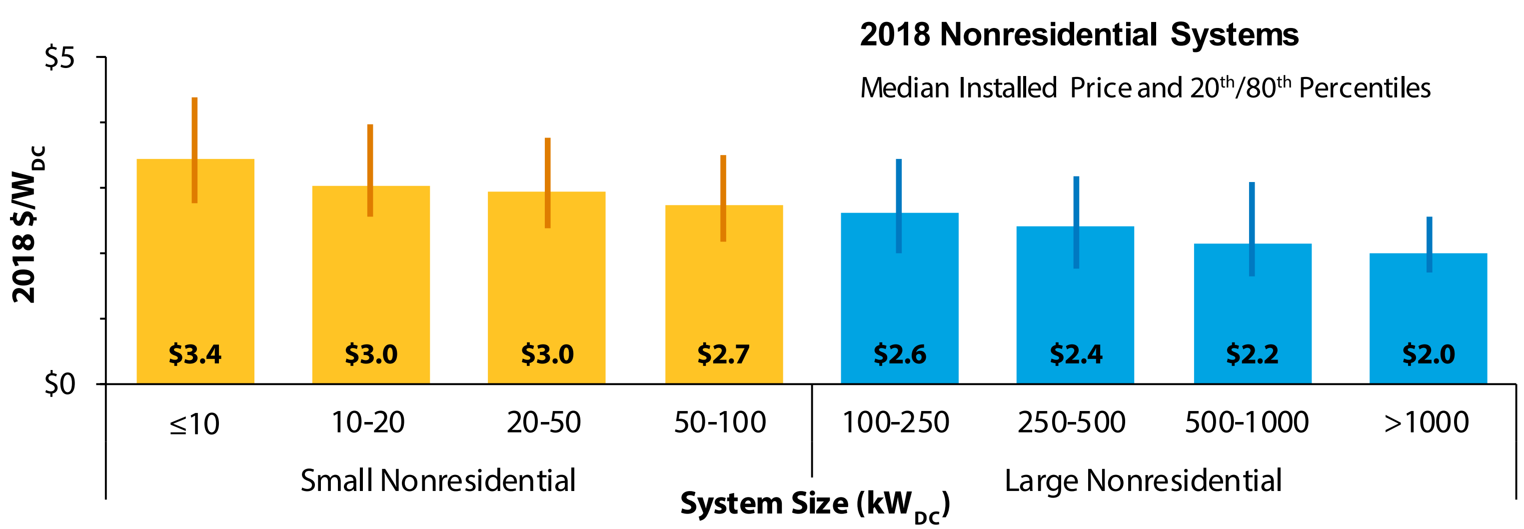


FIGURE 11. Installed price (2018$/Wdc) versus system size range (kWdc) for sample of nonresidential systems installed in 2018

Source: LBNL Tracking the Sun, 2019

Phasing District Development

In any large and complex development project, the time span can be long—in some cases more than a decade—from the initial vision to groundbreaking. This extended time frame means initial assumptions, economic conditions, technologies, and environmental scenarios can change and may require updating, either through phasing or modifying building types in response to market demand. This is why active and ongoing community and stakeholder engagement is critical (see **Engaging Stakeholders on page 23**).

Depending on the energy system the district has chosen, implementing HP at the district scale can be more complex to phase cost-effectively. One of the benefits of a district approach is the ability to create economies of scale with large energy systems. If the project has to be phased, this benefit may be lost or minimized. Therefore, it is critical at this stage to assess the project assumptions and determine how to align those with the available budget. In some cases, this may mean altering the technologies, over building the energy system to support future phases, or reconsidering how and what will be built first. This challenge may also open up new opportunities, such as coordinating with surrounding neighbors to export energy services for a period of time or negotiating with the utility to have it use excess energy in the short term.

Some key considerations that should be evaluated when determining whether and how the project will be phased include:

- **Technology innovations.** Recognize that new technologies and equipment will continue to come to market and enable different savings and opportunities. Use a plug and play approach as much as possible by designing the buildings with standard connections and limiting unique and specialized elements that could restrict future options.
- **New projects and development.** District energy must be designed to add to a backbone and phase investments in expensive infrastructure in line with buildings. Major up-front costs to build large systems can upend a project. At the same time, the inherent benefits of an HPD are to create a single synergistic energy system that serves many buildings and shares costs among them. Questions to address include:
  - What can/should be added at the beginning of a project and what should be added later?
  - Can the up-front investment of energy systems be leveraged before all the buildings are completed? For example, can a large solar array or ground source heat pump system serve the surrounding neighborhood? Will the utility purchase excess power?
  - Will the lack of investment early likely result in no investment and a return to business as usual?
- **Existing projects**.[12] Leverage trigger points to transition existing buildings to HP by developing protocols for buildings undergoing major renovations or sale. In addition, oversize renewable energy and storage systems on adjacent new buildings and on the site to help offset energy use in older buildings, particularly those that are historic or difficult and expensive to retrofit.
- **Energy modeling.** Maintain/develop a usable energy model, ideally available to help run scenarios over time to assess new technology options, account for future technical improvements, and address new demands.
- **Build in flexibility.** Build flexibility into the planning and financing model to enable adaptation and evolution of the energy system and assumptions over time.
- **Develop performance goals.** Ensure that there are specific energy and sustainability performance goals that allow a future developer to be innovative and achieve goals in different ways depending on market, technologies, and current needs. These performance goals may be different from vision and project goals that are more aspirational in nature.

It is important to note that private real estate owners and developers often do not own the property for its entire life cycle, so reducing life cycle costs may not be a motivator for them. Rather, they expect to see financial returns within their ownership period; operating and energy costs over the life of the district don't figure into the calculus.

There are exceptions to this rule, however, notably government- or other nonprofit-led projects. For example, reduced life cycle costs can be very attractive to cash-strapped school districts. A district's energy costs are usually its largest expense after salaries, and the money saved by reducing energy use can be used to support educational programs.[13] Brownfield developments such as **Hazelwood Green** in Pittsburgh, Pennsylvania, provide other examples.

12 rmi.org/insight/zero-over-time-for-building-portfolios

13 A Guide to Zero Energy and Zero Energy Ready K–12 Schools, www.nrel.gov/docs/fy19osti/72847.pdf

Mill 19 at Hazelwood Green has the largest single sloped solar array in the United States—4,784 silicon solar photovoltaic panels that will power the entire facility

Photo from Scalo Solar Solutions

CHAPTER 4

ENGAGING UTILITIES

The Peña Station Parking Facility uses solar photovoltaics to produce energy for lighting, controls, and **electric vehicle** charging stations; the rooftop solar also provides shading and protection from the elements.

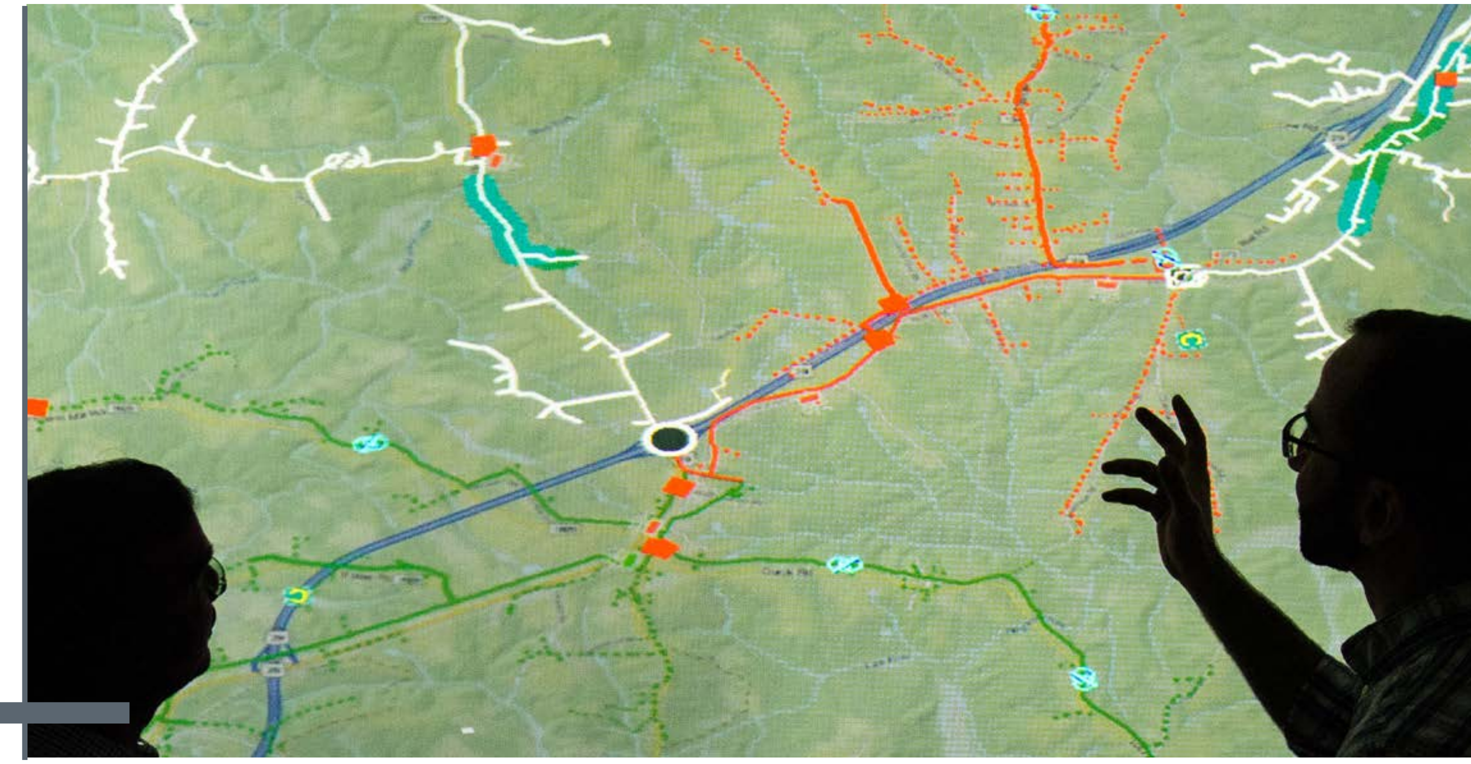
Photo by Dennis Schroeder, NREL 48749

Utilities are key stakeholders and players in the energy master planning of an HPD.

As providers of energy, water, and waste treatment/disposal services, utilities and their associated tariffs, incentive programs, **interconnection** agreements, rules, etc., shape the availability, cost, and complexity of the options for a district. The types of utilities most relevant to HPD projects include electric, natural gas, water, sewer, and waste.

A close, collaborative relationship with local utilities from the outset can be critical because the HPD project may:

- Push the limits of existing utility infrastructure and conventions
- Leverage multiple utility programs
- Require advanced technologies to enable and accommodate flexible building demand, distributed generation, battery storage, and advanced controls.



Utility planners evaluating electrical distribution system to determine future solar photovoltaic system locations

Photo by Dennis Schroeder, NREL 34467

Contact Relevant Utilities and Compare Goals

Successful projects engage utilities early and often to explore options and avoid challenges. Establishing open communication can help avoid surprises, delays, and roadblocks. Although it is not always possible, engaging utilities as strong supporting partners throughout the project can improve the likelihood of success.

Identify local account managers (who are assigned to specific customers) and community relations managers (who are assigned to specific cities and municipalities) as well as utility personnel responsible for new and innovative technology and/or pilot programs. Ideally, identify an internal champion at the utility—someone who will assume ownership of the project—perhaps from an innovation, business model, or research and development department. Look for contacts who can connect and collaborate with staff from different departments to achieve a more complex, integrated district design.

When engaging with the utility, it can be useful to understand the differences between publicly-owned (nonprofit) utilities and investor-owned (for-profit) utilities.[1] Work with utility contacts to understand how local utilities are structured and regulated and the related constraints placed on their potential services and support. For example, there may be long lead times associated with exploring some solutions because of the regulated environment in which the utility operates and the approvals required to pilot or implement new programs. Friendly contacts at the utility can help explain these constraints and navigate these processes.

> *Successful projects engage utilities early and often to explore options and avoid challenges.*

Although each utility may be initially engaged individually, consider the potential interactions between energy, water, and waste. For example, a water or wastewater utility may be interested in heat (energy) recovery or rejection services. Consider which services are more easily integrated (e.g., a municipal public utility that provides multiple services) versus those that are not (e.g., a private electric utility that provides only one service). Consider that a district thermal system may have key interactions with the electric grid and affect the required electric infrastructure; engage utilities early in the process to explore these types of interactions.

1 https://perma.cc/U9UL-LNR7

Power lines in Denver, Colorado.

Photo by Dennis Schroeder, NREL 18975

Consider working with other district-scale projects in your region to engage utilities on topics of shared interest.

Consider working with other district-scale projects in your region to engage utilities on topics of shared interest. One development project is likely small compared to the overall customer base of the utility, but when multiple projects request similar services, the utility can more easily justify devoting resources to engaging with the districts. For private developers, it may be possible to enlist local governments to help engage with utilities.

During the engagement process, it is important to assess how the HPD's goals might align or conflict with utility goals, objectives, and business models. Key questions include:

- Does the utility have energy efficiency, renewable energy, and/or emissions goals/targets (e.g., those mandated by a renewable portfolio standard)?
- Does the utility have other initiatives and priorities that may align with the project, such as:
  - Grid modernization and advanced metering infrastructure
  - Equity and community integration
  - Energy storage
  - Electrification
  - Wastewater heat recovery
  - Peak load shaving.
- Does the utility have challenges that may be exacerbated by the proposed project without proper considerations and design, such as:
  - **Ramp rate** and peak period grid challenges[2]
  - Local supply/capacity distribution constraints.
- Can the district project team work with the utility to lessen the impact of these challenges? Can they quantify the level of investment needed to alleviate these issues?

Understand Utility Rate and Metering Options

A key step to understanding potential energy costs is to gather information about applicable utility rates. Different utility rates may be applicable to different building types. For example, commercial buildings in a district may be subject to demand charges while residential buildings may not. Are there "opt-in" or "pilot" rates that are not required but may be relevant and provide cost savings for efficient, low-peaking districts?

The total costs associated with the electrical energy consumption of buildings and other devices connected "**behind the meter**" within the district will depend on the rate structures of the local electric utility. In many cases, mass market customers such as residential and smaller commercial buildings are billed based on the total amount or volume of electricity they consume (e.g., kWh) during a monthly billing period.[3] This is sometimes referred to as a "flat rate" or "flat volumetric rate."

Most commercial buildings, however, are billed based on both the total amount of electricity they consume and the magnitude and/or timing of their peak power consumption events, often referred to as "**peak demand**." Whereas total energy consumption is often expressed

2 www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy Ramp rate in this case refers to how quickly the grid net load changes. For example, when PV production decreases as the sun sets but building loads remain relatively constant or even increase due to late afternoon/early evening air-conditioning loads, this can result a relatively steep increase in the grid net load.

3 www.smartgrid.gov/recovery_act/time_based_rate_programs.html. Rates often also include fixed charges, which do not vary based on the volume or time of energy consumption.

in kWh, **peak demand** is a power or an average power metric (energy consumption divided by time) and is often expressed in kW. There are many variations, but a common approach is for demand values to be calculated over 15-minute time periods and for the highest demand value over the course of the billing period to be treated as the **peak demand**. Demand rates often include a $/kW charge, which can vary based on time of year, time of day, and/or other factors. Thus, districts that include energy-efficient buildings with reduced **peak demand**s relative to business as usual can experience energy cost savings. For new construction or retrofit district scenarios, energy efficiency and associated peak load reductions can also lead to building heating, ventilating, and air-conditioning cost savings through the downsizing of equipment. This anticipated cost savings can be considered in the financial pro forma calculations for district project.

> *The total costs associated with the electrical energy consumption of buildings and other devices connected "behind the meter" within the district will depend on the rate structures of the local electric utility.*

As smart electric meters—which can collect and communicate more information about energy consumption at shorter timescales than conventional electric meters—become more common, utilities are offering more forms of time-based rate programs such as time-of-use (TOU) pricing, real-time pricing, variable peak pricing, critical peak pricing, and critical peak rebates.[4] These programs reflect the fact that electric generation and distribution costs vary with time. This presents an additional cost-savings opportunity for buildings and districts with more advanced load control and flexibility.

Explore District Master Metering Options

If the district can be billed on a master electric meter through a demand- or time-based rate structure and utility and local laws and regulations allow it,[5] there may be cost-savings opportunities as a result of the diversity in loads between buildings. However, this may require that electrical infrastructure **behind the meter** is developed and maintained by the district (not the utility) and there may be implications regarding the redundancy of service. An example is the electrical distribution infrastructure on the customer/district side of the meter that is needed to distribute power to individual district buildings.

Consider Utility Rate Changes

Although it is impossible to know how utility rates will change in the future, any pending changes to rates on the horizon for the local utilities of a district-scale project should be identified and possible future scenarios considered (e.g., an electric utility moving from a volumetric rate to TOU rate for residential buildings).[6] Renewable energy—especially when it is coupled with energy storage—can also help mitigate uncertainty about future energy costs in an HPD (see **TABLE 1 on page 36**).

Determine Utility Involvement in the District Thermal System

If a district thermal system is under consideration, explore the various utilities' potential interests and roles in the development and operation of that system. For example, does the electric and/or natural gas utility manage/operate other district thermal systems? See **CHAPTER 7 on page 68**, for more information about the technical planning and analysis of district thermal systems.

Identify Renewable Energy and Interconnection Procedures

Utilities may have programs that allow customers to purchase renewable energy from the utility. Even if renewable and distributed energy resources are not utility-owned, it is important to understand the utilities' **interconnection** procedures, policies, limits, rules, etc., and to discuss program options with the utility. These technologies are covered in more detail in **Photovoltaics and Solar Access Planning on page 85**, but some specific utility engagement discussion topics include:

- Solar (on-site, off-site; see **Locating Photovoltaics on page 85**)
  - Does the utility offer off-site solar programs? How are the programs configured and who retains the **renewable energy certificates**? Is **community solar** enabled by the utility, and does the utility have channels to **community solar** developers?
  - Is on-site solar allowed? What are the system **interconnection** rules and size limits? Is there net metering? If so, is it monthly net metering or annual net metering or other? How is net production compensated for and/or carried over to subsequent months? What are the fees and other expenses? Are there additional incentive programs such as the ability to sell **renewable energy certificates**?
- Wind (on-site, off-site)
- Electric batteries
- **Electric vehicle** charging
- **Combined heat and power**
- Geothermal (e.g., electricity generation, direct use)
- Waste heat recovery
- Other topics.

4 www.smartgrid.gov/recovery_act/time_based_rate_programs.html
5 Although the buildings may be grouped under a common meter for billing purposes, it is still useful to have energy submetering to understand the consumption for each building and even end uses within buildings.
6 Obtain information from the utility on current rates and pending rate changes (e.g., changes that have been approved, but will not take effect until a later date).

Utility-scale wind turbines at the Cedar Creek Wind Farm in Grover, Colorado

Photo by Dennis Schroeder, NREL 31194

It may be advisable to have a renewable energy procurement specialist on the owner/developer team. Utilities may be limited as to what renewable energy options they can present and discuss.

Identify Utility Programs

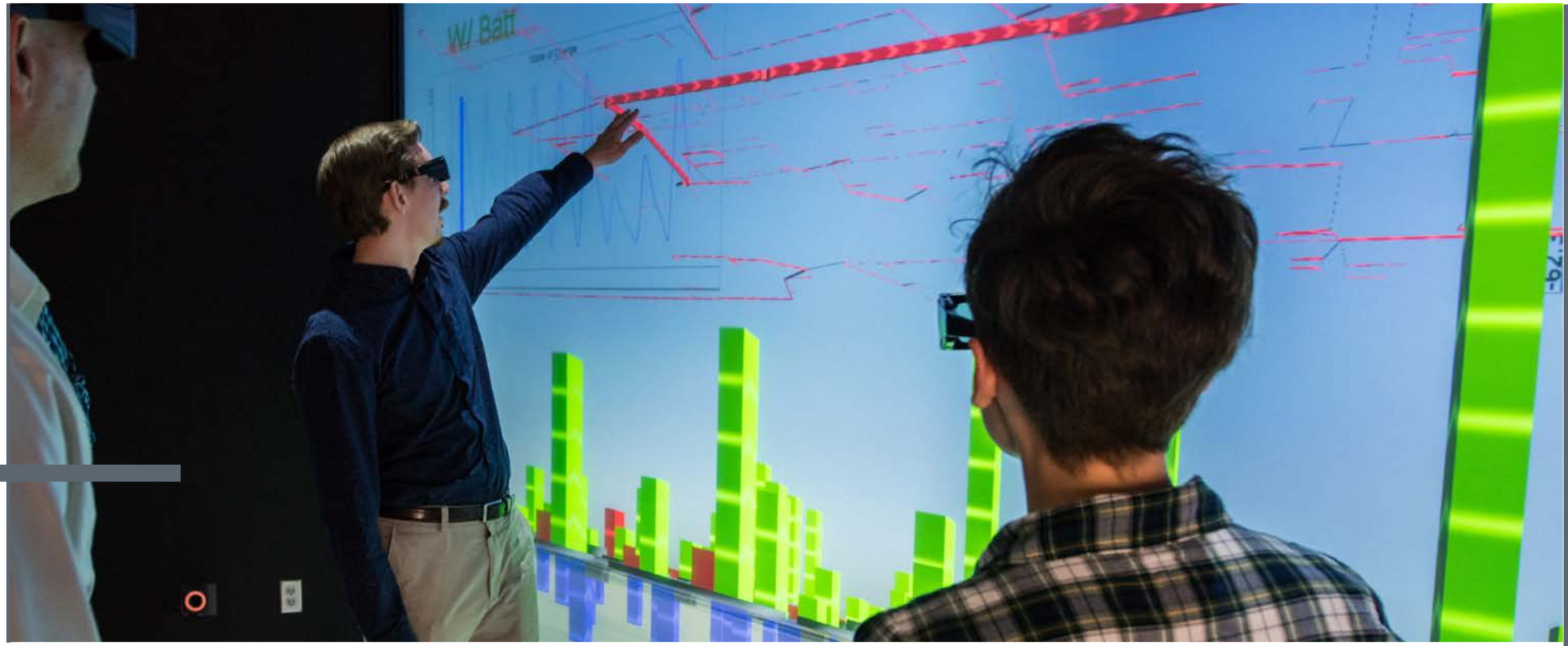
In 2017, electric and natural gas utilities in the United States and Canada spent close to $9 billion on **demand-side management**, which includes energy efficiency and demand response programs.[7] Identify the **demand-side management** programs offered by the local utilities, regional transmission organizations, and/or independent system operators of your district project to ensure all cost savings incentives and rebates are considered. These programs can cover the following sectors[8]:

- Commercial
- Residential
- Low-income
- Industrial
- Cross-sector
- Others.

For example, some utilities offer new construction programs that incentivize buildings more energy-efficient than current code or that meet a certification program's criteria (see **Goal Setting Decision Analysis on page 59** for examples of certifications). Some offer demand response programs to incentivize reductions in load during peak periods (e.g., using technologies such as ice storage for cooling—see **Example Analysis: Building and District Scale Grid Interactivity on page 102**). With all types of utility **demand-side management** programs, work with utility contacts to understand the timing of the district build-out relative to the utility's planning horizon. For example, utility planning is often on 1- to 4-year cycles, while the development project may be on a much longer timeline.

7 library.cee1.org/system/files/library/13981/CEE_2018_AnnualIndustryReport.pdf

8 A detailed list of program types is in the appendices of library.cee1.org/system/files/library/13981/CEE_2018_AnnualIndustryReport.pdf



National Renewable Energy Laboratory engineers Shanti Pless, Andrew Parker, and Kate Doubleday use a 3D visualization of energy model outputs for the Peña Station NEXT district to discuss potential energy loads of the proposed development.

Photo by Dennis Schroeder, NREL 50651

Engage Utility Engineers

Utility distribution capacity planning engineers are responsible for designing the electrical infrastructure (whether new or upgraded) that serves the district. Work with the electric utility as the design evolves to understand the anticipated loads, on-site generation, and local distribution feeder characteristics and design (see **CHAPTER 9 on page 96**).

Peña Station URBANopt and Distribution Modeling Analysis

A collaboration between Panasonic, land developer L.C. Fulenwider, local electric utility Xcel Energy, the City and County of Denver (through Denver International Airport), and other groups, the Peña Station NEXT district in Denver, Colorado, is an example of an HPD engaging utility engineers early in a project. Peña Station NEXT will be a mixed use community located on a commuter rail line at the first stop west of Denver International Airport (see Peña Station NEXT case study on **page 136**).

Working with project partners, NREL researchers combined an advanced analytics platform for high-performance buildings and energy systems, URBANopt™,[9] with grid modeling software, OpenDSS,[10] to model the interaction of the Peña Station NEXT district with the local distribution grid. The effort produced a number of different designs for the Peña Station NEXT system that highlighted the trade-offs between economics and reliability by using different energy technologies such as energy storage, PV, and energy efficiency in the models.

The project team and NREL researchers used the visualization capabilities at NREL's Energy Systems Integration Facility[11] to allow stakeholders to react to different outcomes. They investigated various district-scale scenarios for building energy efficiency, on-site PV, and distributed energy resources such as batteries and smart inverters. For example, researchers explored the impacts of building energy efficiency approaches on building load profiles, timing of PV exports to the local grid, and the effects on distribution feeder voltages and power flows.

9 www.nrel.gov/buildings/urbanopt.html
10 sourceforge.net/projects/electricdss/
11 www.nrel.gov/esif/index.html

Explore New Technologies, Programs, and Business Models

HPDs often push the limits of utility technologies, **demand-side management** programs, and business models. With a strong utility partnership, this challenge can become an opportunity to participate in utility pilot programs. Key questions include:

- What partnership opportunities are there?
- How can the partnership deliver value to the district and the utility?
- What is the utility interested in piloting?
- Are there opportunities for the utility to explore new business models?
- How much lead time is required to get a pilot in place, given the constraints and regulatory environment in which the utility operates?

National Western Center and Xcel Energy Partner in Energy Program

The National Western Center project in Denver, Colorado, (see case study on **page 134**) is another example of successful utility engagement strategies. The National Western Center project team engaged contacts from Xcel Energy—the local gas and electric utility—early on in the planning process, including the local account manager, the community relations manager for the City and County of Denver, and innovation and product development staff.

One key point of engagement was through Xcel's Partners in Energy program.[12] This was initiated and formalized when Xcel Energy and the City and County of Denver signed a memorandum of understanding that defined each entity's role and the deliverables of the agreement. Partners in Energy is a facilitated planning process that occurs over 6 months and results in an Energy Action Plan Technical Advisory Report[13] and then follow-on implementation support from the utility.

The development of the Energy Action Plan for the National Western Center involved several planning workshops, data collection, and modeling and analysis. A diverse group, comprising project staff and stakeholders, were involved in the process, which also included local energy advisors such as Metro Wastewater Reclamation District, Colorado State University, and NREL. The plan analyzed the projected energy, carbon, and economic differences for three different scenarios:

- A baseline LEED Gold v4 scenario
- A ZE but not carbon neutral scenario
- A ZE and carbon neutral scenario.

One of the key findings was that sewer heat recovery from sewer lines running through the National Western Center district could support more than half of campus energy needs based on information at the time, and that sewer heat recovery was a crucial strategy for pursuing a cost-effective ZE district. Partners in Energy also helped identify relevant Xcel incentive programs and factor those incentives into the cost analysis of different scenarios. Xcel Energy further defined and committed to their support in a letter[14] to the National Western Center.

Following the Partners in Energy study, the National Western Center has worked closely with the Metro Wastewater Reclamation District to assess the feasibility of sewer heat recovery. The City and County of Denver and Metro Wastewater Reclamation District formalized their commitments through an intergovernmental agreement[15] to relocate and bury the lines, improving public access to the nearby South Platte River; make the wastewater accessible to a heat recovery system; and mitigate odors from the sewer line through a new biofilter.

12 www.xcelenergy.com/working_with_us/municipalities/partners_in_energy
13 nationalwesterncenter.com/wp-content/uploads/2017/11/NWC-Energy-Action-Plan.pdf
14 nationalwesterncenter.com/wp-content/uploads/2018/04/Xcel-National-Western-Center-letter-04232018.pdf
15 nationalwesterncenter.com/denver-city-council-approves-agreement-to-improve-environmental-conditions-provide-odor-control-at-national-western-center/

The National Western Center, located on the historic grounds of the Denver Union Stock Yard Company in Denver, Colorado, is expected to be a sustainable, multipurpose **zero energy** campus that attracts visitors year-round.

Rendering from the Mayor's Office of the National Western Center

CHAPTER 5

DEVELOPING AN ENERGY MASTER PLAN

The control room at Stanford University's Central Energy Facility.

Photo from Linda Cicero

The master planning of an HP district, campus, or community includes energy-related planning activities that are integrated into the conventional real estate, land use, and urban design planning process.

These energy-related HP activities span the entire master planning process, beginning at the conception of the project and continuing until the plan is implemented.

An HPD involves new stakeholders and team members and requires urban design and planning principles that are informed by analysis and careful consideration of energy impacts. HPD master planning focuses on the urban design and master planning activities that transform an HP vision into a detailed master plan. Like conventional real estate developments, the implementation of that plan includes activities such as building design, building construction, site and infrastructure construction, and building and district operation. In an HPD, however, there is also a focus on planning for district-wide energy efficiency approaches, community-scale district energy, deeper engagement with the local energy utility, and large scale renewable energy solutions.

Energy Master Planning Process

A conventional **development program** describes the building area, densities, building types, and **construction phasing** plans for the overall development. It ties directly into the financial model because it dictates the cost of construction and the potential for revenue. In an HPD, the **development program** and financial model also tie directly into the HP energy design, which balances the energy loads and renewable energy production of district buildings and infrastructure. This **energy balancing** is a way to cost-effectively optimize district energy use (see **Balancing Energy Consumption and Production on page 61**).

The concept energy master plan describes the land entitlement and regulatory approval process as well as community or other stakeholder engagement processes. The HP goal and plan for a district can be a great asset in achieving regulatory approval, as more municipalities are setting emissions reduction targets and looking for innovative projects to help meet them.

For example, some jurisdictions provide zoning incentives and/or expedited permitting or expedited review cycles for high performing buildings. Local authorities may also mandate energy and/or emissions performance thresholds. Policy incentives like these can help make the HPD business case because they speed up an often onerous process.

Stakeholders at a public meeting in Gastonia, North Carolina, provide input on locations for future plug-in **electric vehicle** charging stations. This effort was one of 16 Clean Cities community-readiness projects across the country.

Photo from Centralina Clean Fuels Coalition, NREL 27659

The Mill 19 building in Hazelwood Green was left to rust when the steel industry collapsed, but its exoskeleton was still strong. The Regional Industrial Development Corporation has redeveloped Mill 19 as a "building within a building" that honors the area's history while incorporating state of the art high-performance energy strategies.

Photo from Robert Schaffer, BALA Consulting Engineers

The HPD energy master plan can be a useful tool for building public support. HPDs are often popular with community activists, and an HP goal can help foster support and advocacy for the HPD. Master planning reviews can become opportunities to engage the community and stakeholders while addressing concerns about the energy goal and its anticipated solutions (see **Engaging Stakeholders on page 23**).

Detailed Energy Master Plan

The concept energy master plan process explores design options for the physical attributes of the site including land use planning and zoning, block structure, movement and transportation, architectural massing, and open space. It also conveys the vision of the development and outlines key physical frameworks that will make it work.

The detailed energy master plan takes the preferred concept plan and demonstrates compliance with all regulatory requirements. Conventional detailed master plans include information about street design, landscape and open space, parking plan, site grading, utility infrastructure, architectural character, and, often, development guidelines. For HPDs, all energy-related systems and solutions need to be finalized, brought up to a similar level of detail, and integrated into the development master plan.

For example, the detailed energy master plan outlines the requirements for the final engineering of district thermal energy systems (see **FIGURE 12** and **CHAPTER 7 on page 68**) and renewable energy systems (see **Engaging Stakeholders on page 23**). The detailed energy master plan also includes building performance guidelines or requirements for each building or building type. At a minimum, these guidelines should include the energy use and energy generation targets for each building; this guidance is particularly important if individual buildings are being completed by different developers and should be included in requests for proposal for prospective developers.

Developing a deep understanding of the building types in the program can also help balance heating and cooling loads for a district thermal energy system. An example of this is using a mix of homes and offices, which have occupancy peaks at different times. This is one of the strategies that can reduce the overall size of the district thermal energy system. In addition, the residential spaces may be in heating mode when the office spaces are in cooling mode, allowing the heat removed from the offices to be moved to the residential units within the district thermal energy system. The greater the load diversity, the greater the potential energy and first-cost savings.

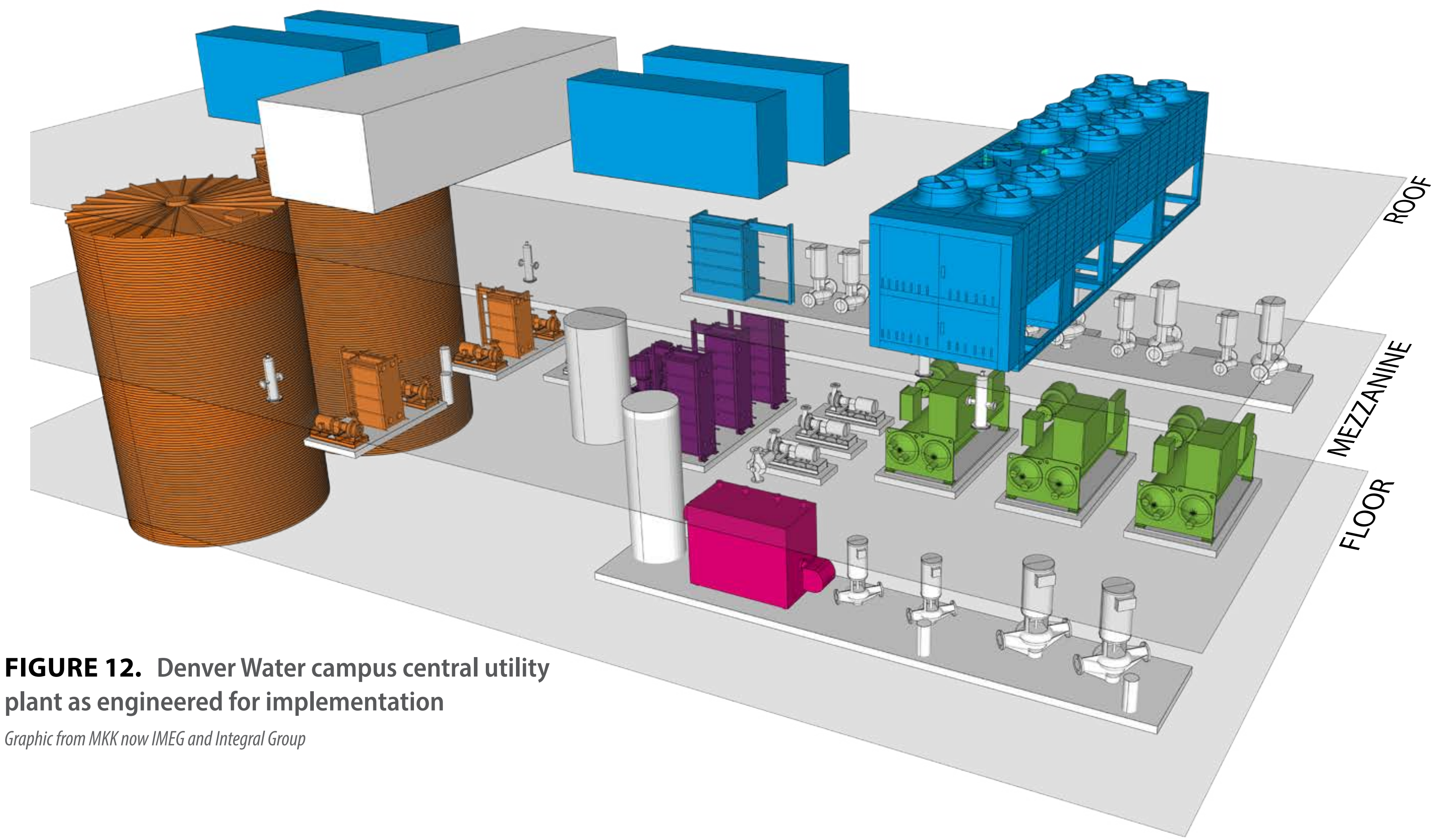


FIGURE 12. **Denver Water campus central utility plant as engineered for implementation**

Graphic from MKK now IMEG and Integral Group

Energy Systems Financial Planning

HPDs have up-front investments in energy systems that are not common in conventional districts. These systems may include distributed renewable energy systems, a **microgrid** that integrates renewables with battery storage and district-level control, and/or district thermal energy systems. These up-front investments need to be integrated into the financial models for the development. Developing a life cycle cost analysis for proposed energy systems will help stakeholders assess these investments' long-term economic value. Life cycle cost analysis is a critical tool for evaluating the benefits of HP performance targets because it accounts for trade-offs between higher up-front costs and reduced energy and operating costs in the future. For example, investing in optimized energy efficiency reduces ongoing energy costs, which also reduces the size—and thus the cost—of renewable energy generation.

Resilience Planning

What is Resilience?

Resilience has many definitions but is generally the ability of a system, community, business, etc., to mitigate damage, respond effectively to power and other disruptions, and rebound quickly after a crisis or disaster. Many communities have adopted more expansive definitions that include the ability to bounce back from a disaster stronger than they were before it. A few definitions of **resilience** from leaders in the field include:

- "**Resilience** is the capacity of a system, be it an individual, a forest, a city, or an economy, to deal with change and continue to develop. It is about how humans and nature can use shocks and disturbances like a financial crisis or climate change to spur renewal and innovative thinking." *Stockholm Resilience Centre*[1]
- "The capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kind of chronic stresses and acute shocks they experience." *100 Resilient Cities*[2]
- "The ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." *The Urban Land Institute*, as first coined by the *National Academy of Sciences*[3]

High-Performance Districts and Resilience

Energy efficiency, flexible building loads, distributed PV, battery storage, and coordinated controls can enhance the **resilience** of buildings and districts during power outages. For example, most **behind the meter** PV systems disconnect from the grid for safety reasons during outages and do not continue to deliver power to the building. However, if systems are explicitly designed for stand-alone operation—which can require additional electronics, controls, batteries, and generation sources—then critical loads in buildings can be met during outages.

> *If systems are explicitly designed for stand-alone operation…then critical loads in buildings can be met during outages.*

When applied at a district scale, these "**microgrids**" can help achieve similar **resilience** across multiple buildings. Energy efficiency and flexible building loads help enable **resilience** by decreasing the amount of energy that must be generated, extending the time backup power can be provided, and better aligning loads with generation. This helps reduce the amount of storage required and can improve the cost-effectiveness of the system. See the NREL brochure, *Distributed Solar PV for Electricity System Resiliency*[4] for more information.

In fact, HPDs are emerging as important strategies for **resilience** and vulnerability planning. This is in part an outgrowth of the Federal Emergency Management Agency's (FEMA's) local hazard mitigation planning and in part a function of the need to address and adapt to climate change. All jurisdictions are required to have a local hazard mitigation plan as a precondition to receive FEMA funding. Historically, that has been tied to disaster recovery but is now also connected to mitigation planning and projects. This change in focus is due to the tangible benefits of creating more resilient systems, communities, and environments that can reduce the impacts from human-caused and natural hazards (earthquakes, hurricanes, flooding, fires, etc.).

HPDs provide **resilience**-related benefits by:

- Creating distinct energy hubs in community facilities that can be used by members of the community and businesses in the case of an emergency, typically as an islandable **microgrid** that can provide communications, battery charging, and other important services.
- Establishing central community centers that can be used as warming or cooling centers
- Providing a separate energy source for critical facilities in the event of a disaster; this is also typically a **microgrid** but designed to support emergency control centers for cities, ports, governments, or services for health care or water pumping.

Incorporating Resilience into a High-Performance District

The first step is to develop a **resilience** goal that helps to define the ultimate use, purpose, and need for **resilience** as part of the HPD energy systems planning process. The goal(s) will, in turn, inform the design of the district. It is essential that the design and development of the district incorporate these **resilience** goals at the inception of the project and that they are evaluated as the energy strategy and master plan is developed. For example, an energy **resilience** goal that provides 8 hours of backup

1 www.stockholmresilience.org/research/research-news/2015-02-19-what-is-resilience.html
2 www.rockefellerfoundation.org/100-resilient-cities/
3 developingresilience.uli.org/about-resilience/
4 www.nrel.gov/docs/fy15osti/62631.pdf

power for critical community functions in a district that anticipates frequent power outages could result in a community resiliency center program being added to the district program. In addition, the project team would identify critical community services and determine the energy consumption and generation requirements associated with them.

Utility and energy provider engagement is also an important aspect of ensuring that the district achieve its **resilience** goals. If planners intend to leverage funding from FEMA mitigation funds, they should tie the project to an overall hazard mitigation plan that includes an evaluation of potential vulnerabilities specific to the site. For example, a district located on a waterfront susceptible to sea level rise or in a floodplain would not be acceptable.

> *Utility and energy provider engagement is an important aspect of ensuring that the district achieve its resilience goals.*

Careful infrastructure planning is essential. If the project will not include a **microgrid** and is instead considering a grid-connected system with on-site generation and battery storage to provide power, policies and **interconnection** agreements need to be established with the utility to enable operation during an outage.

Implementation Success Factors

The success of an HPD master plan requires that it be implemented as envisioned. Key success factors to help ensure the plan is realized include that:

- The advocates and champions keep the vision alive at all phases, including during construction and operation
- **Value engineering** does not sacrifice sustainability
- Clients, developers, and builders understand the business case for an HPD
- The master plan is clear and sufficiently detailed, includes realistic goals, and presents a well-articulated intent and purpose
- The technical and financial feasibility of the plan is supported by rigorous data and economic analysis
- There is alignment and coordination across jurisdictional departments and a strong relationship and partnership with the utilities
- Stakeholders and decision makers are vocal supporters of the project
- There are adequate performance goals in the developer request for proposal, ideally supported by policies (zoning, codes and standards, sustainability ordinances, etc.)
- The project vision, goals, and principles are reflected in the **land entitlements**
- The goals are integrated into the homeowners' covenants, conditions, and restrictions as well as commercial leases
- Energy monitoring and control is integrated into the district and building energy systems.

Denver Water's Operations Complex is a showcase of energy efficiency and **resilience** strategies comprising 11 new structures and the renovation of the historic Three Stone Buildings

Photo from Frank Ooms for Denver Water

University of California Davis West Villiage **zero energy** community (first phase)

Photo from University of California Davis

Operations Planning

Achieving HPD status goes beyond the design and build process. Buildings—homes and businesses—must also be operated as designed. HPD operation is a substantial concern for developers, who cannot promise HP if occupants do not behave in ways that conserve energy. One of the benefits of a district approach is the ability of the energy developer to manage energy loads across multiple buildings. Therefore, as whole, a district can achieve HP even if individual buildings, particularly those with high EUIs, cannot.

Strategies to ensure an HPD achieves its energy goals over its lifetime include:

- **Measuring and verifying results**. As individual milestones are met, the relevant contractors should be informed of the results of the third-party measurement and verification process. Contractors would then receive **performance-based** rewards or requests to investigate and fix performance issues.
- **Monitoring and advanced energy controls.** In a development with larger district-scale or community-scale energy systems, monitoring and assessing building energy use is critical and must be built into the initial cost estimates and business model. For example, the West Village community at the University of California, Davis (UC Davis) is a student and faculty residential campus with some mixed use buildings. After the first year of operation and evaluation, UC Davis found that energy use was much higher than anticipated. It turned out that students had added devices such as small dorm fridges and often forgot to turn off lights or close windows when the air conditioning was on. On the basis of this initial assessment, UC Davis used extensive monitoring systems to help inform changes in operations, establish set temperatures for all the dorm rooms, and identify problems early to reduce overall energy use. UC Davis also instituted programs to educate residents and businesses about wise energy use.[5]
- **Establishing strong covenants, conditions, and restrictions for homeowners.** Covenants, conditions, and restrictions are part of residential developments that have homeowner associations. If this type of requirement is desired, it may need to be added into the **land entitlements**, as not all developers want to manage or deal with homeowners' associations.
- **Dictating energy performance in a commercial lease (green lease)**. A green lease requires the building owner to effectively manage the building systems and shell as well as the tenant to meet specific requirements such as TOU energy consumption and temperature set points, among others.
- **Designing buildings to require as little intervention and management as possible.** Perhaps the most effective operational strategy is to ensure at the very start of the project that operations are considered an important performance goal, and have architects and engineers strive to create buildings that require minimal resources for maintenance, monitoring, and operations.

5 www.davisenterprise.com/local-news/ucds-west-village-is-82-percent-toward-zero-net-energy/

CHAPTER 6

PLANNING FOR ENERGY DEMAND AND EFFICIENCY

By replacing a natural gas-fired **combined heat and power** plant responsible for 90% of Stanford University's greenhouse gas emissions with the Central Energy Facility combined heating and cooling system shown here and committing to procure much of its electricity from solar photovoltaics, the university reduced overall greenhouse gas emissions by 68% from peak levels.

Photo from Steve Proehl for Stanford University

In an HPD, the amount of energy consumed is reduced as much as cost-effectively possible, and then the remaining loads can be largely met with energy production from renewable energy sources.

Accomplishing this requires careful and iterative analysis of energy use and generation from the level of individual appliances, devices, and buildings to district-wide evaluations. Strategies for determining and meeting energy demand and efficiency targets include:

- Setting energy goals early
- Prioritizing energy efficiency
- Including energy goals in procurement, contract, and other documents
- Assessing technical feasibility and energy budget
- Balancing energy consumption and production.

Computer modeling provides powerful tools for refining the design of buildings, energy systems, and entire districts. The initial simulations can determine whether pursuing HPD is feasible and affordable. If it is, the project team should set energy goals at the outset of the planning process and include those goals in all subsequent communications.

Analysis and Approaches

Goal Setting Decision Analysis

The earlier energy goals are set, the more cost-effective the energy solutions can be. Districts should use building energy efficiency as a starting point in HP planning, which helps ensure that initial building investments include the most cost-effective energy efficiency strategies. This, in turn, reduces the amount—and cost—of the renewable energy used to meet the remaining energy loads.[1] **FIGURE 13** demonstrates the importance of getting the early design decisions right.

This strategy of prioritizing energy efficiency is effective in individual new construction and retrofit projects as well as scalable approaches such as design guidelines that specify energy efficiency targets for all future buildings in a district. The energy efficiency standards for an HPD are typically more stringent than code requirements, encouraging investment in the newer technologies and design approaches needed to achieve HP. HPD planners can ensure that the most cost-effective strategies are incorporated into the design guidelines by establishing aggressive EUI targets from the outset.[2] There may be economies of scale associated with the development and use of such guidelines and specifications, such as using

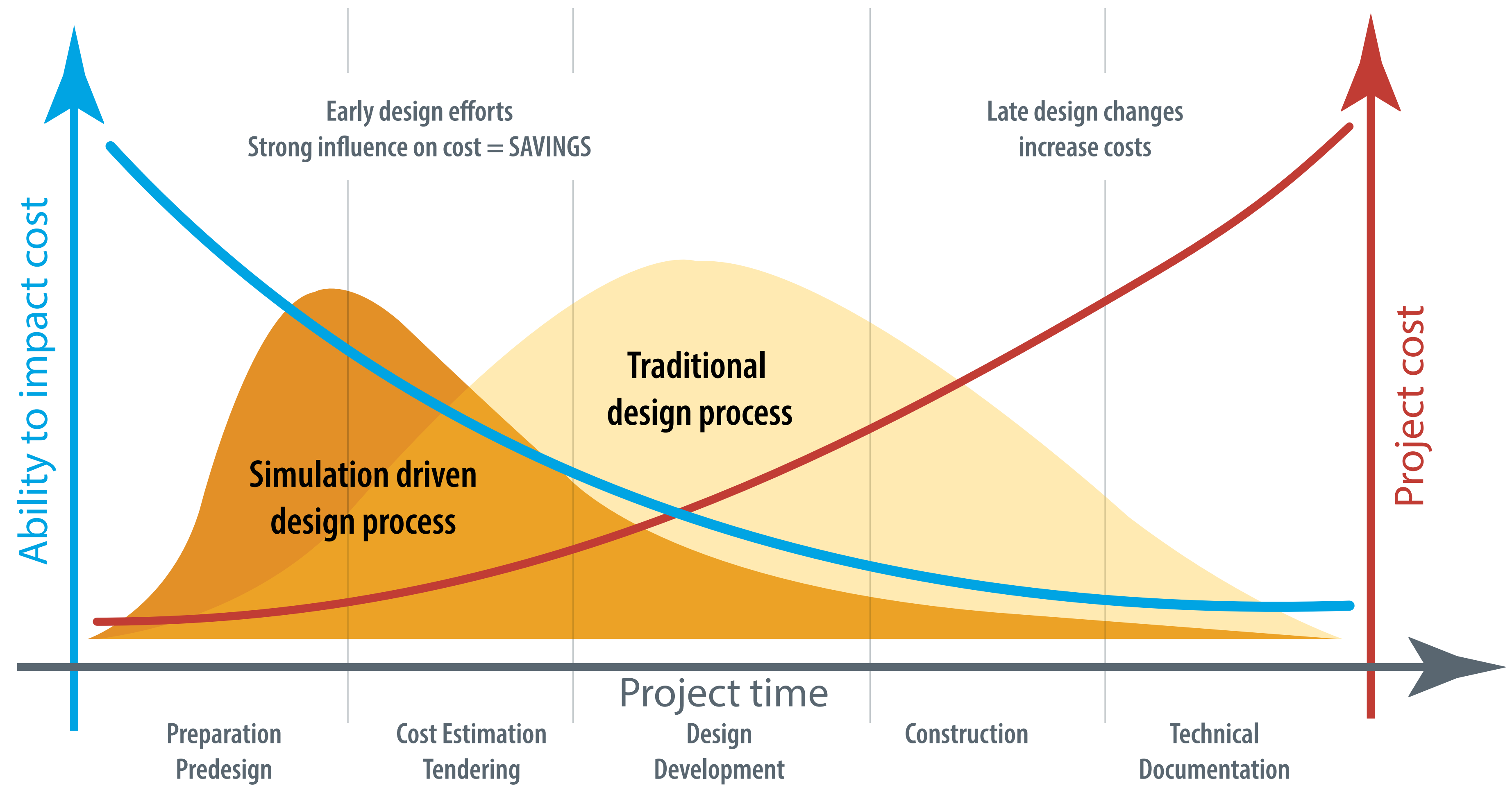


FIGURE 13. Early design decisions versus project cost projections

1 www.nrel.gov/docs/fy18osti/71841.pdf

2 www.nrel.gov/docs/fy18osti/71841.pdf

replicable technical design solutions across buildings in a district. Examples of related questions that district planners should consider in the early stages of planning include:

- What are the EUIs in the project climate zone for different building types and mixes of building types for "business as usual" efficiency levels (e.g., standard efficiency) to high-efficiency levels (e.g., approaching ZE)?
- What are the savings that can be expected by requiring optimized energy efficiency in district design guidelines?
- How do the EUIs compare to what has been achieved in local projects and/or projects in similar climates?

Following the promising practices below can help ensure that the energy goals are aggressive, easy to interpret, measurable, and tied directly to performance.

Define goals at the project's outset to align stakeholders around common objectives. For example:

- All relevant stakeholders should be aware of and support all goals before design and planning begin. This can be accomplished through a goal-setting and visioning **charrette**.
- The site owner should ensure that these goals are made clear to the energy developer, master real estate developer, and any design and construction personnel involved with the project.
- Goals should be documented, and, where possible, included in contracts, covenants, and other legal documents that legitimize the goals and the team's commitment to meeting these goals throughout the project.
- Stakeholders whose efforts will be measured against these goals should be involved in the goal-setting process and supportive of the final outcome.

Incorporate goals into the procurement process and contracting documents for all design and construction team members. Strategies for accomplishing this can include energy **performance-based** procurement mechanisms[3] as well as predefined measurement and verification protocols that specify success criteria.

> *By balancing the energy use intensity targets for each building type with on-site (and, if necessary, off-site) renewable energy production targets, the project team can achieve aggressive high-performance goals and even aspirational goals like zero energy.*

Make goals specific and clear by identifying performance targets for building energy consumption based on building type. The EUI is a familiar and useful metric for building designers, engineers, and parcel developers. Similarly, there should be energy production targets for renewable energy generation based on the size of each rooftop, plot of land, or other surface available for installing renewables. By balancing the EUI targets for each building type with on-site (and, if necessary, off-site) renewable energy production targets, the project team can achieve aggressive HP goals and even aspirational goals like ZE.

A number of organizations have developed guidance to inform this process that can include certification or other documentary evidence that a project has met its goals:

- In *Guide: Best Practices for Achieving Zero over Time for Building Portfolios* from the Rocky Mountain Institute and the Urban Land Institute,[4] the authors suggest a hierarchy of renewable energy options from exclusively on-site resources to local **community solar** to other local off-site renewable energy sources to sources such as **renewable energy certificates**.
- *The EcoDistricts Protocol*[5] requires zero emissions and its energy goal is to "achieve net **zero energy** usage annually."[6]
- International Living Future Institute's Zero Energy Building Certification™ requires that "100% of a building's energy needs on a net annual basis… be supplied by on-site renewable energy, and no combustion is allowed."[7] Some exceptions are acceptable, however.
- LEED Zero[8] recognizes zero emissions, water, and waste achievements in addition to ZE.
- LEED for Cities and Communities[9] recognizes—among other things—**resilience** and energy strategies designed to create cities powered by clean and reliable energy.

3 www1.eere.energy.gov/buildings/publications/pdfs/rsf/performance_based_how_to_guide.pdf
4 rmi.org/insight/zero-over-time-for-building-portfolios
5 ecodistricts.org/wp-content/uploads/2013/03/EcoDistricts_Protocol_Executive_Summary_ISSUE_6.242.pdf
6 ecodistricts.org/wp-content/uploads/2016/06/ed-protocol-guide-v1.3-FINAL.pdf
7 living-future.org/zero-energy/certification/
8 www.usgbc.org/resources/leed-zero-program-guide
9 new.usgbc.org/leed-for-cities

- Architecture 2030 publishes a ZERO Code standard for new building construction that integrates cost-effective energy efficiency measures with on-site and/or off-site renewable energy to get to zero emission buildings.[10]

Develop metrics to emphasize the market competitiveness of an HPD such as the expected first cost and life cycle cost for both conventional and HP buildings and districts (see Chapter 3: **Developing Financial and Business Models on page 32**). Include the life cycle energy costs as well as energy-related operating costs. This analysis can make it possible to use financing mechanisms and other tools that demonstrate how larger up-front investments in energy infrastructure can be paid off over time. As always, specificity is preferable. For example, consider wording such as "The commercial buildings in this district will achieve an EUI of 20 kBtu/ft²·yr, not including the district heating and cooling system." Lower EUIs indicate reduced energy use, which saves owners and tenants money in operating costs. Further statements could cover energy efficiency requirements and the configuration of district-level PV and heating and cooling systems.

Feasibility and Energy Budget Analysis

The energy balance calculation can be completed as soon a preliminary **development program** is drafted. This first pass energy balance allows the technical feasibility of HP to be assessed very early. An experienced energy consultant can make assumptions about building EUIs and renewable energy system parameters to provide a credible assessment.

Key risks can be identified during the feasibility assessment:

- Do the buildings need very low or potentially unachievably low EUIs for the energy balance to be achieved?
- Is there enough potential roof or open space area for the PV needed to achieve the energy balance?
- Is it advisable to explore other locations for PV?

One of the greatest barriers to achieving the full vision of an HPD is unrealistic or inadequate budgeting in the early project planning stages. It is important to develop a complete budget comprising the details required to achieve an HPD and get buy-in from key decision makers about the value and benefit of those additional costs. As the project team assesses energy system options, the **development program**, and other infrastructure needs, initial costing for those systems and technologies must be included in the budget. These costs, along with other trade-offs, can be discussed early and choices made to alleviate costs now or in the future. If this is not done, it can derail the project or reduce the probability of reaching the HP goal.

> *One of the greatest barriers to achieving the full vision of an HPD is unrealistic or inadequate budgeting in the early project planning stages.*

Balancing Energy Consumption and Production

Although the **development program** is primarily a response to a project vision, the owner's financial model, market dynamics, and zoning regulations, considering the balance of energy consumption and renewable energy production can enable synergies at the district level. One key to balancing consumption and production is to Include diverse building types.

For example, residential and commercial buildings are often used at different times of the day, and thus can have complementary heating and cooling load profiles. Low-rise, low EUI buildings with large roofs like warehouses can balance higher EUI buildings like those that house restaurants. Taller buildings with small roof areas relative to their floor areas will also require more PV than will fit on their roofs to balance out their energy consumption.

In addition, the presence of nonbuilding features in a district's **development program** provides balancing opportunities, notably when parking lots and parking garages are used to site PV for renewable energy generation. In addition, parks and open spaces can serve as sites for ground source heat pump bore fields as part of a district thermal energy system and bodies of water such as lakes can be used for a water source in lieu of bore fields.

For districts with existing buildings that can be renovated or replaced, it can be useful to map out scenarios comparing existing performance to new code and HP levels. A sample scenario map comparing existing energy use by building type and the energy use target pathways from code to HP, net zero electric, and ZE is shown in **FIGURE 14 on page 62**.

10 architecture2030.org/zero-code/

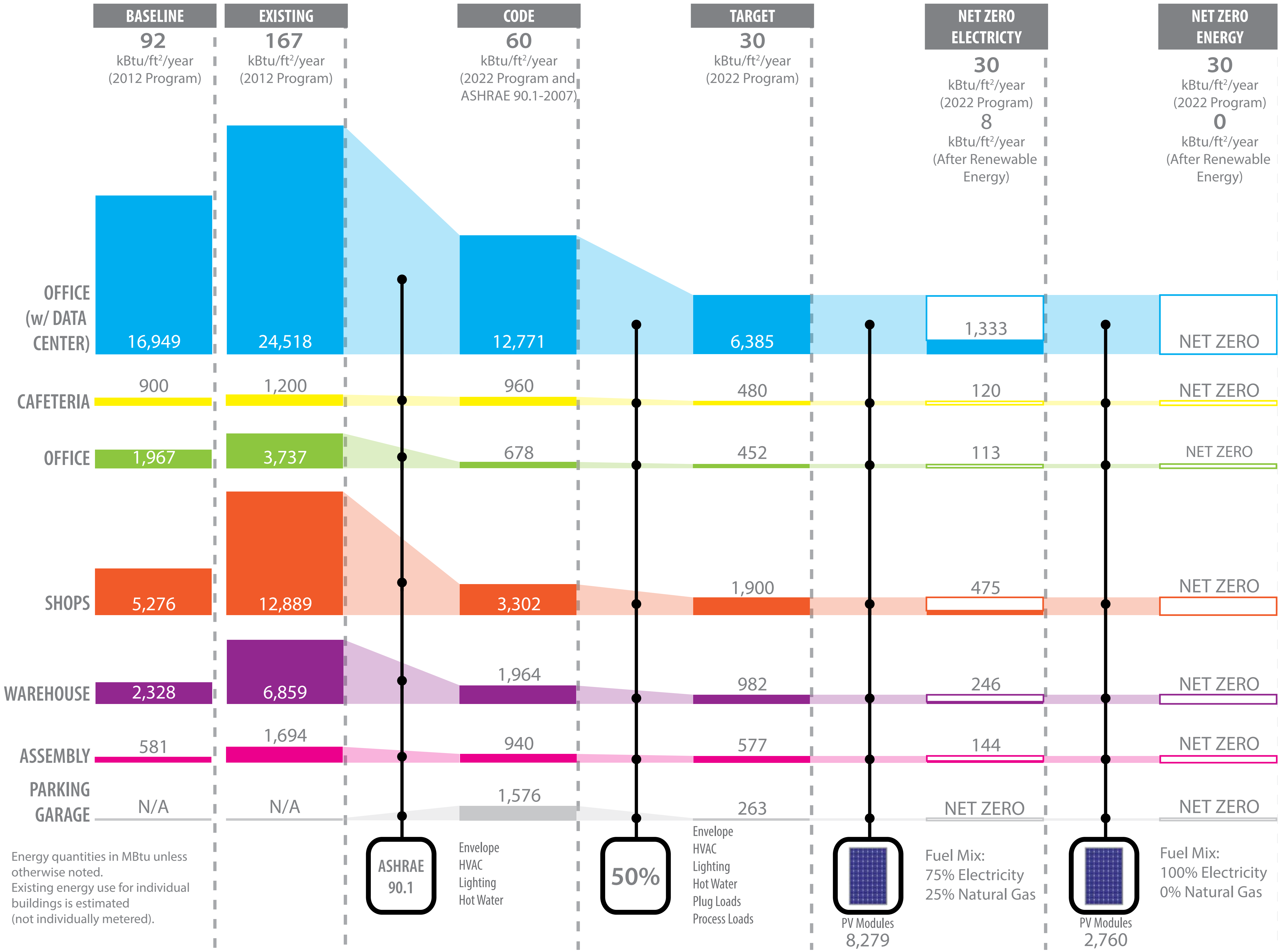


FIGURE 14. Flow map showing the transformation of an existing campus into a high-performance campus

Graphic from RNL Design, now Stantec

District design teams can use a variety of approaches to explore district **energy balancing** issues, including:

- Review of published case studies and design guidance, such as the Advanced Energy Design Guides[11]
- Analysis of measured and/or surveyed data from previously-constructed buildings/districts of similar use types in similar climates. This can be particularly useful if the developer, owner, or architects have a portfolio of relevant past projects that can be analyzed. Resources include:
  - ENERGY STAR® Portfolio Manager and the U.S. Environmental Protection Agency's Target Finder calculator[12]
  - DOE's Building Performance Database[13]
- Commercial Buildings Energy Consumption Survey[14] (CBECS) and Residential Buildings Energy Consumption Survey[15] (RECS)
- The Architecture 2030 Challenge,[16] which provides EUI targets intended to meet the Challenge's goal of reaching ZE by 2030. A ZeroTool[17] is provided for the calculation of EUI targets based on building type and climate zone.

Energy savings targets based on modeled percent savings of less than a chosen baseline; building energy modeling of code minimum energy use, a set of design models, and a final energy model to calculate whole building energy savings may be required.

Building and district energy modeling of conceptual building types and sizes aligned with the district program; energy modeling tools such as URBANopt enable large-scale conceptual energy target development at various levels of performance, from code minimum to HP to ZE ready and ZE.

Modeling

Various arrangements, frameworks, and other variables can be tested using computer energy modeling. These simulations allow the project team and other stakeholders to refine the designs of buildings, energy systems, and the district as a whole to meet the HPD energy goal. For building and district energy modeling, simulation studies can estimate EUIs in different building types within the district as well as the district as a whole based on potential district **development programs**. The two basic approaches to energy analysis are developing code-level baseline models in which the results are reduced by a targeted efficiency reduction (such as 50% better than code) and/or building the model using the proposed envelope and building systems to directly calculate predicted energy use.

Examples of energy modeling results for two possible district building types—multifamily residential and professional office commercial—are shown in **FIGURE 15 on page 64**. Typically, these models are built as prototypes for each building type, and results are extrapolated to the entire **development program** and alternative program scenarios. It may be appropriate to develop simple models or to start with the DOE EnergyPlus™ and OpenStudio® Prototype Building Models, which can save time in analysis.[18]

In addition to estimating energy use for the buildings in a district, it is also important to analyze and estimate energy use for district-wide systems and infrastructure. These can include lighting, traffic lights, EV charging, water systems, and energy systems, among other energy loads.

11 www.energy.gov/eere/buildings/advanced-energy-design-guides
12 www.energystar.gov/buildings/service-providers/design/step-step-process/evaluate-target/epa%E2%80%99s-target-finder-calculator
13 www.energy.gov/eere/buildings/building-performance-database
14 www.eia.gov/consumption/commercial/
15 www.eia.gov/consumption/residential/
16 architecture2030.org/2030_challenges/2030-challenge/
17 zerotool.org/
18 www.energycodes.gov/development

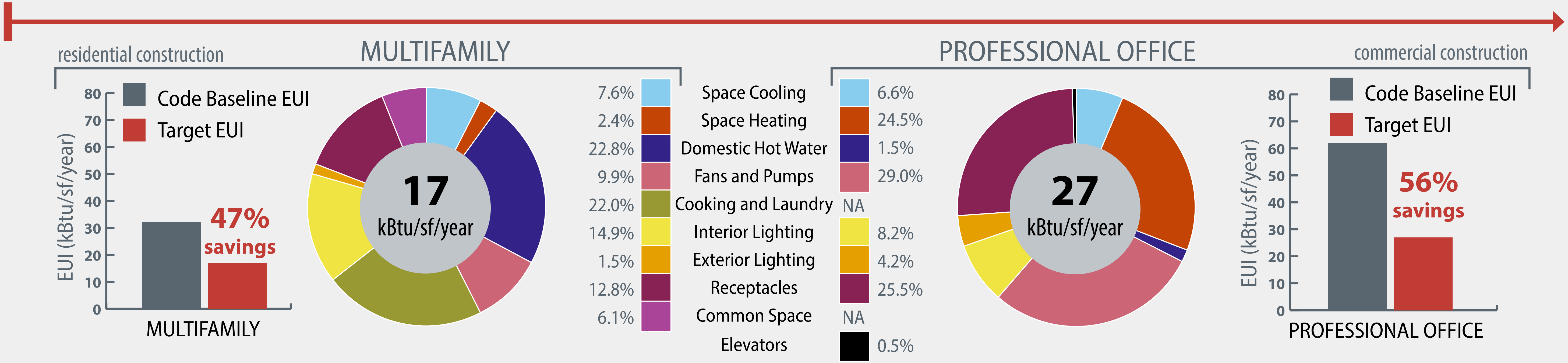


FIGURE 15. Example of energy model results informing **energy use intensity** targets for two building types

Graphic from RNL Design now Stantec

Example Analysis: Energy Use Intensities

The following district energy analysis of mixed fuel prototype buildings in Atlanta, Georgia, which simulated business as usual scenarios using OpenStudio/EnergyPlus, provides an example of this approach. The business as usual scenarios are compared to higher efficiency scenarios (roughly 20% more efficient than the ASHRAE 90.1-2013 baseline scenario) to understand the EUIs that might be achievable using a specific set of energy efficiency strategies. These types of simulation analyses can leverage DOE's Commercial Prototype Building Models[19] as well as OpenStudio-Standards Gem[20] workflows that allow modelers to generate prototype building models in different climates with certain baseline features corresponding to different efficiency code levels (e.g., ASHRAE-90.1). The analyses can also leverage OpenStudio components and measures through the Building Component Library[21] to explore how beyond-code efficiency technologies and measures can reduce EUIs across different building types in the district.

As shown in **FIGURE 16**, EUIs can vary substantially by building type. However, achieving aggressive HP goals generally requires the use of advanced energy efficiency strategies in all building types.

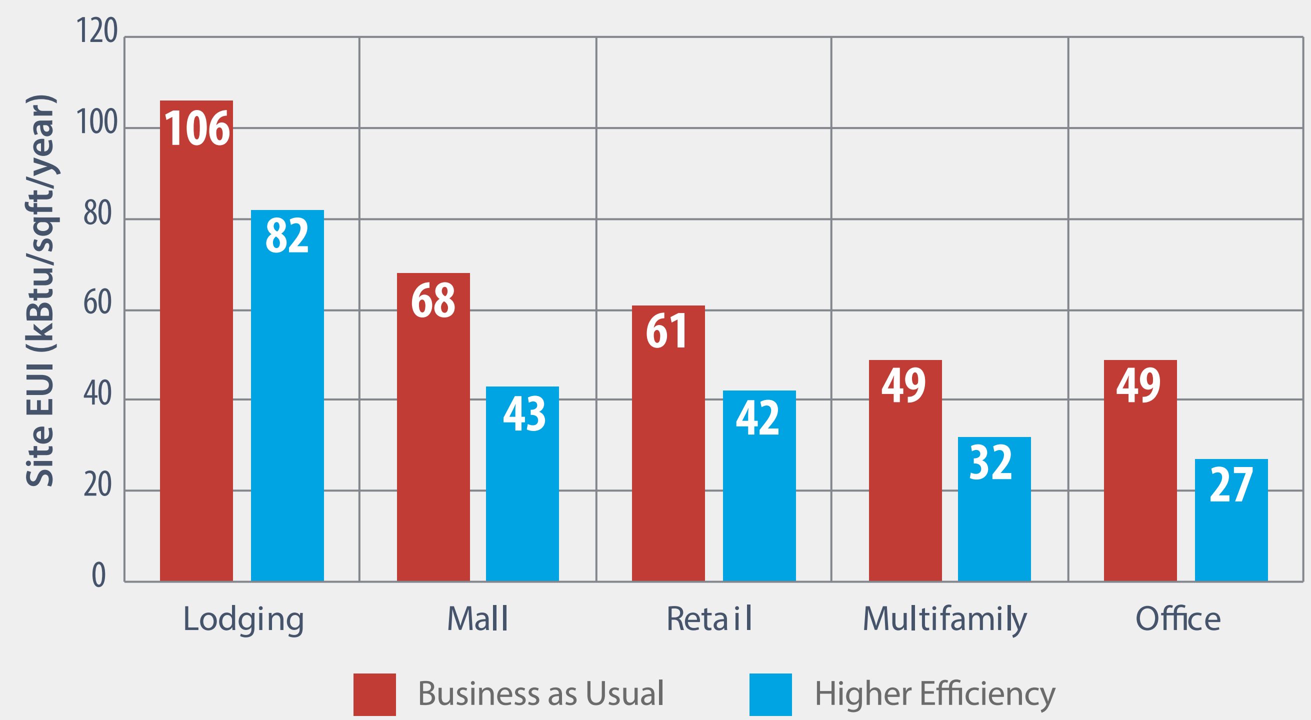


FIGURE 16. Example building energy simulation analysis to identify achievable **energy use intensity** values in different building types relative to business as usual; simulations were performed for DOE prototype buildings in the IECC 3a climate zone (Atlanta, Georgia) using OpenStudio/EnergyPlus workflows

19 www.energycodes.gov/development/commercial/prototype_models
20 www.energy.gov/eere/buildings/articles/new-openstudio-standards-gem-delivers-one-two-punch
21 bcl.nrel.gov/

Three different hypothetical districts were also simulated according to the square footage breakdowns in **TABLE 3** and the average EUI values are shown in **FIGURE 17**. Note that these hypothetical districts are examples only and not intended to be statistically representative of certain types of developments. Although not shown in **FIGURE 16**, a food service prototype building was also simulated and included in the office park and live-work-play districts; the food service prototype had a business as usual site EUI of 405 kBtu/ft²·yr and a higher efficiency EUI of 363 kBtu/ft²·yr.

TABLE 3. Hypothetical District Square Footage Breakdowns Example

	Office Park	Multifamily	Live-Work-Play
Office	80%	5%	30%
Multifamily	0%	85%	30%
Retail	0%	10%	15%
Food Service	10%	0%	5%
Lodging	10%	0%	20%

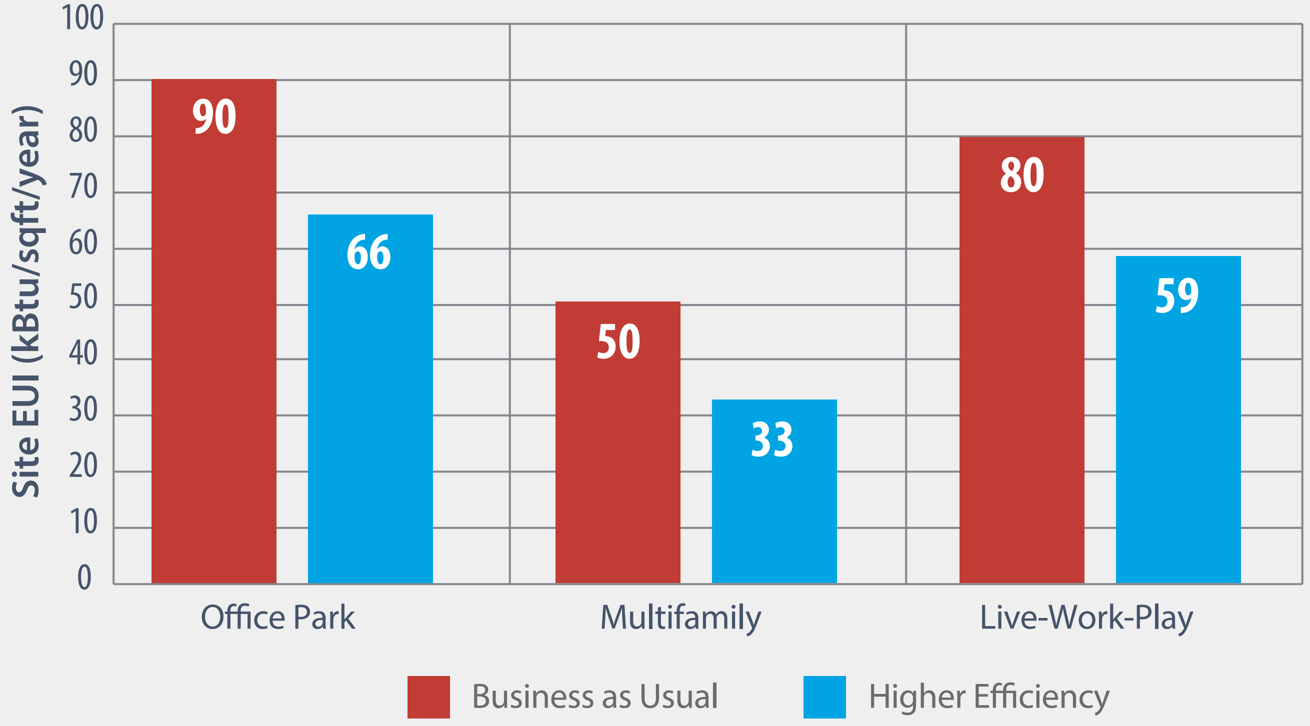


FIGURE 17. Example building energy simulation analysis to identify achievable **energy use intensity** values in different hypothetical district types relative to business as usual; simulations were performed for DOE prototype buildings in the IECC 3a climate zone (Atlanta, Georgia) using OpenStudio/EnergyPlus workflows.

Considerations

Bioclimatic Design and Energy System Frameworks

The urban design and the development of block structures, architectural massing and siting, and other physical planning attributes including shading from trees and adjacent buildings, has a direct impact on the energy use of the buildings (see **FIGURE 18**). Proper solar orientation, roof solar access for PV, access to natural ventilation, green spaces for cool summer breezes, and access to daylight are all part of good bioclimatic site design and will reduce the energy use of the buildings.

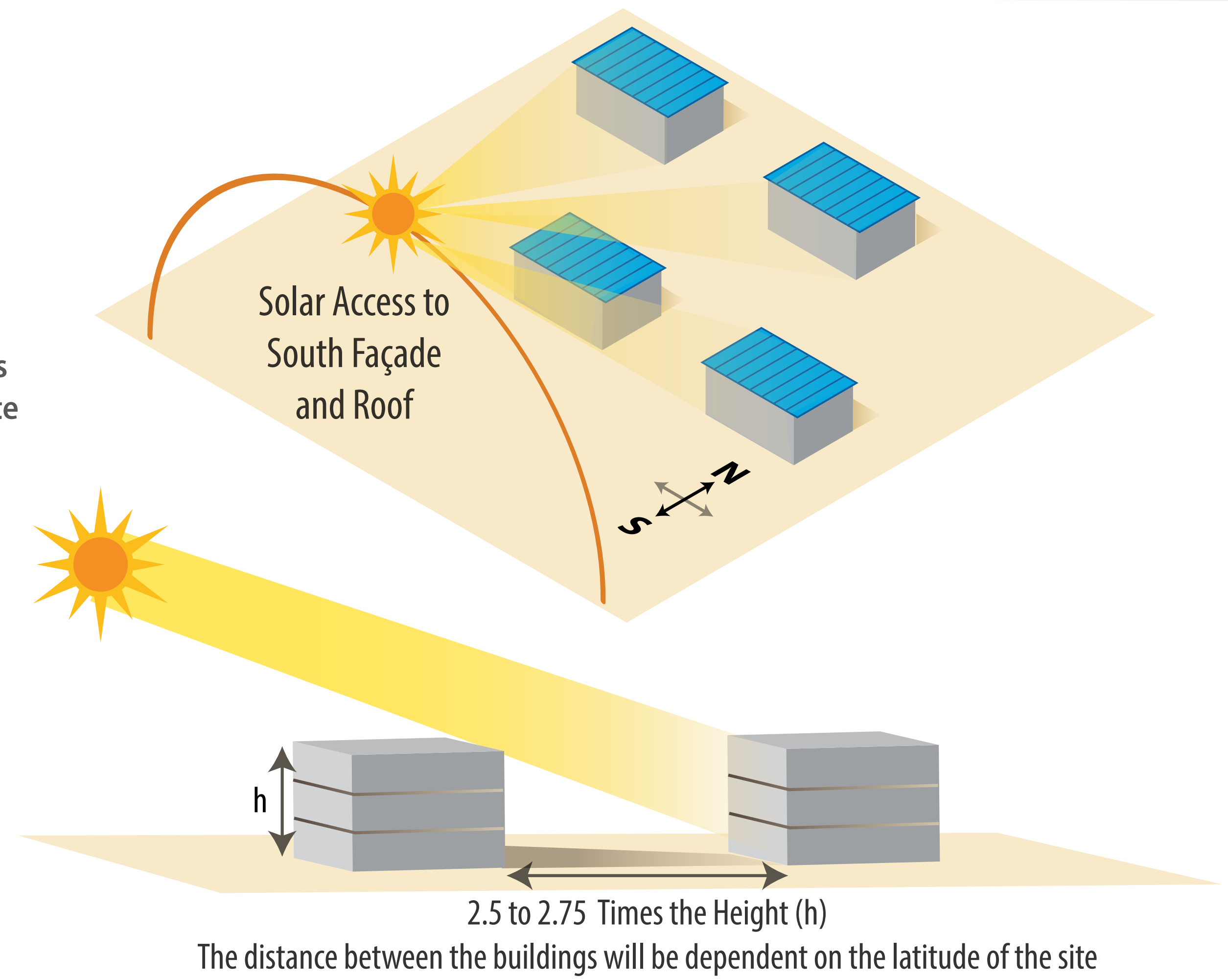


FIGURE 18. Simple sketches can convey key bioclimatic site design concepts

Graphic from RNL Design now Stantec and Marjorie Schott, NREL

Climate analysis using a relevant weather file provides insights into climate-related challenges and opportunities and their timing throughout the year. It is useful to look at annual, seasonal, and daily climate data to understand the climatic challenges and opportunities at different timescales. It is also useful to combine the climate analysis with the site analysis to consider microclimate issues such as shading and wind patterns.

The urban design and the development of block structures and arrangement of buildings and open space should be integrated with the design and organization of district energy systems (see **FIGURE 19**). Energy systems such as renewable energy or thermal energy systems have spatial implications based on their required capacity, the buildings they serve, how they are connected to buildings, and their integration into the urban design structure of the district. It is important to develop the energy system frameworks during the early master planning phase and in collaboration with the urban designers.

The energy concept master plan should include framework plans that summarize key energy systems, including their capacity and locations along with energy use targets for each building (see **FIGURE 20**). The concept master plan may include several alternative design concepts to compare and test. The energy concept development and analysis should be extended to each master plan alternative.

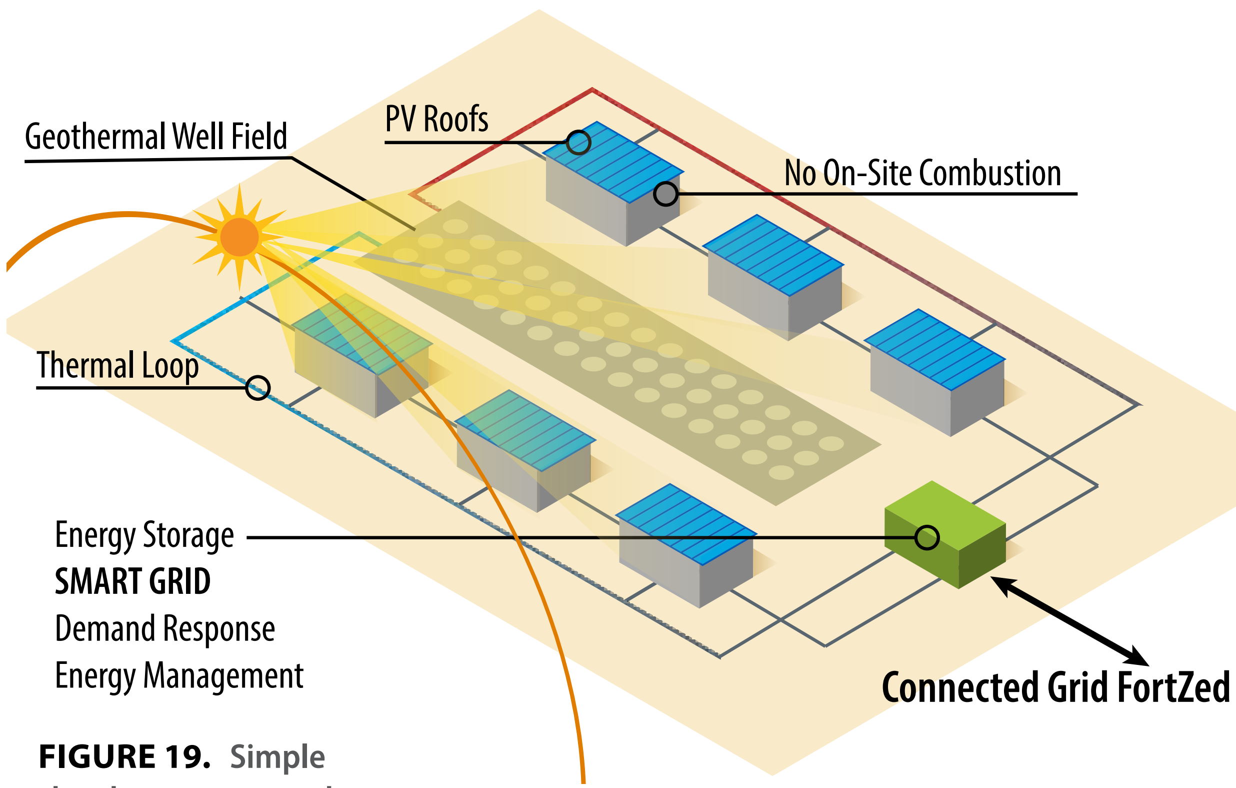


FIGURE 19. Simple sketches can convey key energy system frameworks

Graphic from RNL Design now Stantec and Marjorie Schott, NREL

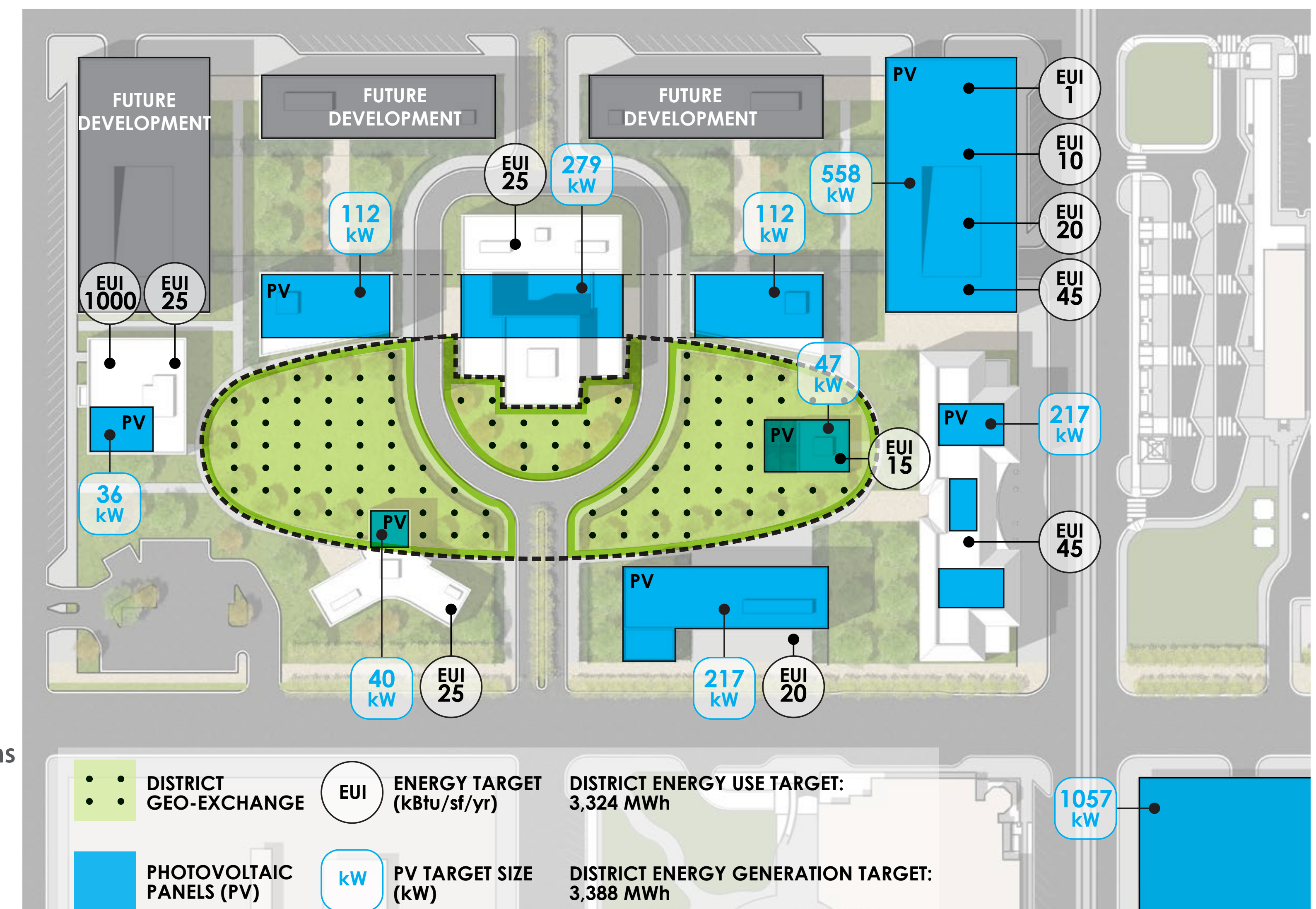


FIGURE 20. High-performance framework plan for the Fort Collins Civic Center

Graphic from RNL Design now Stantec and Integral Group

Integration

District energy planners should use building energy efficiency as a starting point in HP energy planning. This ensures that initial building investments maximize cost-effective energy efficiency, which reduces the amount of renewable energy needed to achieve HP. Achieving a higher standard of efficiency than the code requires encourages investment in the newer technologies and design approaches needed to reach HP and ZE goals. Once measurable and enforceable energy goals are set, district planners and developers should identify opportunities to require energy efficiency levels that exceed code across all buildings in the district by specifying performance requirements in district/neighborhood/community design guidelines. These energy performance requirements can then be incorporated into the procurement process and contracting documents for all the design and construction projects in the district. This can be accomplished through energy **performance-based** procurement mechanisms[22] as well as predefined measurement and verification protocols that specify success criteria.

Energy savings targets based on modeled percent savings below a baseline require building an energy model of code minimum energy use, a set of design models, and a final energy model to calculate whole building energy savings. In districts that have design guidelines requiring energy savings that exceed code and/or LEED certification, a percent savings minimum may be required. An example of the required energy savings and modeling process from the Peña Station NEXT design guidelines is shown in **FIGURE 21**.

22 www1.eere.energy.gov/buildings/publications/pdfs/rsf/performance_based_how_to_guide.pdf

Including Energy Use Intensities in Design Guidelines and Master Plans

Establishing energy efficiency targets based on a percent improvement compared with a building code or standard is one path to an HPD; another is to identify clear, specific energy performance goals. The EUI is a useful metric to describe these goals because it is familiar to developers and design and construction professionals and it is conceptually simpler and easier to understand than codes and standards. Key strategies include:

- Establishing EUIs by building type early in the design process
- Developing computer models and running multiple simulations to refine building and district energy profiles during the design process
- Including the EUIs in all procurement and contracting documents
- Requiring that successful proposals include a commitment to attaining the energy goals
- Encouraging project teams to use their expertise and creativity to achieve target EUIs within the budget
- Using the EUI targets to highlight the benefits and market competitiveness of the HPD.

ENERGY USE

INTENT

1. Buildings should be designed to reduce energy at design and during occupation.
2. Improvements should be designed to optimize building energy considerations and to respect the solar access needs of adjacent buildings.

STANDARDS

- Perform a preliminary energy model prior to the completion of schematic design to optimize the energy approach for the building.
- Building commissioning of energy systems shall be performed by a certified commissioning authority.
- Building shall reduce its energy consumption by at least 25% from an ASHRAE/IESNA 90.1-2010 baseline energy model.
- Energy Star appliances shall be utilized as applicable.
- Building and site design shall strive to optimize energy performance.

GUIDELINES

- 35% of energy should come from green sources, such as solar.
- Energy audits should be completed every five years.
- Consider advanced energy metering, such as sub-metering of energy end uses that represent 10% or more of the building's annual energy consumption.
- Consider demand response infrastructure and plans.

Source: Peña Station NEXT Design Standards and Guidelines[1]

1 business.flydenver.com/bizops/documents/PSN_DesignStandardsGuidelines.pdf

FIGURE 21. Design guidelines example from Peña Station NEXT design standards requiring energy modeling and minimum energy savings for all vertical development

Rendering from Fulenwider

CHAPTER 7

DISTRICT THERMAL ENERGY PLANNING

The False Creek Neighbourhood Energy Utility in Vancouver, British Columbia, uses waste thermal energy captured from sewage to provide space heating and hot water to buildings in several neighborhoods.

Photo from City of Vancouver, British Columbia

For HPD planning teams, a wide variety of potential approaches exists for district thermal systems.

Given the loads and site-specific opportunities and limitations, the most promising approaches should be evaluated and compared on technical and economic bases. To provide cost-effective and energy-efficient heating, cooling, and hot water at a district level requires that the planning team consider:

- **Load density.** District energy systems are most viable in dense and mixed use applications because there is more thermal load in a concentrated area. Concentrating thermal loads minimizes thermal distribution costs and maximizes benefits in a district system.
- **Load diversity and energy sharing among buildings.** The more diverse the building types included in a thermal district system, the greater the opportunity for meeting simultaneous space heating, cooling, and hot water loads as well as making use of waste heat.
- **Access to centralized waste energy recovery.** Some types of district thermal systems enable cost-effective access to waste heat or free cooling resources.
- **Ownership and operational models.** Emerging thermal utility models[1] can be used to access planning, design, capital, operations, and billing mechanisms for a district thermal energy system.
- **Development phasing.** Starter thermal networks and phased district infrastructure can better match the development build-out and are important implementation considerations.
- **Feasibility model for business as usual comparison.** Early, detailed hourly or 15-minute annual energy modeling, combined with a comparison to various business as usual scenarios are critical planning and feasibility evaluations to support the necessary infrastructure planning for district energy systems.
- **Operational benefits from centrally located thermal systems.** Simplified and centralized maintenance and operations can ensure high operational performance because of the ease of operating a single HVAC system rather than multiple distributed systems.

As technologies and thermal energy district system applications have expanded, district thermal systems have moved from first generation steam heating systems to fourth generation hot and chilled water district systems. To take advantage of new opportunities to reuse low-grade waste heat, meet climate and renewable energy goals, promote electrification and energy sharing, better align thermal system phasing with the long-term build-out, and accommodate lower density districts, fifth generation multiuse district systems are now coming online, as shown in **FIGURE 22.**[2]

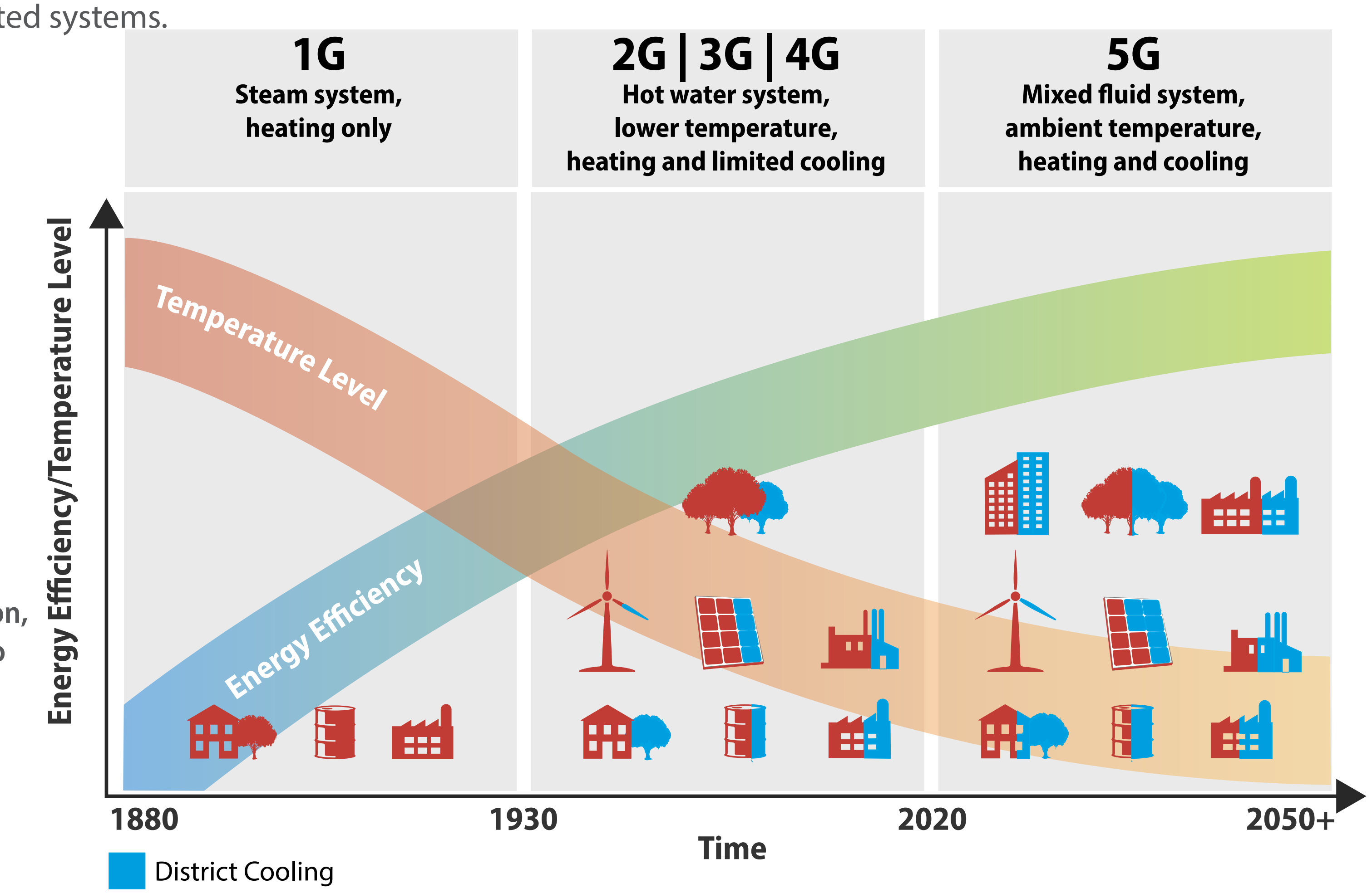


FIGURE 22. District energy system evolution, from first generation to fifth generation

(G=generation)

1 www.edf-innovation-lab.com/wp-content/uploads/20180517_ThermalMicrogrid_WhitePaper_FINAL.pdf

2 www.integralgroup.com/wp-content/uploads/2017/06/IntegralGroup_District-Energy-101.pdf

Analysis and Approaches

Load Diversity and Energy Sharing

A key advantage of a district thermal approach compared with a building-by-building HVAC approach is that the diversity of thermal loads across buildings (e.g., time of day, days of week, months of year) can lead to additional savings by creating opportunities for waste heat recovery and energy sharing. Load diversity also helps maximize the return on investment for the shared energy infrastructure and enables a district thermal system to be sized for the district peak rather than the increased installed capacity in a building-by-building approach.

For example, the capacity of a district thermal system can be smaller than the sum of the capacities of individual building HVAC systems, because the buildings' heating and cooling demands may peak at different times. In addition, because of their unique occupant needs and use types, some buildings may operate in cooling mode when others are in heating mode. Certain types of district thermal systems can allow waste heat from cooling in one building to be used for heating in another building, improving overall energy efficiency. Because equipment costs generally scale with capacity, load diversity can also help reduce initial capital costs.

One approach is to combine centralized district heating and cooling plants with a heat pump loop system similar to the systems often found in stand-alone HP building projects. This combined fifth generation district heat pump loop system distributes low- or ambient-temperature water that is boosted by heat pumps in each building to provide heating or cooling. This configuration offers the potential for optimal heat recovery from multiple sources while minimizing district piping costs. Another advantage of this approach is that low-temperature heat sources in these **ambient loop**[3] district systems can be well-matched to low-temperature heat loads such as those for radiant heating systems. In addition, backup boilers and cooling towers can be shared across the district, requiring fewer of these expensive and minimally used systems.

> *One approach is to combine centralized district heating and cooling plants with a heat pump loop system similar to the systems often found in stand-alone high-performance building projects.*

Among many factors, the technical and economic evaluation of these systems must consider the energy use and costs associated with district system piping and pumping—such systems may not be optimal for districts with low building and energy load densities, for example. Fifth generation systems enable use of low-grade waste heat sources to increase the efficiency of the heat pump-based systems. Examples include:

- Data center cooling
- Refrigeration systems such as those in warehouses or grocery stores
- Wastewater heat recovery from a central district holding tank or city wastewater system
- Other Industrial waste heat sources, such as **combined heat and power** or factory heat generation sources.

Centralized free cooling options are also easier to access across a district, reducing building cooling and chilled water energy use and costs. Examples include:

- Central ground water wells
- City water (potable and nonpotable irrigation sources)
- Lake water, river water, or ocean water cooling systems with a central heat exchange point.

Heating and Cooling Load Analysis

Conventional thermal energy plants are often heating only or have separate hot water (or steam) and chilled water generation and distribution. New generations of district thermal energy systems combine cooling and heating, with buildings serving as one of the many heat sources and/or sinks on the system's loop. This allows thermal energy to be shared across buildings before a heat pump or other active heat source or heat rejection technology is deployed. Each building type in the development will have its own unique load profile. By overlaying and comparing load profiles, it is possible to determine when some buildings are in cooling mode and others are in heating mode, with the potential to offset loads. The heating and cooling peaks for each building type will be unique and may not occur at the same time as other building peaks. This can result in a district-level heating and/or cooling peak that is significantly lower than the sum of all building peaks, resulting in a dramatically downsized central heating and cooling plant.

Determining the potential for district thermal systems requires an analysis of the heating (including service hot water) and cooling load profiles for the development. Early assessments can be made by applying educated assumptions about heating and cooling loads to the **development program** to understand the potential for a combined heating and cooling district system. To develop and size a district system, annual load profiles will need to be developed using modeling. The energy modeling process used to test and track the energy use target for each building type can be used to develop

3 www.designingbuildings.co.uk/wiki/Ambient_loop

more accurate and detailed load profiles (see **FIGURE 23**). The energy modeling process should also be used to test different district thermal system designs. **FIGURE 24** through **FIGURE 26** illustrate the range of thermal district systems that were considered and evaluated for the Denver Water campus (see the **Denver Water case study on page 118**).

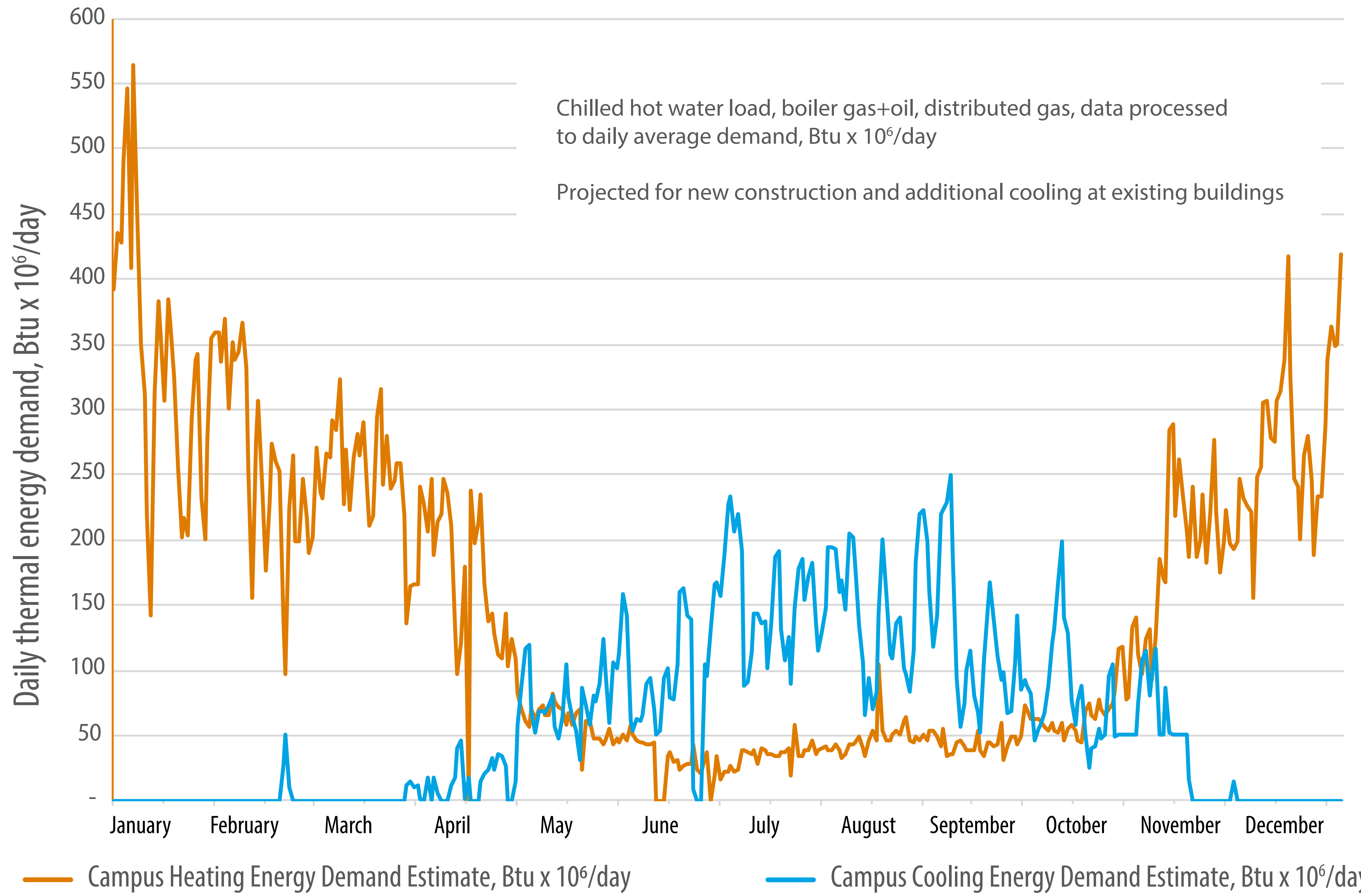


FIGURE 23. Example of load profile analysis of the Swarthmore College campus

Graphic from Integral Group

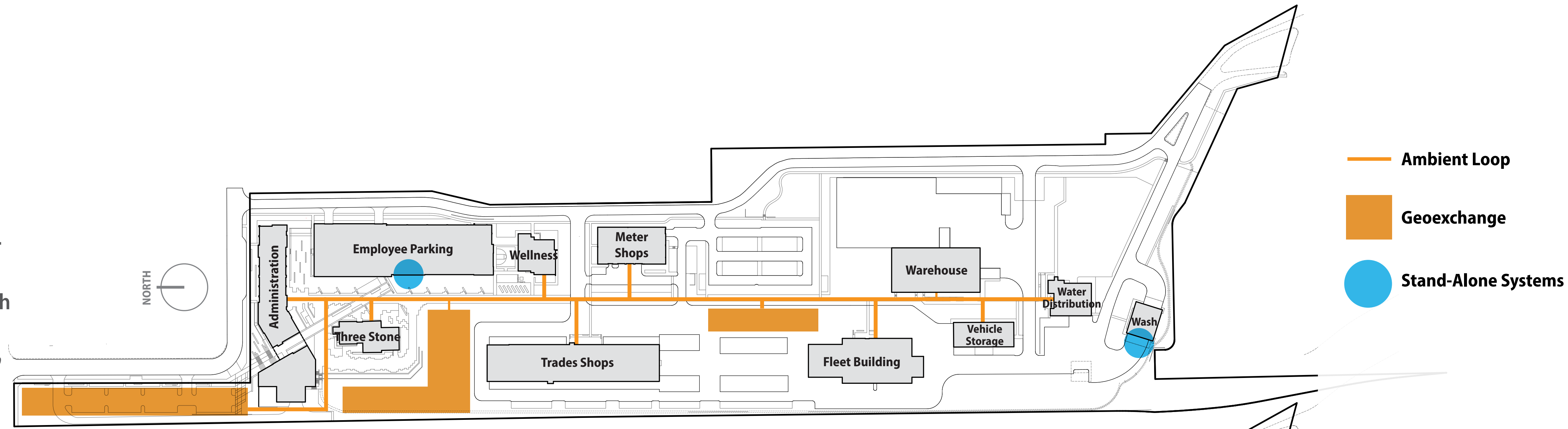


FIGURE 24. Denver Water campus thermal system option 1: **ambient loop** with geothermal loop fields

Graphic from MKK now IMEG and Integral Group

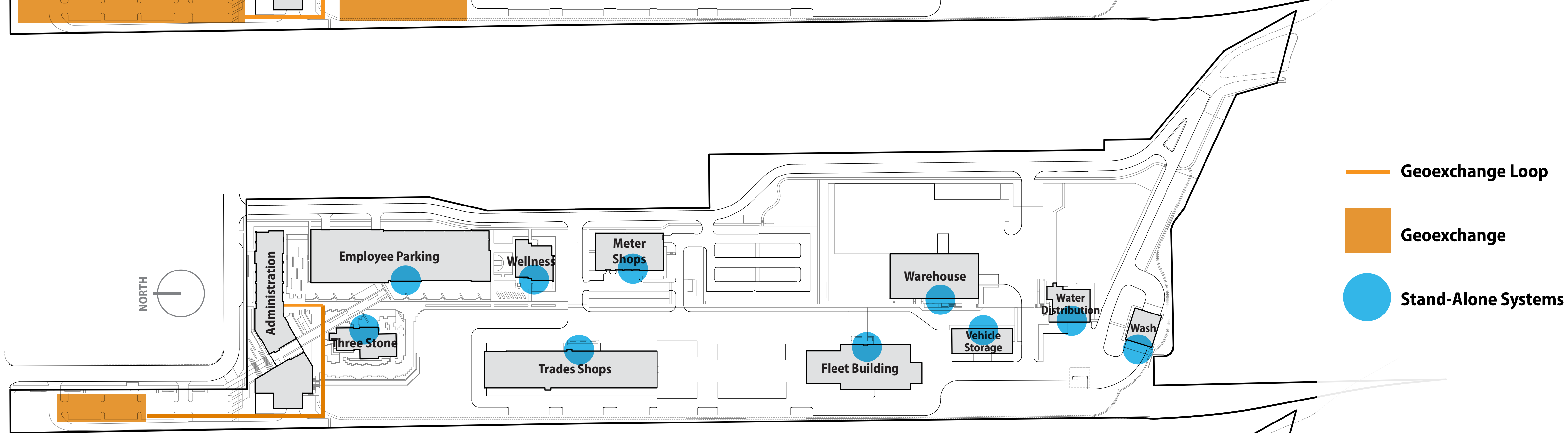


FIGURE 25. Denver Water campus thermal system option 2: Stand-alone systems with geothermal for administration building

Graphic from MKK now IMEG and Integral Group

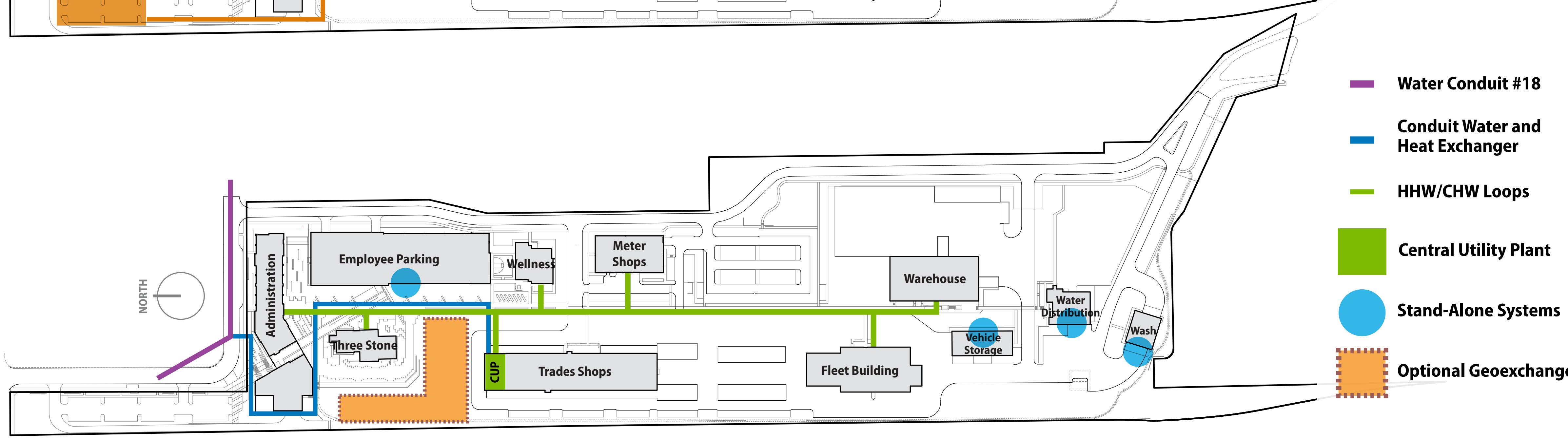


FIGURE 26. Denver Water campus thermal system option 3: Central utility plant with water main heat exchanger

Graphic from MKK now IMEG and Integral Group

If a district ground source heat pump system is under consideration, early sizing of the system is important in the overall district planning process. Locate appropriate open space and/or surface parking in the development and overlay the ground source heat pump system loop field footprint onto the area of open space to assure space requirements for the system can be met. The loop fields can be centralized or distributed depending on the availability of open space and the need to minimize losses inherent in distribution to the buildings. **FIGURE 27** shows an example of overlaying the ground source heat pump loop field footprint on the district site plan for the Buckley Annex in Denver, Colorado. The ZE plan was commissioned by the city to validate the HP economics and identify the most effective approach. Ultimately, however, the developer chose a different direction for the project.

FIGURE 27. Example of a study for a potential geothermal loop field footprint sized for a district and overlaid on the master site plan at Buckley Annex in Denver, Colorado

Graphic from RNL Design now Stantec

Example Analysis: Heating and Cooling

Planners should consider energy and cost questions in the early district planning stages, including:

- Based on the mix of building types and sizes for the district in question, are there enough periods of simultaneous heating and cooling in the district to convince designers that a district thermal system with heat recovery is feasible?
- Is there sufficient annual balance between heating and cooling loads for a district ground source heat pump system? Are soil properties suitable for a ground source heat pump system?
- Are the district energy benefits sufficient to justify distribution and piping costs for the district distribution system?
- Are the centralized waste heating and cooling resources sufficient to justify a district scale thermal distribution system?

District planners can use building energy modeling and/or utility and submeter data analysis to investigate the expected occurrences of simultaneous heating and cooling in the district. Modeling is likely required for new construction districts or retrofit districts in which deep building energy efficiency improvements are being considered along with the addition or upgrade of a district thermal system. For new construction districts, the analysis builds directly on the district building energy efficiency analysis reviewed in **Planning for Energy Demand and Efficiency on page 58**. Using prototype building models generated for the different building types in the district, the analyst's objective is to estimate the hourly or subhourly heating and cooling loads over the course of a year and then quantify the degree to which those loads overlap in timing and magnitude.

An example of this type of analysis is shown in **FIGURE 28–FIGURE 30** for a live-work-play hypothetical district in the IECC 3a climate zone (Atlanta, Georgia). The example district is 1 million total square feet comprising 30% office, 30% multifamily, 15% retail, 5% food service, and 20% lodging. The building prototypes were simulated at approaching ZE efficiency levels. The district-wide total aggregate hourly heating and cooling loads were estimated based on the simulation end use output data (power consumption for heating and cooling converted to estimates of heating and cooling loads based on system efficiencies). It is important that heating and cooling loads are calculated and compared in the same energy units (e.g., millions of British thermal units or MBtu).

FIGURE 28 visually shows how heating and cooling loads can be compared on a daily basis for example days in the fall/spring, summer, and winter. The yellow area represents the amount of overlapping heating and cooling loads for those days. **FIGURE 29** shows the overlap in heating and cooling loads over the course of the entire year. For this type of visualization, cooling loads are plotted in the positive y-axis direction and heating loads in the negative direction. The magnitude of the overlapping heating and cooling loads is plotted in black in both the positive and negative directions. For this hypothetical live-work-play district in Atlanta, Georgia, **FIGURE 28** and **FIGURE 29**[4] make it apparent that there are substantial overlapping heating and cooling loads. The largest opportunities occur during the summer when there is abundant waste heat from cooling that could be used to meet almost all of the heating requirements in the district (e.g., service water heating for multifamily buildings) if a shared district thermal system was in place.

Thermal overlap can also be quantified by performing calculations based on the hourly or subhourly heating and cooling load data. One calculation approach is:

$$OL = \sum_{hour=1}^{hour=8760} min\,(HL_{hour}, CL_{hour})$$

where OL is the total annual overlapping load, HL is the hourly heating load, CL is the hourly cooling load, and "min" indicates that for a particular hour of the year, the hourly overlapping load is the minimum of the heating and cooling loads, whichever is lesser. The overlapping load can also be expressed as a percentage of either the cooling or heating load in the district:

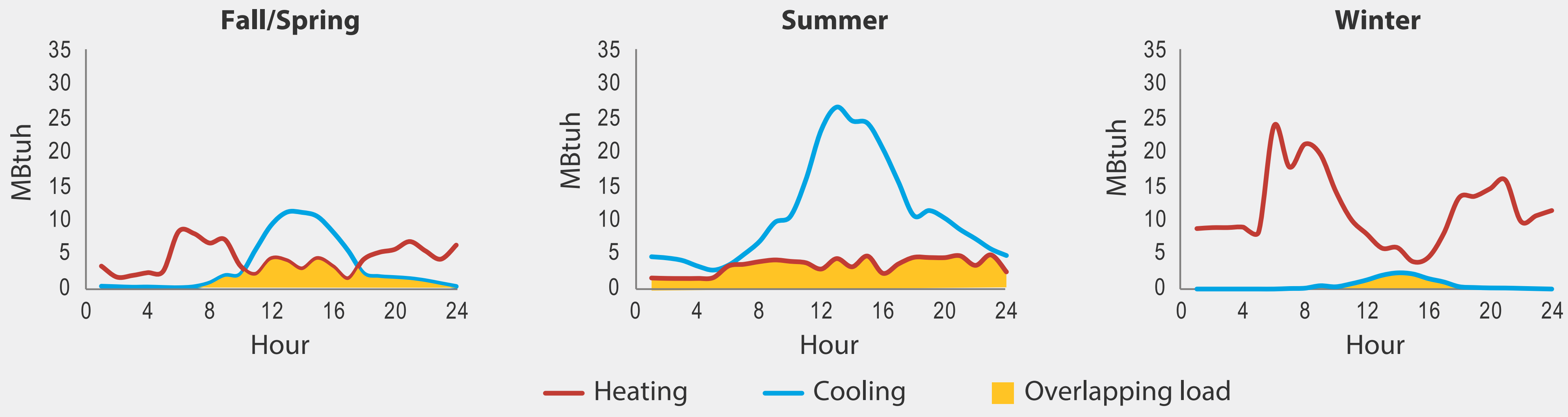
Percent heating overlapped by cooling = **OL/HL**

Percent cooling overlapped by heating = **OL/CL**

For example, these values were calculated for several hypothetical district types in IECC 5B climate region (Denver, Colorado). As **FIGURE 30** shows, the amount of overlap varies by district type, but each district has some opportunity for energy savings through energy recovery. In addition to varying based on the mix of building types and sizes, overlap varies depending on the climate so it is important to consider the local climate of the district in these types of analyses.

4 The types of visualizations shown in Figures 28 and 29 were inspired by prior analysis performed by Stanford University for the Stanford campus district energy system (see **Stanford case study on page 142**).

FIGURE 28. EXAMPLE ANALYSIS: Plots of estimated heating and cooling loads of hypothetical live-work-play district in Atlanta, Georgia; For example days in fall/spring, summer, and winter. Shaded (yellow) area represents overlapping load that indicates potential for energy sharing through a district thermal system.



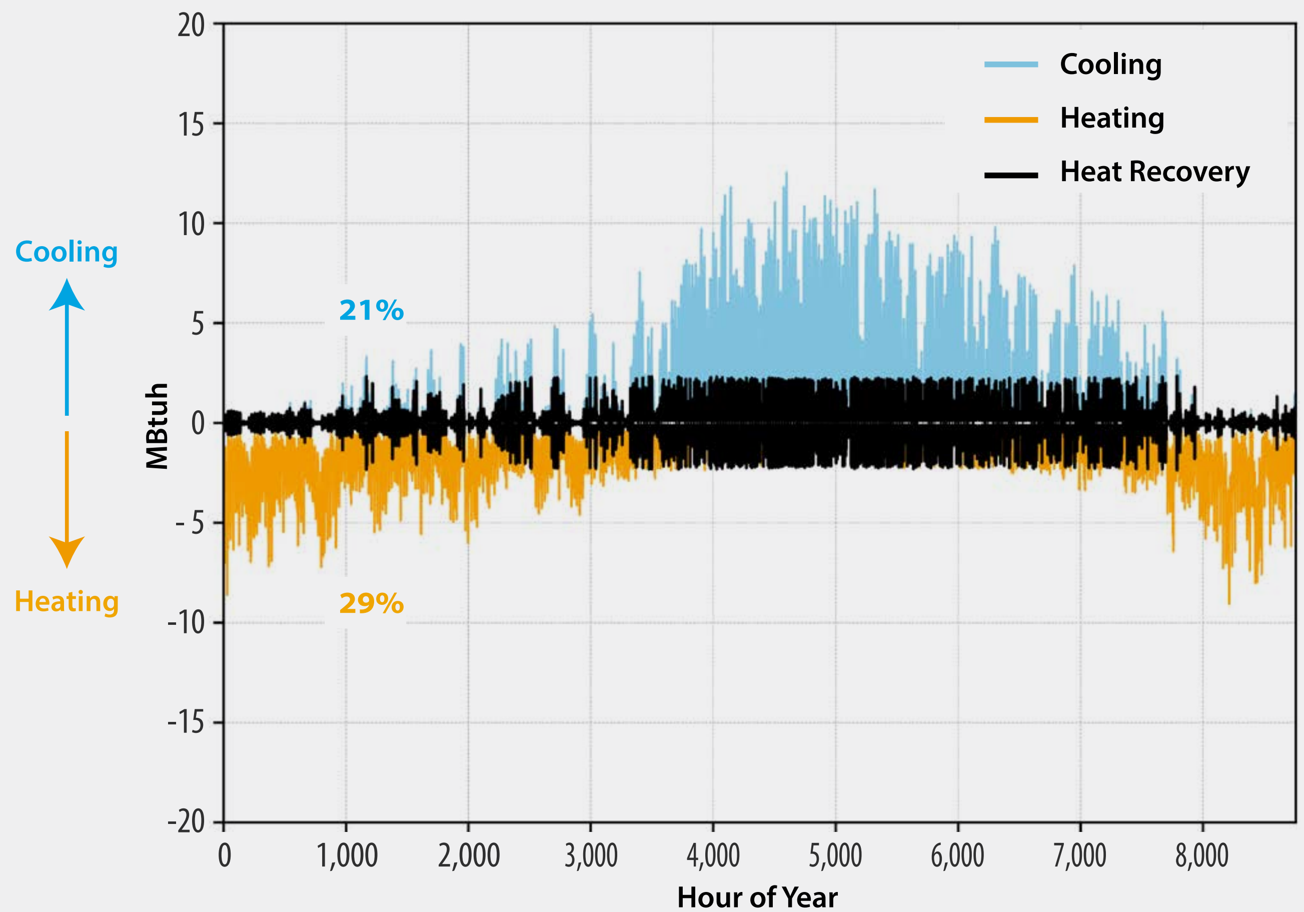


FIGURE 29. EXAMPLE ANALYSIS: Estimating hourly heating and cooling loads of hypothetical live-work-play district in Atlanta, Georgia; The black areas represent overlapping load (plotted in both positive and negative directions) that indicates potential for energy sharing through a district thermal system.

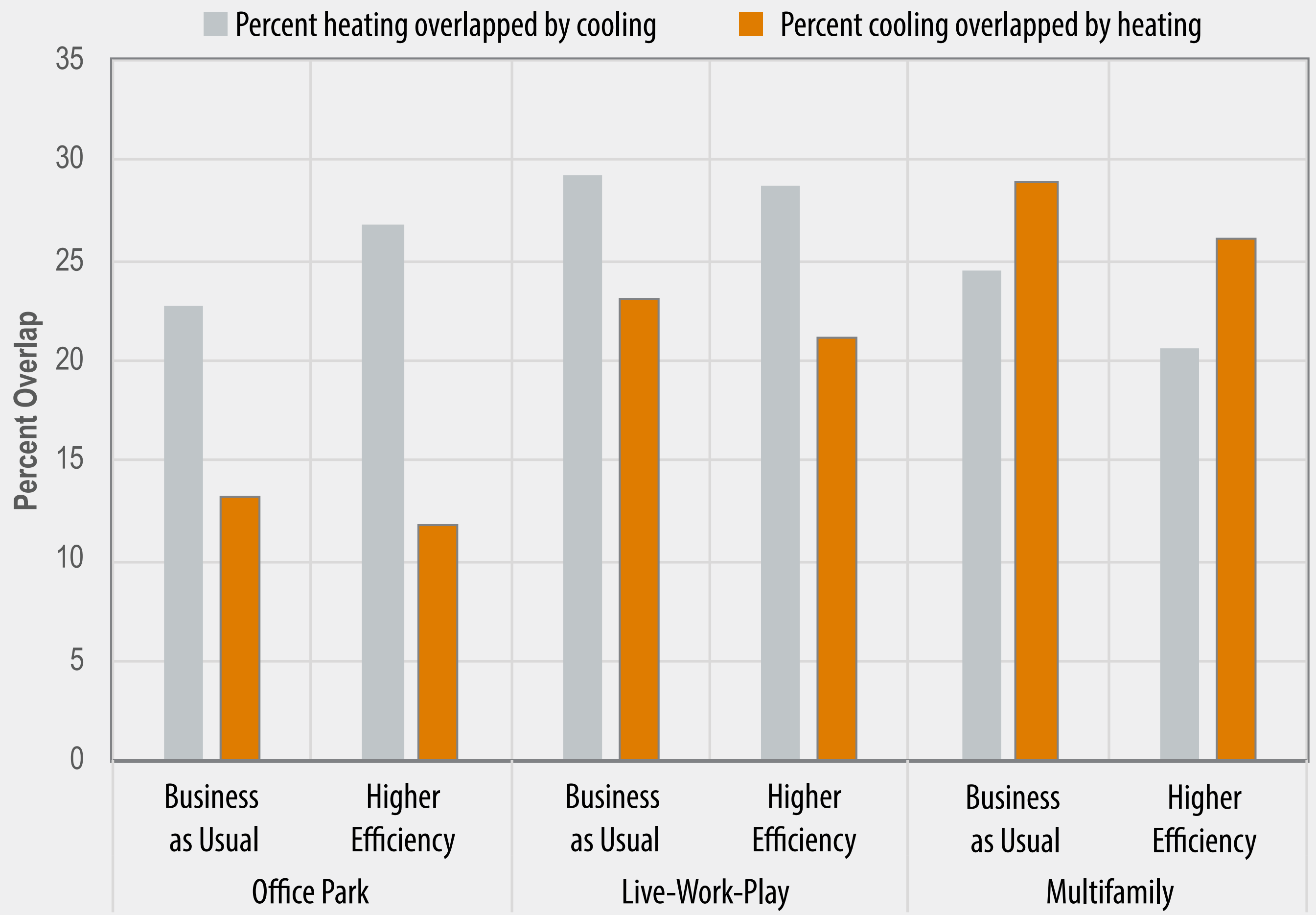


FIGURE 30. EXAMPLE ANALYSIS: Estimating overlapping hourly heating/cooling loads; Loads are expressed as a percent of total heating and cooling loads for hypothetical office park, live-work-play, and multifamily district types in IECC climate zone 5B (Denver, Colorado).

Considerations

Despite the promise of district energy systems, a number of challenges inhibit their wide use in the United States. The infrastructure needed to distribute energy, typically underground pipes, can be expensive and is not typically included in the cost calculations of traditional developments. One study found that 77% of the cost of installing heat distribution networks consists of excavation (37%), installing pipes (17%), and installing the equipment that connects the district system to buildings (23%).[5] When excavation work is aligned with excavation for other projects, such as transportation, water/wastewater, or data infrastructure, the additional excavation cost of installing a district system can be eliminated or reduced significantly. Infrastructure costs can be particularly high in retrofit scenarios in which distribution system rights of way have not yet been secured and individual buildings have to be built without clarity on the district energy system design and **interconnection**. In Europe, district thermal systems have been shown to be 13%–26% less expensive in **greenfield** developments than in existing development retrofits.[6]

Phasing

A district energy system has to be built before it can begin to collect revenue and that construction can take a long time. This investment/revenue time lag can be a challenge for attracting private sector capital to these projects. Securing commitments from anchor customers can help spur the construction of the first "starter network," which can then be expanded as the development phasing progresses. It is important to get this first district project or phase right so that it serves as a compelling example of the efficacy of district thermal energy systems.

Architectural Benefits

There are many nonenergy benefits of district systems (see **TABLE 1 on page 36**), such as minimizing the need for rooftop HVAC equipment, which makes larger rooftop PV systems possible. District systems also free up building floor area for more valuable uses than an HVAC mechanical room.

Business Model Approaches

When district systems are owned and used by one entity, such as a university campus or hospital system, business and governance models are typically straightforward. However, when the district system connects many different building owners, multiuser agreements can be very complex and successful models are still not widely shared.[7] This holds true for smaller thermal energy sharing agreements between residential homeowners and land developers or homeowners' associations. Business models for district energy systems can be categorized as public, hybrid public/private (see Chapter 3: **Developing Financial and Business Models on page 32**), and private. The vast majority of district systems have some sort of public involvement as an owner, lender, operator, consumer, or demand aggregator.

Most of the existing district systems worldwide are wholly publicly owned. One advantage of publicly-owned systems is that they can be a means for aligning public goals such as reducing carbon emissions, improving **resilience**, or providing affordable heat to residents. Another advantage of publicly-owned systems is access to lower cost financing through the bond market than is possible in the private sector.

District systems that are wholly public often create a "special purpose vehicle" or other subsidiary, governed by a separate board, to reduce the financial liability of the city or other entity, ease the administrative burden, expedite the development process, and make selling the system down the road easier. Once the system is built out and collecting stable revenue, it will have a more established value and the public owners may be able to recoup their investment by selling it off in whole or part.

Hybrid public/private systems share the risk of the system development and operation between governments—typically local authorities—and a private entity—typically an energy services company. These systems usually have higher rates of return than wholly-public systems, which makes them attractive to private investors. Each entity brings forth its competitive advantages, skill sets, and resources to create a mutually beneficial partnership. As risk, decisions, and authority are often shared, clear agreements between the parties are key to long-term success.

Three common types of the hybrid model are the joint venture, the concession contract, and the community owned nonprofit.[8] In the joint venture, ownership of the special purpose vehicle created for the project is split between the public and private entities, which may use a pooled asset model to create a combined single company to which each brings its expertise and skills. In other cases, the two entities independently carry out their agreed upon functions using a split asset model.

5 d2umxnkyjne36n.cloudfront.net/teaserImages/Reducing-the-capital-cost-of-district-heat-network-infrastructure.pdf?mtime=20171103092304
6 www.witpress.com/Secure/elibrary/papers/ESUS13/ESUS13009FU1.pdf
7 higherlogicdownload.s3.amazonaws.com/DISTRICTENERGY/UploadedImages/06ccd955-5616-4383-af4d-ee333155fa32/EXEC-2018-003761_AMO_District_Energy_Report.pdf
8 www.districtenergyinitiative.org/sites/default/files/report_pdf/03%20District%20Energy%20Chapter%203_print.pdf

In a concession contract model, the private sector entity runs the system for a specified period of time. This model can be a good fit for retrofit projects in places where the system network uses public streets and rights-of-way because it allows the district or community to buy back the system after the concession period. The private entity typically assumes the risk associated with designing, building, and operating the system, but the public entity may mitigate that risk by guaranteeing certain revenues via a connection policy.

Lastly, the community-owned nonprofit model typically places the risk on the local authority at the beginning of the project and then passes the system to a nonprofit operator once it is stable. To avoid the risk of a monopoly increasing the price of service, all district heat providers can be required to be cooperative or municipally-owned nonprofits. The City of Copenhagen, Denmark, is an example of this approach.[9]

The private business model is less common and may require returns of more than 10% in order to attract private investors. Even when systems are privately owned, government entities often assist the projects by attracting grants and financing, streamlining permitting and administration, and committing to or aggregating demand. Project risk, financing, and control are the private entity's responsibility, but strategic partnership models can provide mutual benefits. For example, the public entity may reduce risk by encouraging demand growth through economic and planning policies, and the private entity may offer the public reduced tariffs, profit sharing, or other social or environmental benefits. Further guidance on district and community shared energy coordination and operations can be found in Chapter 24, "Establish ZEC Governance" in *A Guide for Developing Zero Energy Communities*.[10]

7 www.districtenergyinitiative.org/sites/default/files/report_pdf/03%20District%20Energy%20Chapter%203_print.pdf
8 www.researchgate.net/publication/328703276_THE_ZEC_GUIDE_A_Guide_for_Developing_Zero_Energy_Communities

Integration

Once a district begins the development of a district thermal energy system, the planning team must ensure that the buildings to be connected to the system are designed so that the connections are easily accomplished. The district design guidelines and master plans should specify the building HVAC system type and the configuration required to connect to the district. Depending on the phasing of the buildings and the district infrastructure, it may be necessary to complete a building's HVAC system before the district system is in place. In this case, ensuring the building's HVAC system is "district system ready" is key. An expandable shared ground source heat pump loop is one way to ensure a building is district system ready. In this case, sizing the primary distribution system for the full build-out will be a key design element to ensure successful operation after all buildings have been connected. A similar strategy that uses modular heat pumps with space allocated for future full capacity build-out can also be used to enable an expandable district thermal energy system.

Successful Implementation Examples

The National Western Center (NWC) in Denver, Colorado, is an example of a low-carbon district under development as of this writing (July 2020). This is a multiuse district being built on the site of Denver's annual stock show. A key feature is a six-foot diameter wastewater pipe running through the property. The temperature of this wastewater stays within a narrow range of 61°F and 77°F throughout the year. This represents more than 150 MW of low grade waste heat and makes the pipe an ideal heat source in winter and an ideal heat sink in the summer so that heat pumps can efficiently heat and cool the district.

The use of wastewater as a heat source is not new and, as an example, has been used to heat buildings in the city of Vancouver, British Columbia,[11] since 2010. The False Creek Neighbourhood Energy Utility uses waste thermal energy captured from sewage to provide space heating and hot water to buildings in several Vancouver neighborhoods, is self-funded, and is simultaneously providing a return on investment to taxpayers and affordable rates to customers.

Similarly, the NWC district wastewater pipe, in conjunction with heat pumps, will serve as a central heating and cooling plant. This plant will transfer heat to and from an **ambient loop** circulating throughout the district to multiple tenants, including the City of Denver's NWC and Colorado State University's Spur campus laboratories. The district energy system will be expandable to future NWC phases, with distribution infrastructure and space available for future thermal networks and heat exchanger capacity.

The first costs associated with the wastewater heat exchangers and an **ambient loop** distribution system, however, were not included in the NWC build-out funding. Rather, an innovative partnership was formed to select a third party energy partner managed by the City of Denver through a public procurement process.

EAS Energy Partners was selected to become the official NWC campus energy partner and will be responsible for financing, designing, and constructing the district and renewable energy solutions as well as the long-term operation and maintenance of the NWC energy systems.[12] The campus facility build-out by NWC and Colorado State includes design requirements for buildings to use the **ambient loop** for building scale heat pump systems

11 vancouver.ca/home-property-development/southeast-false-creek-neighbourhood-energy-utility.aspx
12 nationalwesterncenter.com/wp-content/uploads/2017/11/NWC-Energy-Action-Plan.pdf

(see FIGURE 31). The operating and financing agreement with EAS Energy Partners also mandates ongoing thermal energy billing at a cost comparable to business as usual heating and cooling operations over a 38-year term.

Another example of a district designed to minimize community scale heating and cooling loads through the use of a shared district thermal energy system is the Whisper Valley community[13] being built in Austin, Texas. Phase 1 was completed in 2019, and future phases are expected to accommodate 30,000 residents.

This multiuse development consists of all-electric homes, commercial buildings, retail stores, restaurants, schools, a community center, and other facilities. It uses a shared district **ambient loop** heated and cooled by heat pumps with geothermal wells located at each house, as shown in **FIGURE 32 on page 79.** A local energy homeowners association, EcoSmart Solution,[14] supports ongoing ZE home operations, monthly homeowners association and shared system billing and fees, and homeowner energy coaching.

EcoSmart Solution also operates the shared ground source heat pump system. A shared fluid cooler connected to the first phase of the district **ambient loop** provides a shared backup for peak cooling conditions, reducing peak cooling system costs for all residences connected to the district. Each homeowner has the option of including a 5 kW rooftop PV system to operate the heat pump and energy-efficient appliances, including heat pump water heaters and inductive stovetops. According to the developer, the economies of scale in the community make it possible to sell the homes for $50,000 less than the median price of a home in Austin.

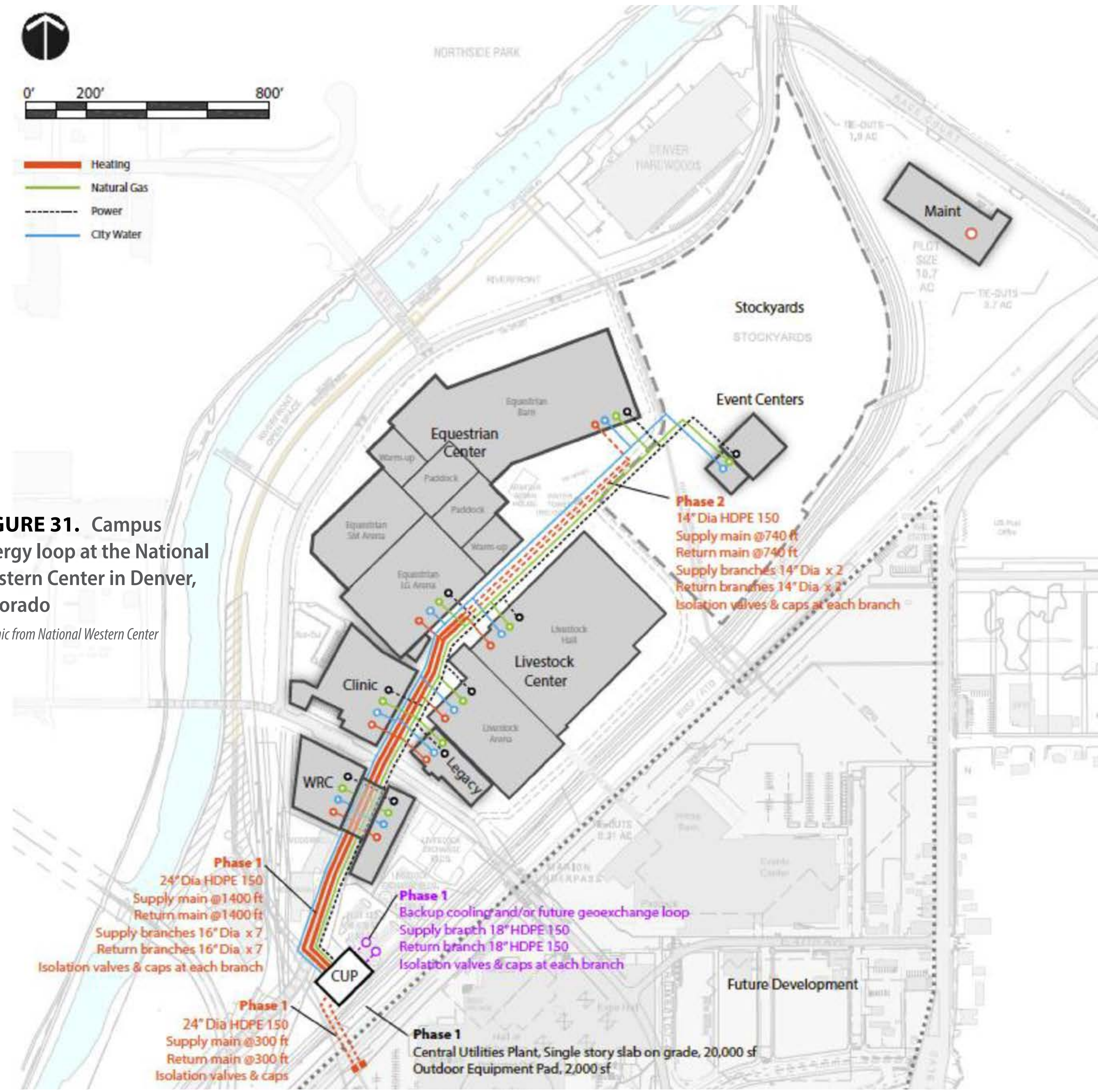


FIGURE 31. Campus energy loop at the National Western Center in Denver, Colorado

Graphic from National Western Center

13 www.whispervalleyaustin.com/living-ecosmart/net-zero-energy/#geothermal
14 ecosmartsolution.com/communities-builders/

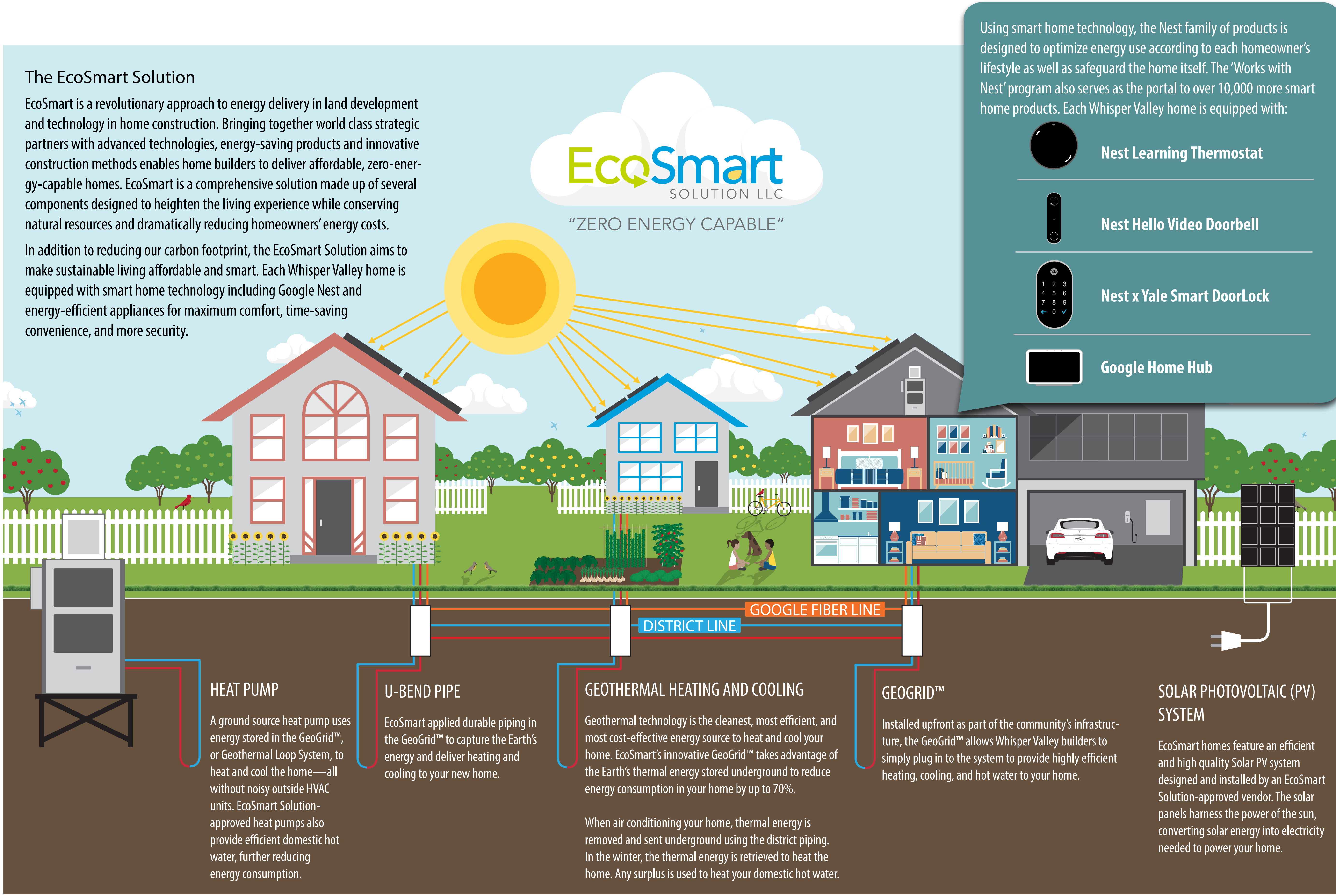


FIGURE 32. Whisper Valley shared ground source district system layout

Graphic from Whisper Valley

CHAPTER 8

RENEWABLE ENERGY ANALYSIS AND PLANNING

Careful planning for the Geos Neighborhood in Arvada, Colorado, enables solar access in a dense development.

Photo from Philip Wegener for Geos Neighborhood

HPDs use energy efficiency strategies to reduce energy loads (see **Planning for Energy Demand and Efficiency on page 58**) and renewable energy resources to meet those reduced loads, most commonly PV systems.

To ensure the most cost-effective applications for PV within the district, consider the following promising planning strategies:

- Determine and plan the PV output required to meet energy goals, and include system sizes and designs in district master plans and design guidelines
- Consider the suite of locations for PV systems, from building scale to district scale to regional scale systems that balance performance, costs, local production, and resiliency goals
- Ensure the early concept renderings and master plans include the planned PV integration in the district and on buildings
- Use energy-driven planning to enable all individual buildings to optimize a building's solar access and minimize solar shading
- Leverage architectural design guidelines and master plans to ensure **solar ready** building design.

Analysis and Approaches

Renewable Energy Analysis

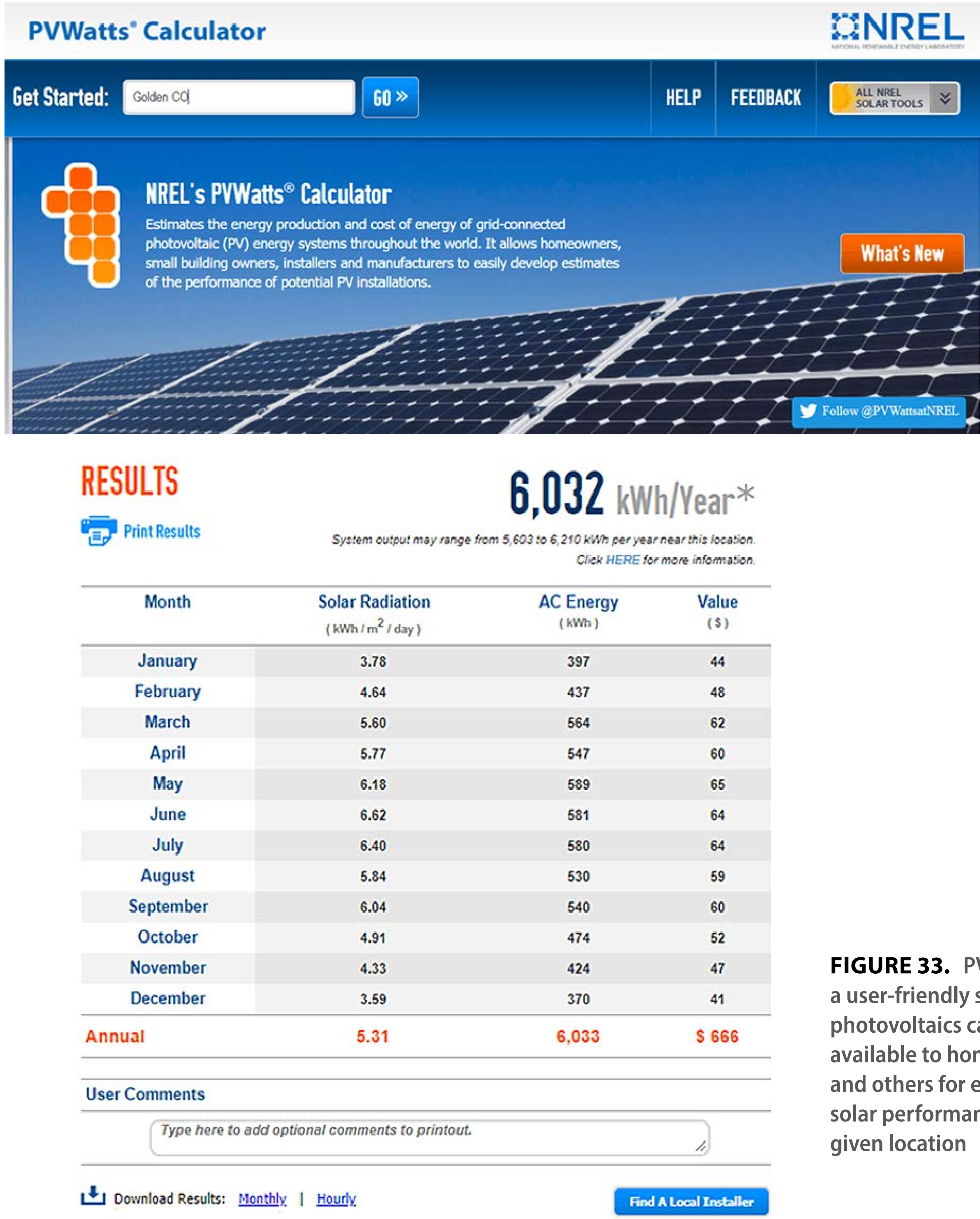
During the energy master planning of an HPD, the energy planner should estimate the energy generation potential of proposed renewable energy systems as well as their size and location within the district. These renewable energy system planning parameters are tightly linked. The locations available for siting a renewable energy system will impact the size of the system and the size and location of the system will determine its generation potential. As outlined in **Balancing Energy Consumption and Production on page 61**, to achieve the HP and ZE goals, the renewable energy generation of the district is balanced with its annual energy use. The relationship between energy consumption and production forms the basis of the **integrated energy solution** for every HPD.

> *The relationship between energy consumption and production forms the basis of the integrated energy solution for every HPD.*

Using the **development program** and/or site plan, it is possible to estimate the area available for PV systems—the most common renewable energy generation source in HPDs—by taking an inventory of shade-free roofs, areas appropriate for site-mounted arrays, and parking canopy locations. In some instances, it may also be feasible to locate PV systems on building façades. The sum of all potential PV locations determines the total footprint of the renewable energy system in square feet (ft^2). The PV module efficiency (in terms of watts/ft^2) then determines the total size of the system in kW. With this information, the PV system size and orientation(s) can be modeled to calculate the total renewable energy generation in kWh per year using the appropriate weather file and modeling tool (such as PVWatts®, System Advisor Model, or EnergyPlus). **FIGURE 33 on page 82** provides examples of PV Watts outputs.[1]

If the renewable energy analysis includes multiple district PV scenarios, it can be useful to calculate the solar generation ratio for each PV module orientation used in the district. The solar generation ratio is the annual kWh of energy generated for every 1 kW of PV module capacity installed. Each orientation of PV modules will result in a different energy production per kW of PV, so it is necessary to have a different solar generation ratio for each orientation. These solar generation ratios can then be applied to kW PV sizes in a number of scenarios to calculate renewable energy generation potential. This total generation potential determines the maximum energy use that can be targeted to achieve the HP or aspirational ZE goal. Note that it is often financially beneficial to identify the best combination of energy efficiency measures and renewable energy generation, as the economics of these systems vary based on market and local utility incentives, **interconnection** rules, and billing considerations.

1 www.nrel.gov/news/program/2019/pvwatts-at-20.html



Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	3.78	397	44
February	4.64	437	48
March	5.60	564	62
April	5.77	547	60
May	6.18	589	65
June	6.62	581	64
July	6.40	580	64
August	5.84	530	59
September	6.04	540	60
October	4.91	474	52
November	4.33	424	47
December	3.59	370	41
Annual	5.31	6,033	$ 666

FIGURE 33. PV Watts®, a user-friendly solar photovoltaics calculator available to homeowners and others for estimating solar performance for a given location

Each **development program** scenario may result in a different renewable energy generation potential based on its allocation of appropriate locations for PV systems (see **Photovoltaics and Solar Access Planning on page 85**). In addition, some project teams may have the interest and resources to integrate other types of renewable energy generation systems such as hydropower, biomass, geothermal, landfill gas, and wind.

> *The PV system(s) should be sized to offset the energy use within the district based on the energy use or efficiency targets set by building type.*

Determining Photovoltaic Output Requirements

The PV system(s) should be sized to offset the energy use within the district based on the energy use or efficiency targets set by building type. PV system production and size should also be balanced with other district renewable energy sources as appropriate. As a starting point to analyze PV output, district energy planners can use NREL's PVWatts® tool[2] to estimate the electricity production of a grid-connected, roof- or ground-mounted PV system based on several simple inputs.

More detailed solar analysis is possible using NREL's System Advisor Model,[3] which can make performance predictions and cost-of-energy estimates for grid-connected renewable energy projects based on specified system design parameters. To further optimize renewable energy options, economic decision support models such as REopt Lite[4] can evaluate energy systems for buildings, campuses, communities, and **microgrids**. REopt recommends an optimal mix of renewable energy, conventional generation, and energy storage technologies to meet cost savings and energy performance goals. The REopt Lite web tool helps evaluate the economic viability of grid-connected PV, wind, and battery storage at a site; identify system sizes and battery dispatch strategies to minimize energy costs; and estimate how long a system can sustain critical load during a grid outage. PV analysis approaches are summarized in **TABLE 4**.

TABLE 4. Selected Highlights of Solar Photovoltaic System Analysis Approaches

Tool or Approach	Approach Use Case
Resource Estimate (kwh per kW of PV system)	Rough estimate of possible annual PV system output based on solar resource and panel orientation
PVWatts	System annual calculation of output and estimate of system financial performance for various system sizes, locations, and types
System Advisor Model	Performance predictions and cost-of-energy estimates for grid-connected renewable energy projects based on specified system design parameters
REopt	Technical and economic optimization tool to determine optimal combination of solutions for building, campus, and **microgrid** energy systems

Example Analysis: Highland Bridge Ford Redevelopment Site Solar Photovoltaics

A redevelopment project at **Highland Bridge (Ford Site)** in Saint Paul, Minnesota,[5] with an aspirational goal of ZE demonstrates this modeling approach and attempts to answer the following questions early in the district energy feasibility development process:

- How much electricity might be consumed under different development scenarios?
- How much rooftop PV generation might be possible at the site?
- How much of the annual electric load could be offset with rooftop PV?
- What PV design and development approaches should be pursued to meet HP energy goals?

Annual electrical energy use of the individual development scenarios was estimated by multiplying EUI values by the gross development square footage values for each building type based on the distribution of space types. The EUIs used were representative averages across building types as well as standard and energy-efficient buildings in Minnesota.

Next, annual PV production estimates were calculated. This analysis assumed net metering is available so that PV electricity can be exported to the grid and credited to the utility customer's electricity bill at retail rates. A mix of flat roofs and south-facing roofs with 50%–70% of roof area available for PV was modeled for standard and high efficiency PV options using PVWatts.

5 www.stpaul.gov/sites/default/files/Media%20Root/Planning%20%26%20Economic%20Development/NREL%20Report%20-%20Ford%20Site%20Solar%20Potential%20-%20March%202015.pdf

TABLE 5. Build-Out by Space Type for Each Site Development Scenario at Highland Bridge Ford Site Redevelopment

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Single family	87 units	44 units	242 units	0
Townhome	36 units	74 units	206 units	0
Multifamily, low rise	250 units	404 units	230 units	300 units
Multifamily, medium rise	251 units	723 units	250 units	730 units
Multifamily, high rise	0	0	0	320 units
Office/institutional	250,000 ft^2	750,000 ft^2	260,000 ft^2	375,000 ft^2
Retail	135,000 ft^2	200,000 ft^2	275,000 ft^2	194,000 ft^2
Industrial	590,000 ft^2	0	0	0

TABLE 6. Estimates of Solar Photovoltaics Needed for Zero Electricity and Rooftop Space Available at Highland Bridge Ford Site Redevelopment

Scenario	Building Electricity Usage	PV Needed for Zero Electricity (MW)	PV Module Efficiency	PV Needed for Zero Energy Met by Rooftop Capacity (%)	PV Shortfall (MW) of Rooftop Space
1	Low	12.1	High	57	5.2
			Mid	45	6.6
	Typical	16.6	High	46	8.9
			Mid	37	10.5
2	Low	9.1	High	50	4.6
			Mid	41	5.4
	Typical	12.1	High	44	6.8
			Mid	36	7.8
3	Low	6.8	High	63	2.5
			Mid	55	3.1
	Typical	9.0	High	62	3.4
			Mid	56	4.0
4	Low	6.5	High	49	3.3
			Mid	43	3.7
	Typical	8.9	High	44	5.0
			Mid	35	5.8

The analysis estimated that 7–17 MW of PV are needed to make all of the buildings in the development at the Ford Site ZE depending on the development scenario and level of electrical energy use required. According to these estimates, under no scenario is the site able to achieve ZE electricity with rooftop PV alone. Rooftop PV could provide approximately 63% of electricity under Scenario 3 with low building electricity usage (high efficiency buildings) coupled with a specification for high efficiency PV. In Scenario 4, high efficiency rooftop PV is estimated to meet approximately 49% of the ZE goal with high efficiency building electricity consumption estimates. The results across all the Ford site scenarios are shown in **TABLE 6**.

These results were only indicative and were used for estimating purposes to help inform development goals and requirements moving forward. Key planning recommendations from the solar feasibility analysis included:

- Maximize building energy efficiency to ensure a higher portion of total electricity needs can be met with PV while reducing the total PV system size and cost.
- Consider PV as part of the building infrastructure in the planning process phase by including **solar ready** building design concepts such as ensuring sufficient, shade-free roof areas; structurally preparing buildings for PV loads; and making sure PV can be cost-effectively added in the future.
- Target 50%–70% roof coverage area of high efficiency PV systems for maximum rooftop PV energy production.
- Because HP goals may not be feasible with rooftop PV alone, expand on-site areas capable of hosting PV by adding shade structures over parking areas that can support PV systems as well as provide shading and shelter from snow and rain for parked cars.
- Pursue district development of a **community solar** garden. These systems can either connect directly to individual building meters if the location permits cost-effective **interconnection** or be developed as **community solar** gardens with ownership shares dedicated to utility customers within the development. **Community solar** gardens have capacity limits set by local jurisdictions, so achieving 100% renewable electricity this way is not assured.

Highland Bridge is a high-performance district planned for a 122-acre site along the Mississippi River in Saint Paul, Minnesota, that was once the home of Ford Motor Companies' Twin Cities Assembly Plant.

Rendering from Ryan Companies

Considerations

Photovoltaics and Solar Access Planning

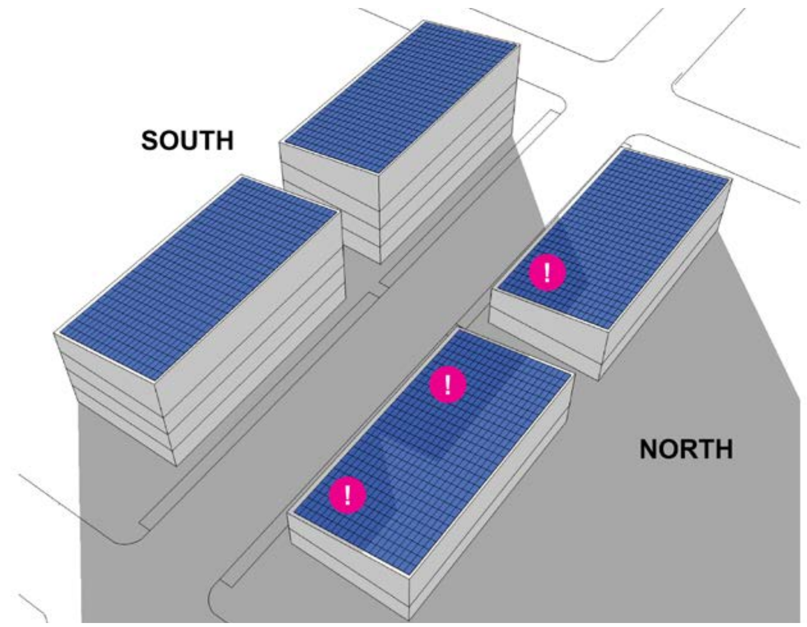
PV is a key on-site renewable energy system to consider for districts and communities pursuing HP and ZE goals. To ensure the most cost-effective PV applications within the district, consider the following summary of promising planning strategies:

- Determine and plan for the PV output required to meet energy goals
- Determine suitable locations for PV systems, starting with building and district scale options
- Ensure early concept renderings and master plans include the planned PV location(s)
- Use energy-driven planning to optimize building solar access and minimize shading (see **FIGURE 34**)
- Include **solar ready** building design specifications in architectural design guidelines.

Locating Photovoltaics

Achieving aggressive district-wide HP energy goals such as ZE requires significant on-site and sometimes off-site renewable energy systems. Therefore, all viable and cost-effective PV solutions, from 2 kW single family residential rooftop systems to 10 MW ground-mount tracking **community solar** PV systems need to be explored. In general, PV integrated into or installed on buildings and parking structures produces local electricity that can directly offset a building's retail electricity costs, help support a building-scale **resilience** investment,[6] and be integrated into the design and construction process for a new building construction project. In most climate zones, energy-efficient, low load, medium rise buildings such as offices, multifamily buildings of five floors or fewer, and single family homes, can achieve HP or even ZE with maximized building interconnected PV as shown in **FIGURE 35**.

DON'T — Taller buildings that shade adjacent roofs



Do — Plan taller building locations to provide shade-free roofs

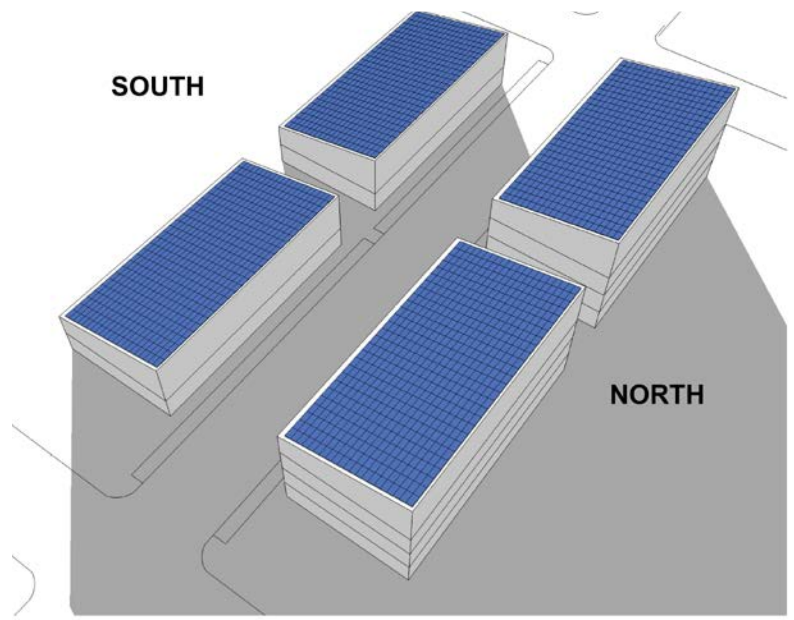


FIGURE 34. Avoid shading roofs by carefully planning the locations and heights of adjacent buildings based on solar access requirements for roofs; design for shade-free roofs between 9 a.m. and 3 p.m. on the winter solstice

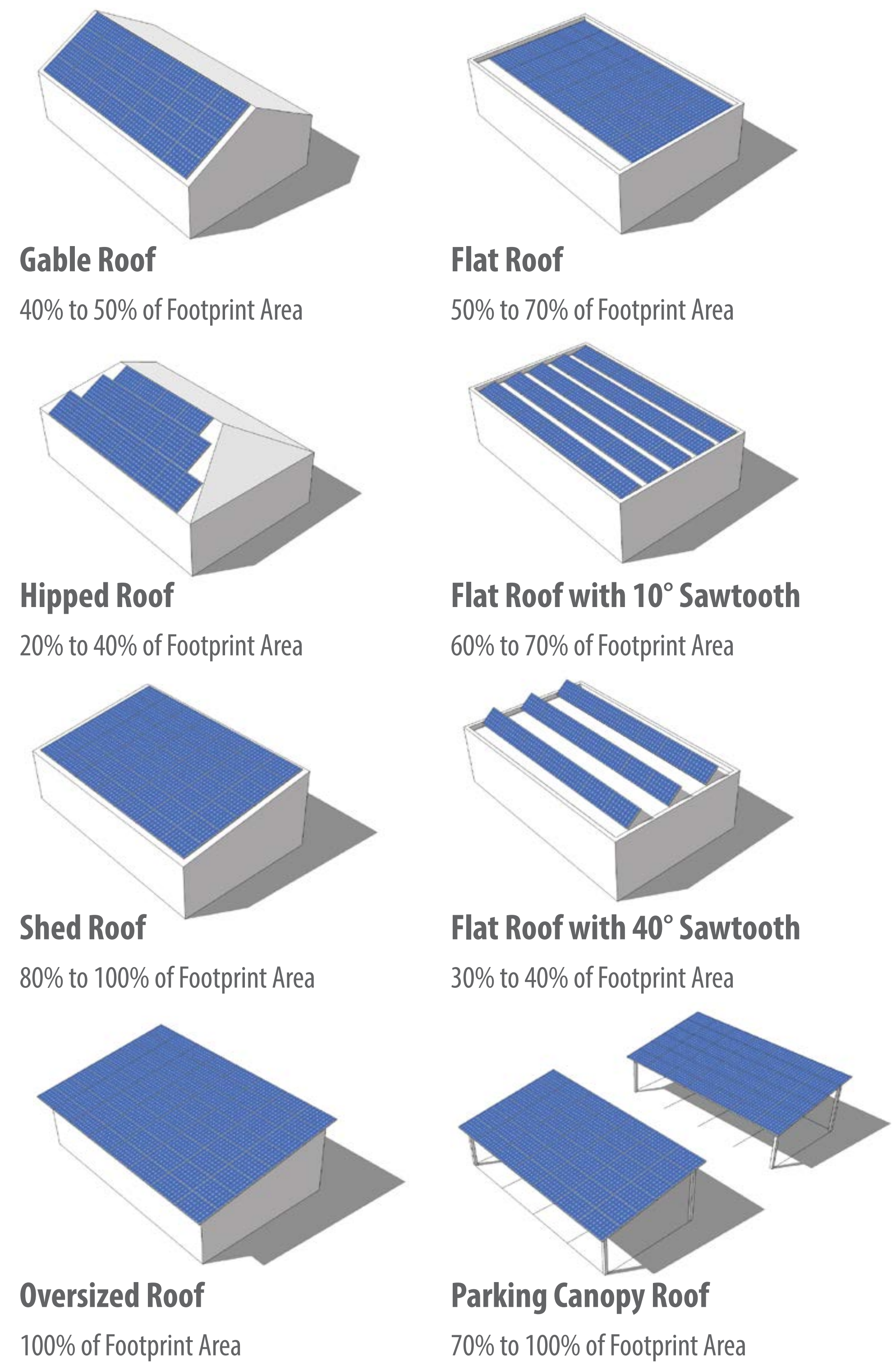


FIGURE 35. Strategies to maximize solar photovoltaic system size for rooftop and building connected systems

6 www.nrel.gov/docs/fy18osti/70122.pdf

Maximize rooftop solar photovoltaics by targeting 50%—75% + rooftop coverage. 75% + coverage is possible if planned from the beginning using **solar ready** buildings guidance.

NREL Research Support Facility **zero energy** office building with maximized rooftop solar photovoltaics.

Photo by Dennis Schroeder, NREL 37839

Use south, southeast, or south-west facing façade solar photovoltaic rainscreen systems if possible. Leverage benefits of using solar photovoltaic as active siding/rain screen to offset first costs.

Boulder Commons southeast façade

Photo from Bruce Damonte for Morgan Creek Ventures

Consider solar photovoltaics canopy for surface parking and parking garage. Leverage benefits of snow control, hail protection, and rain and sun shelters to help cost justify structure investment. Can be connected to buildings directly or part of a district shared system.

Peña Station NEXT shared surface parking lot solar photovoltaic canopy shared across district buildings.

Photo by Dennis Schroeder, NREL 48749

Develop off-site local and community shared solar photovoltaics systems. Often directly owned by district buildings or purchased as a virtual power purchase agreement.

Sunnyside Ranch **Community Solar** Array, a 1.8-megawatt project is leased long-term to Clean Energy Collective with shares owned by residents.

Photo by Dennis Schroeder, NREL 60069

FIGURE 36. Solar photovoltaic location options

FIGURE 36 highlights potential PV locations, starting with maximizing rooftop PV and exploring façade integrated and parking canopy PV, followed by community scale, and, finally, off-site PV solutions. In general, the smaller the individual PV systems, the more they cost to install per watt of PV. Therefore, understanding the ownership and alternative financing models available for each location option is critical during the development of the PV location planning strategy. See **CHAPTER 4 on page 44**, for more specifics related to net metering, utility billing, and **interconnection** limits that will also impact optimal locations and ownership models.

The PV location priorities in **FIGURE 36** are consistent with current industry approaches to HP classification and planning approaches, as detailed in previous publications[7] that have proposed a renewable energy hierarchy for PV planning in HP buildings. This hierarchy is detailed in **TABLE 7 on page 87**.

7 www.nrel.gov/docs/fy10osti/44586.pdf, www.nrel.gov/docs/fy10osti/46065.pdf

TABLE 7. High-Performance Building Energy Supply Option Hierarchy

Option Number	High-Performance Building Energy Supply Options	Example
Prerequisite	Reduce site energy use through energy efficiency and demand-side renewable building technologies	Daylighting; insulation; passive solar heating; high-efficiency heating, ventilating, and air-conditioning equipment; natural ventilation, evaporative cooling; ground source heat pumps; ocean water cooling
On-Site Supply Options		
1	Use renewable energy sources available within the building footprint and connected to its electricity or hot/chilled water distribution system	PV, solar hot water, and wind located on the building
2	Use renewable energy sources available at the building site and connected to its electricity or hot/chilled water distribution system	PV, solar hot water, low-impact hydro, and wind located on parking lots or adjacent open space, but not physically mounted on the building
Off-Site Supply Options		
4	Use renewable energy sources available off-site to generate energy on-site for the building's electricity or hot/chilled water distribution system	Biomass, wood pellet, ethanol, or biodiesel that can be imported from off-site sources or collected from the waste stream of on-site processes and used on site to generate electricity and heat
5	Purchase recently added off-site renewable energy sources as certified by Green-E[8] or other equivalent off-site renewable energy programs; continue to purchase the generation from this new resource to maintain high-performance building status	Utility-based wind, PV, emissions credits, or other "green" purchasing options; all off-site purchases must be certified as recently added renewable energy generation; a building owner could also negotiate with its power provider to install dedicated wind turbines or PV panels at an off-site location with good wind or solar resources; in this approach, the building might own the hardware and receive credit for the power, and the power company or a contractor would maintain the hardware

8 www.green-e.org

On-Site Solar Photovoltaics

PV generation can have impacts on building and district load diversity and peak period demand. For example, in cases where solar systems are located **behind the meter** and where buildings or districts are billed based on their net load, the system could substantially change the total costs of purchased grid electricity.

Off-Site and Community Solar

Emerging HP certification and recognition programs provide guidance on locating PV systems for HPDs. Examples include Architecture 2030's ZERO Code initiative,[9] the U.S. Green Building Council's LEED Zero program,[10] and the International Living Future Institute's Zero Energy Certification program,[11] among others (see **Setting Project Goals and Principles on page 28**). Most programs allow exceptions for off-site renewables after all on-site options have been exhausted.[12] Architecture 2030's Zero Code provides multipliers, or weightings, for how each renewable location is to be allocated to reach the district goal. The Zero Code weighting of renewables based on location, and organized by class, is shown in **TABLE 8 on page 88**.[13]

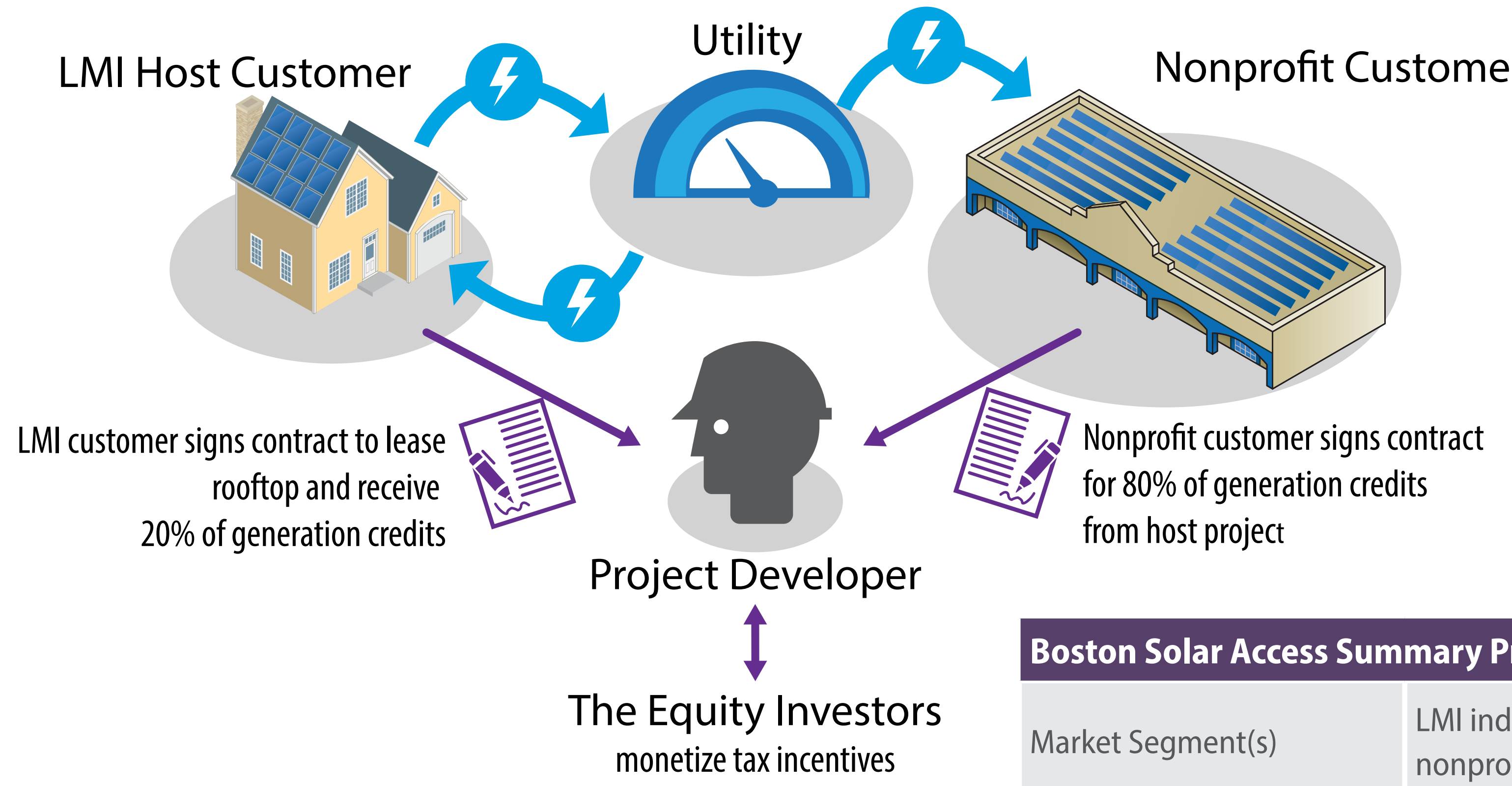
13 zero-code.org/wp-content/uploads/2018/04/Zero-Code-TSD-OffSiteRenewables.pdf

TABLE 8. Summary of Zero Code Renewable Energy Allocation for On-Site and Off-Site Renewable Options[14]

System Type	Procurement Multiplier
On-Site Renewables	1.0
Self-Owned Off-Site **Community Solar** with Retained **Renewable Energy Certificates** Virtual Power Purchase Agreements within Balancing Authority Green Retail Tariffs or Direct Access with Bundled **Renewable Energy Certificates**	0.90
Green Retail Tariffs or Direct Access Virtual Power Purchase Agreements Out of Region	0.60
Unbundled **Renewable Energy Certificates**	0.5

The Zero Code summarizes off-site renewable energy procurement models and the procurement multiplier is applied to the energy procured under each renewable system type to determine the total renewable energy needed to offset on-site energy use. For example, **community solar,**[15] also called shared solar and solar gardens, is a distributed solar energy deployment model that allows customers to buy or lease part of a larger, off-site shared PV system. As of 2019, 16 states have policies in place to directly support **community solar** programs, although two—Minnesota (more than 500 MWac installed) and Massachusetts (more than 250 MWac installed)—account for more than half the total market.[16]

Community solar can be an effective way to give underserved populations access to clean energy. A 2019 study by DOE and NREL[17] explored innovative **community solar** approaches for low and medium income communities. The study identified various ownership and project teams, including for-profit solar developers, community based nonprofits, and local governments. The authors evaluated 178 **community solar** teams across 40 states and profiled 10. The findings demonstrated that expanding solar access to underrepresented markets can be done in an economically feasible way across the United States. **FIGURE 37** summarizes Boston Solar Access, one of the **community solar** programs profiled in the study.



Boston Solar Access Summary Profile	
Market Segment(s)	LMI individuals and nonprofits
LMI Participants	10 households and 8 nonprofits
Project Size	263 kW DC
Business Model/Approach	Community and solar hosting
Location	Boston, Massachusetts
Population	685,094

FIGURE 37. Boston Solar Access low-to-moderate income **community solar** program structure
(LMI: low-to-moderate income)

14 zero-code.org/wp-content/uploads/2020/11/ZERO-Code-2.0.pdf, page 7
15 www.nrel.gov/docs/fy19osti/72575.pdf, *Up to the Challenge: Communities Deploy Solar in Underserved Markets*
16 www.nrel.gov/state-local-tribal/community-solar.html
17 www.nrel.gov/docs/fy19osti/72575.pdf, *Up to the Challenge: Communities Deploy Solar in Underserved Markets*

Integration

Including Photovoltaics in Concept Renderings and Master Plans

Early conceptual designs and graphics are created to support fundraising, community engagement, or local jurisdiction approvals, so it is critical that they include the locations of planned PV systems. This ensures the energy goals are communicated as early as possible in the planning and community stakeholder engagement process and are featured prominently as the plan and district design evolve. For example, early district concept graphics without rooftop PV or parking lot PV canopies suggest the energy generation goals are not yet certain or integral to the district concept, while expansive PV concepts suggest the energy goals are an integral part of the project from the outset. The example HP district concept graphic shown in **FIGURE 38** communicated the energy goals from the very beginning of the visioning of this district.

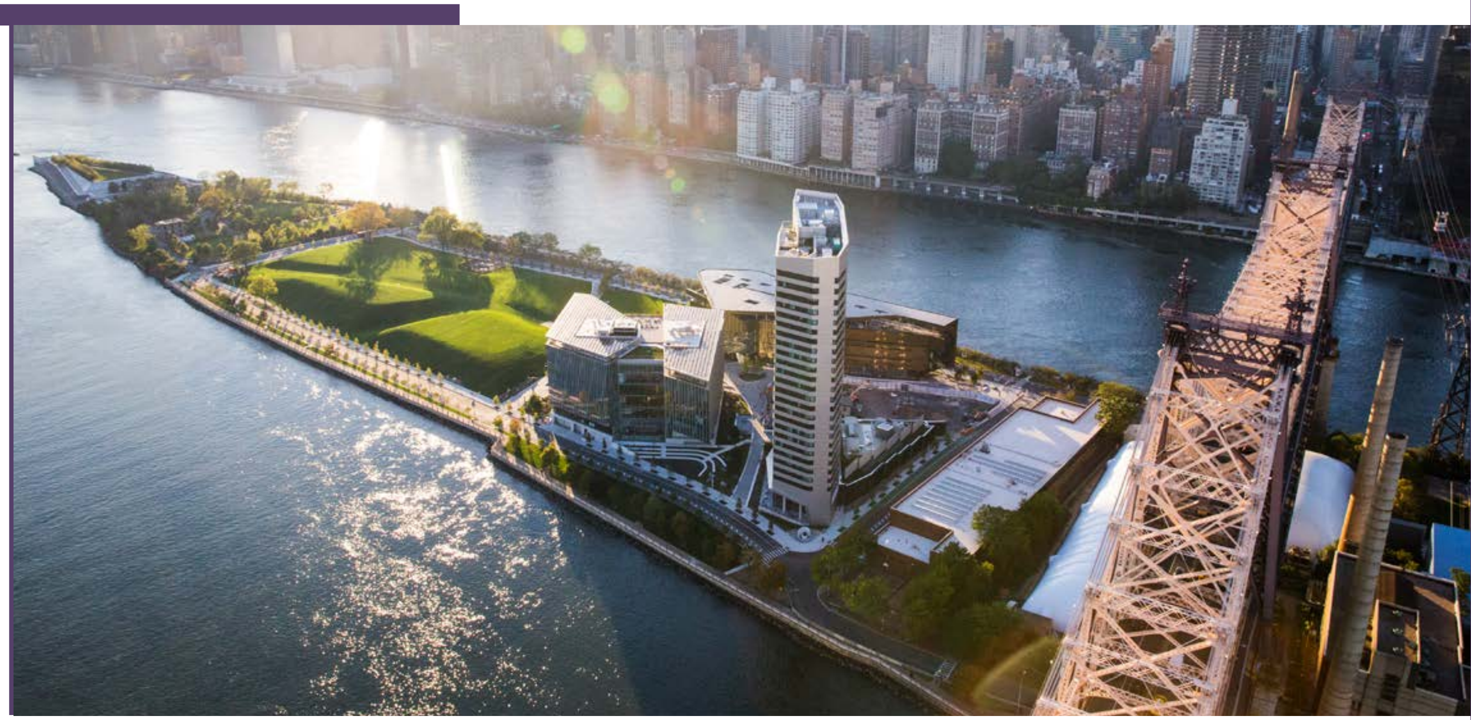
Optimizing Building Solar Access and Minimizing Shading

Solar ready building design is rooted in determining the optimal placement of potential future solar technology. Building orientation and roof design impacts system functionality; if a roof is sloped, siting the PV system on the south-facing segment will optimize annual energy generation. Even small amounts of shading can reduce the output from PV systems, so minimizing shading from surrounding vegetation and neighboring buildings is critical, particularly on the south-facing side of the building. Therefore, the following key solar access planning strategies should be explored as a district is planned:

- When possible, locate buildings in the district with long façades facing north and south, promoting solar access on individual building rooftops. This also minimizes **summer peaking** building loads and high-glare daylight from west-facing windows, and—in colder climates—enhances winter passive solar heating from south windows. **FIGURE 39 on page 90** demonstrates how a district planner at ModernWest implemented this strategy in a dense mixed use industrial and multifamily district.
- Locate buildings in the district to minimize shading of other buildings within the district. For denser urban districts, locate taller buildings to the north to increase solar access for buildings to the south, as shown in the Cornell Tech campus master planned district example (see **Cornell Tech case study on page 116**).
- Typical subdivision planning with cul de sacs should be avoided because each roof would require individual solar siting, reducing overall efficiencies.
- In districts with single family detached homes or other low-rise buildings, choose and locate landscaping so that it does not shade PV systems as it matures.

FIGURE 38. Catalyst Spokane District concept graphic with more than 50% rooftop solar photovoltaics coverage; in the initial district planning of this project, the intent was to meet the remaining renewable generation needs with off-site renewable energy

Rendering from McKinstry



The Cornell Tech master plan included solar access planning to ensure buildings would not shade solar systems

Photo from Lucas Blair Simpson for SOM

FIGURE 39. ModernWest, a 16-acre mixed use light industrial/office/multifamily district in Longmont, Colorado

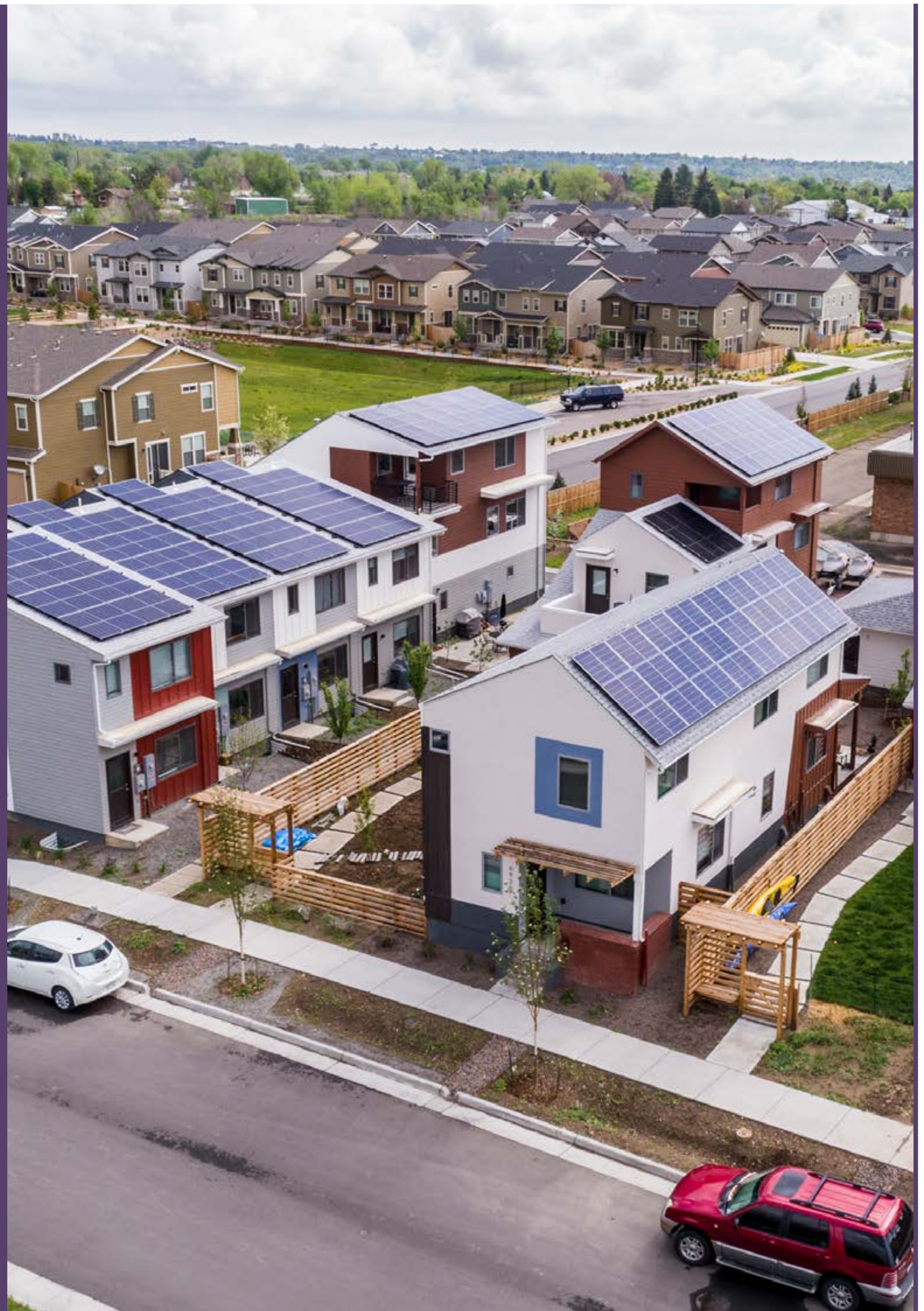
Graphic from ModernWest Ventures Inc.

At ModernWest, a mixed use district currently in the planning stage in Longmont, Colorado, (see **FIGURE 39 on page 90**) planners worked through iterations of the district layout to maximize access to solar. For example, early in the planning process the multifamily program was reoriented from an east/west to a north/south facing program to maximize midday winter solar access to all units. Additional top floor building mass setback details also minimize self-shading and ensure solar access to all units, even on the first floor of multifamily buildings. Early feasibility energy modeling demonstrated a 12% heating energy use reduction and a 3% peak summer afternoon cooling system size and energy use reduction by minimizing west-facing windows and maximizing partially shaded south-facing windows. This early energy planning of the district enabled the design team to cost-effectively maximize passive solar and rooftop PV access.

Consider innovative parcel planning such as a checkerboard layout to minimize shading. The Geos Neighborhood ZE master planned community in Arvada, Colorado, enables dense low-rise townhomes, single family, and home-office spaces by offsetting each building within a checkerboard layout of buildings and landscaping to minimize the potential of buildings shading other buildings (see **FIGURE 40**).

FIGURE 40. **The Geos Neighborhood master plan ensures solar access for all buildings with a checkerboard pattern of homes and landscaping**

Graphic from SUN Studio



The Geos Neighborhood master plan demonstrates dense development while still enabling unshaded rooftop photovoltaics

Photo from Philip Wegener for Geos Neighborhood

Including Solar Specifications in Design Guidelines and Master Plans

Solar ready building design involves designing and constructing a building in a way that facilitates and optimizes the installation of a future rooftop PV system. Installing a PV system on a **solar ready** building is more cost-effective because solar technical feasibility is already established and the infrastructure is in place. Even if there are no immediate plans to install a PV system, understanding special energy load considerations (e.g., whether the building will require an uninterrupted power supply and whether electricity storage will be necessary) before a building is constructed allows designers and building contractors to anticipate those potential scenarios. In addition, assessing the future PV system size and energy production informs the building design and results in optimized system sizing when the system is eventually installed (see **FIGURE 41**). Integrating guidelines[18] into architectural design standards and district master plans ensures that district buildings are designed to optimize PV systems. Key strategies include:

- Maximizing contiguous, south-facing, expansive, and unshaded roof areas for PV system placement
- Requiring the roof design to be compatible with the mounting and support of future PV systems
- Considering in advance where and how PV panels will be mounted, including preinstalling mounting hardware
- Ensuring required electrical conduits are routed from the solar PV system to the building's electrical panel
- Anticipating the mature size of trees and choosing tree species and locations that will not shade potential PV locations
- Allocating sufficient space for PV electrical equipment, including the inverter, other balance of system components, and safety equipment
- Accounting for shading from adjacent buildings; place single family dwellings separately from two-story homes to optimize solar access.

18 www.nrel.gov/docs/fy10osti/46078.pdf

Including roof forms and parapets suitable for PV in architectural design standards provides another opportunity to increase the amount of on-site renewable energy production. Typical architectural design guidelines provide requirements for a specific architectural style to be maintained across the district. When possible, use this approach to suggest options for rooftop form and parapet requirements to be met with rooftop solar canopy overhangs. For example, the Peña Station NEXT design standards require roof forms that add architectural character with shadows and massing, including major soffits and eaves that encroach into the building setback . An expansive PV rooftop canopy overhang system that would enable 75%+ roof coverage is achievable (see FIGURE 42 on page 94).

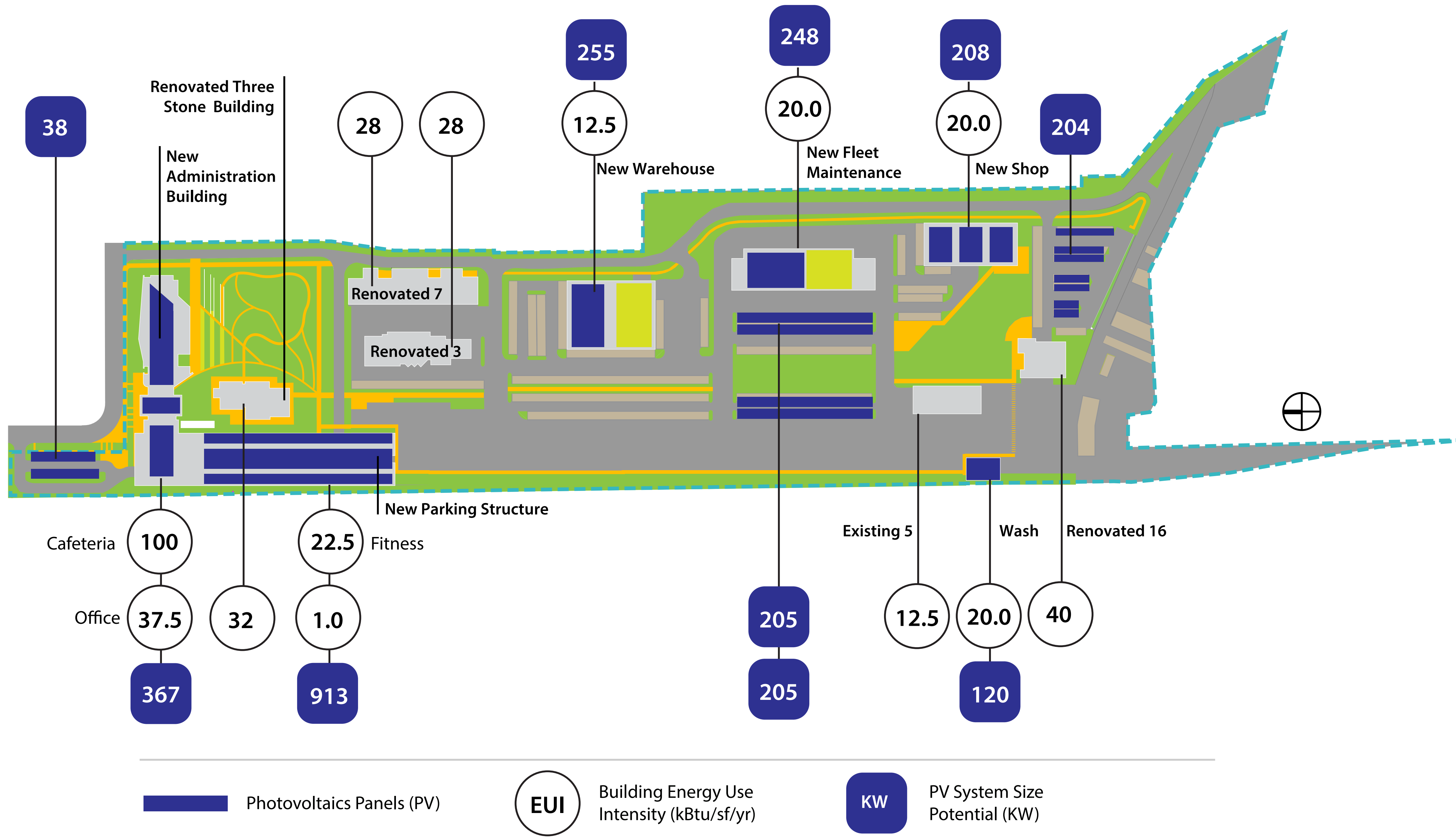


FIGURE 41. Denver Water campus energy master plan with building **energy use intensity** targets at 50% savings and on-site solar photovoltaic systems located on buildings and sized to reach high-performance goals

Source: Denver Water Energy Master Plan

FIGURE 42. Guidance on using roof forms and parapets to optimize the roof areas available for solar photovoltaics from the Peña Station NEXT design standards

Graphic from Fulenwider

ROOF FORMS AND PARAPETS

INTENT

1. Complement and respect the typical forms and materials of the area.
2. Encourage elements that add architectural character with shadows and massing.

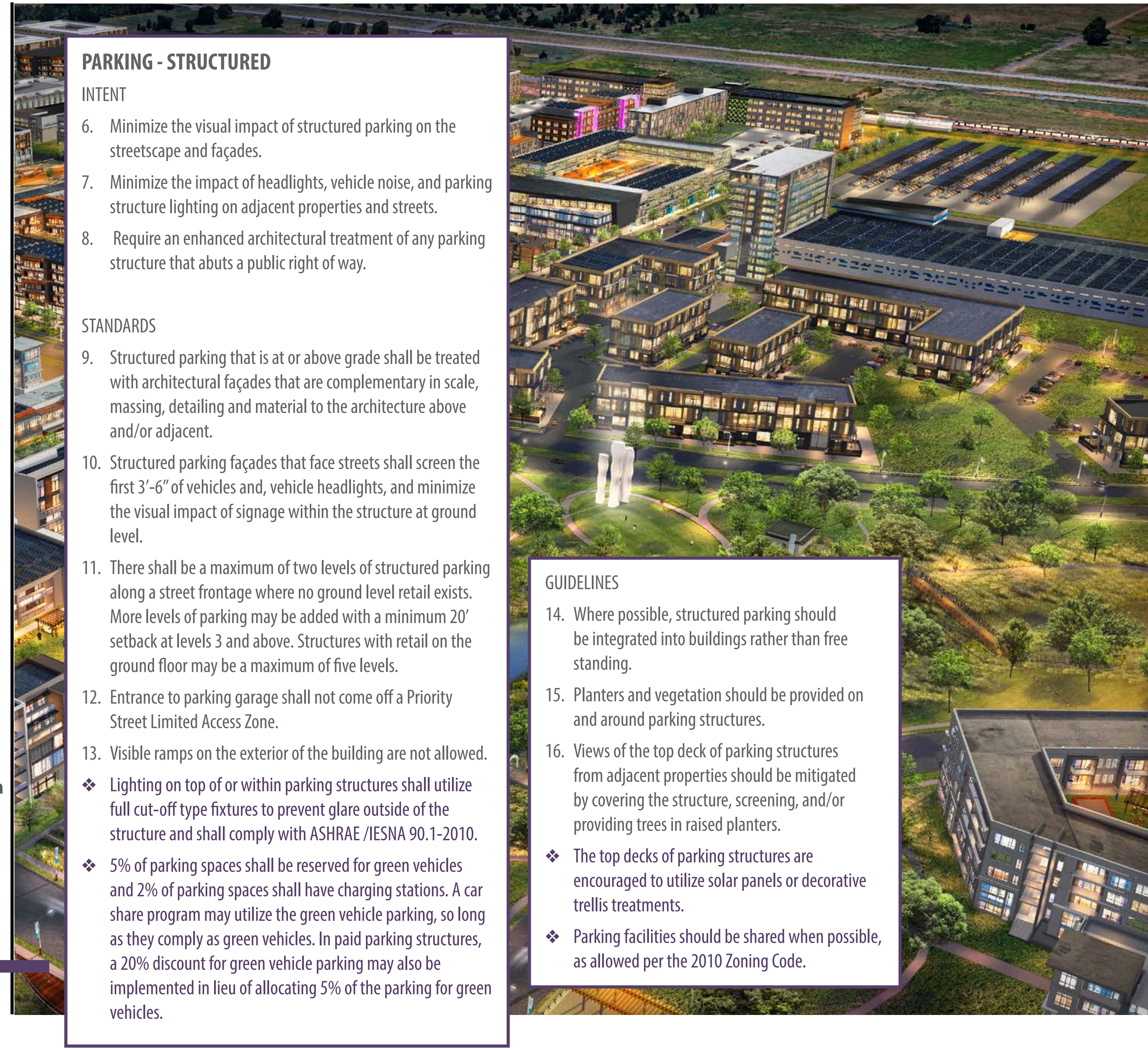
STANDARDS

3. At a minimum, major soffits shall be substantial in their depth: a minimum of 18". Minor soffits shall be proportionately appropriate.
4. Cornices, eaves, and gutters may encroach into the building setback up to 5 feet.

GUIDELINES

5. Roof forms should work to enhance the architectural interest, scale, and massing of the architecture.

The Peña Station Design Standards and Guidelines[19] also recommend PV canopies covering surface parking as well as the top deck of parking garages as shown in **FIGURE 43**.



PARKING - STRUCTURED

INTENT

6. Minimize the visual impact of structured parking on the streetscape and façades.
7. Minimize the impact of headlights, vehicle noise, and parking structure lighting on adjacent properties and streets.
8. Require an enhanced architectural treatment of any parking structure that abuts a public right of way.

STANDARDS

9. Structured parking that is at or above grade shall be treated with architectural façades that are complementary in scale, massing, detailing and material to the architecture above and/or adjacent.
10. Structured parking façades that face streets shall screen the first 3'-6" of vehicles and, vehicle headlights, and minimize the visual impact of signage within the structure at ground level.
11. There shall be a maximum of two levels of structured parking along a street frontage where no ground level retail exists. More levels of parking may be added with a minimum 20' setback at levels 3 and above. Structures with retail on the ground floor may be a maximum of five levels.
12. Entrance to parking garage shall not come off a Priority Street Limited Access Zone.
13. Visible ramps on the exterior of the building are not allowed.

❖ Lighting on top of or within parking structures shall utilize full cut-off type fixtures to prevent glare outside of the structure and shall comply with ASHRAE /IESNA 90.1-2010.

❖ 5% of parking spaces shall be reserved for green vehicles and 2% of parking spaces shall have charging stations. A car share program may utilize the green vehicle parking, so long as they comply as green vehicles. In paid parking structures, a 20% discount for green vehicle parking may also be implemented in lieu of allocating 5% of the parking for green vehicles.

GUIDELINES

14. Where possible, structured parking should be integrated into buildings rather than free standing.
15. Planters and vegetation should be provided on and around parking structures.
16. Views of the top deck of parking structures from adjacent properties should be mitigated by covering the structure, screening, and/or providing trees in raised planters.

❖ The top decks of parking structures are encouraged to utilize solar panels or decorative trellis treatments.

❖ Parking facilities should be shared when possible, as allowed per the 2010 Zoning Code.

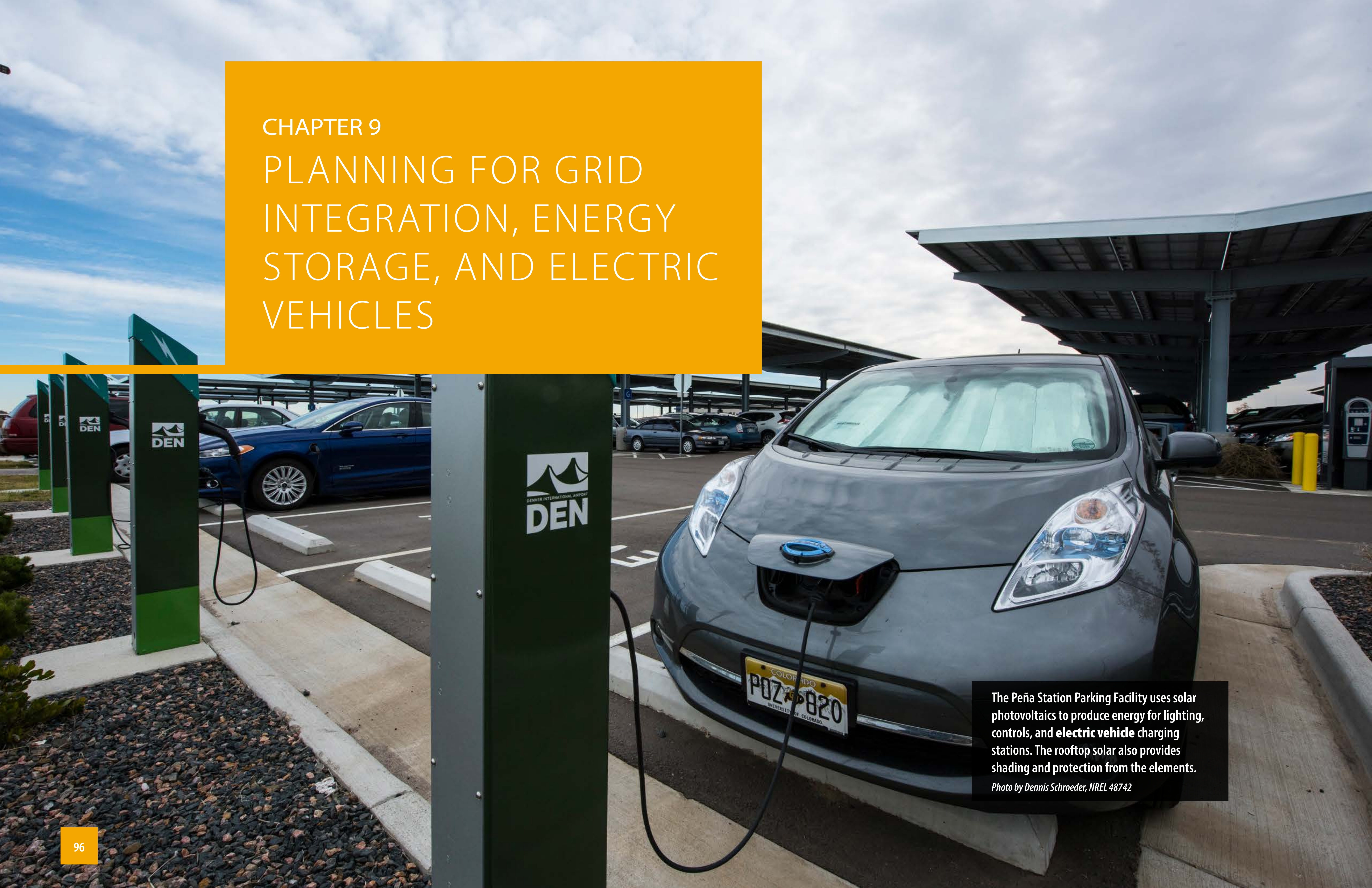
FIGURE 43. Peña Station NEXT design guidelines example for parking lot solar photovoltaic canopy integrated with parking design guidelines

Graphic from Fulenwider

19 business.flydenver.com/bizops/documents/PSN_DesignStandardsGuidelines.pdf

CHAPTER 9

PLANNING FOR GRID INTEGRATION, ENERGY STORAGE, AND ELECTRIC VEHICLES



The Peña Station Parking Facility uses solar photovoltaics to produce energy for lighting, controls, and **electric vehicle** charging stations. The rooftop solar also provides shading and protection from the elements.
Photo by Dennis Schroeder, NREL 48742

Districts offer unique opportunities to capitalize on electric load diversity and demand flexibility across a variety of buildings and shared district infrastructure.

Overview

Managing the coordination (magnitude and timing) of electric loads on a daily and hourly basis, especially during critical peak periods for the grid, can present opportunities and challenges for districts. Key strategies include:

- Incorporating passive design strategies that shift demand away from peak periods
- Using sensors and controls
- Installing smart building technologies that can respond to grid signals
- Examining electrical and thermal energy storage opportunities
- Enabling the use of EVs as distributed energy resources for energy storage and load sharing, which requires:
  - Assessing how new EV loads impact HP district energy goals and energy accounting
  - Considering locations for EV charging stations throughout the district based on alignment with distributed renewables
  - Aligning with local proposed new construction codes by building type with an eye to requiring charging infrastructure in new construction
  - Including EV charging infrastructure requirements in district energy plans and design guidelines
  - Determining the types of charging infrastructure currently available.

1 www.nrel.gov/docs/fy20osti/75478.pdf
2 www.energy.gov/sites/prod/files/2019/04/f61/bto-geb_overview-4.15.19.pdf

Grid-Interactive Energy-Efficient Buildings

DOE defines a grid-interactive efficient building as an energy-efficient building that uses smart technologies and on-site distributed energy resources to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences in a continuous and integrated way.[1] **FIGURE 44** describes key characteristics of grid-interactive energy-efficient buildings,[2] which can also be considered at a district scale.

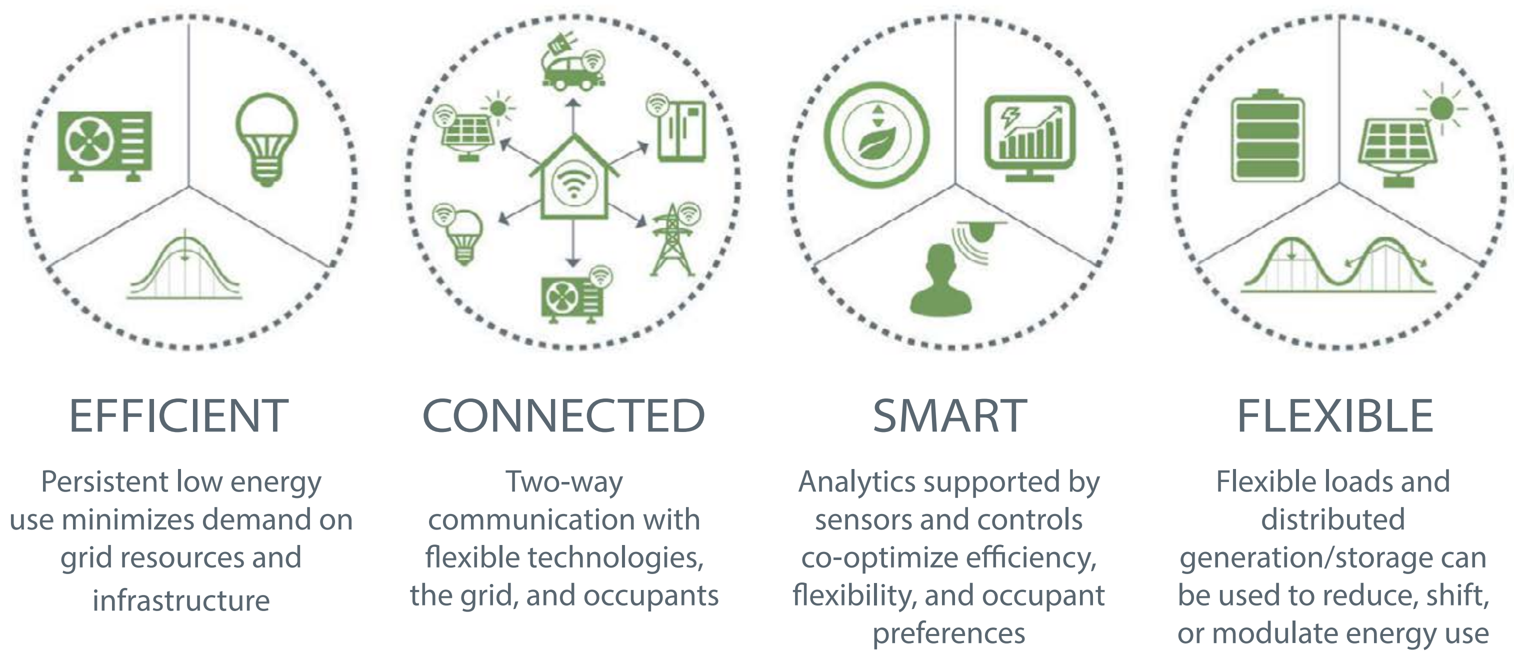


FIGURE 44. Characteristics of grid-interactive energy-efficient buildings

Source: U.S. Department of Energy

Electric Vehicle Charging Infrastructure

Many cities and states have aggressive goals for personal and fleet vehicle electrification. U.S. EV penetration goals have resulted in an average growth of 32% annually from 2012 to 2016 and 45% growth during the year ending in June 2017. EV sales are forecast to reach 75% of all new car sales by 2050 if oil prices increase or technology costs decline.[3] For example, the City and County of Denver set a goal that by 2030, 30% of vehicles would be electric, growing to 100% of vehicles in 2050.[4] Reaching these ambitious goals will require significantly more charging stations for residents and drivers including at workplaces, homes, apartments, and public fast charging stations.

3 www.forbes.com/sites/energyinnovation/2017/09/14/the-future-of-electric-vehicles-in-the-u-s-part-1-65-75-new-light-duty-vehicle-sales-by-2050/#5cc64bde2892
4 www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/80x50/DDPHE_80x50_ClimateActionPlan.pdf

Charging infrastructure build-out is directly linked with EV uptake, and smart EV charging infrastructure planning is an emerging district energy planning promising practice. Electrifying a fleet or a district full of personal and commuter vehicles and providing adequate charging requires a deep knowledge of vehicle routes, locations where charging will take place, available electrical distribution infrastructure, existing facility electricity usage, utility rates, insurance, federal and state policies, and vehicle costs.

> *Charging infrastructure build-out is directly linked with electric vehicle uptake, and smart electric vehicle charging infrastructure planning is an emerging district energy planning promising practice.*

Analysis and Approaches

Potential Energy Cost Savings

To take full advantage of the opportunities to save money on energy in an HPD requires familiarity with the rate structures and demand charges of the local electric utility (see **Understand Utility Rate and Metering Options on page 46**). The anticipated cost savings can be included in the financial pro forma calculations for the district project (see **Additional Benefits on page 37**).

Through analysis, it is possible to estimate the cost savings associated with load shifting technologies in buildings with time-based utility rates. In one example, a study examined retrofitting the cooling system in an 80,000 ft^2 library administration building in Florida that was billed on a time-based rate. The biggest opportunity for cost savings was to reduce demand charges during peak periods and instead use energy when it was least expensive (10 p.m.–6 a.m. in this case). It was estimated that a partial ice storage system would yield total operating cost savings of approximately $15,200 per year compared with retrofitting the building with an air-cooled chiller system without ice storage. Although the initial cost of the ice storage system was higher, its breakeven point was about 3.3 years earlier than the no ice storage scenario. For these types of analyses, the cost savings are highly dependent on building characteristics, utility rates, load shifting system characteristics and costs (initial and maintenance), control strategies, and possibly other factors.[5]

Electric Load Diversity

Different building types have different average electric load shapes and peak consumption timing. For example, a multifamily building is likely to have an electric energy consumption peak later in the day during the summer than an office building operating on a conventional workday schedule. This diversity in the timing and magnitude of electric loads is a feature of most districts, although circumstances differ depending on the mix of building types and utility rates in the district. Furthermore, even district buildings of the same use type built to approximately the same efficiency specifications will have some diversity in electric loads because of factors such as differences in:

- Building orientation, geometry, shading, and exposure
- Timing of HVAC equipment cycling/controls, large electricity-consuming devices, and lighting/controls
- Occupancy and associated variations in plug loads, appliance usage, and service/domestic water heating loads.

If the district is (or could be) billed on a master electric meter[6] through a demand- or time-based rate structure (see **CHAPTER 4 on page 44**), there may be opportunities to achieve cost savings as a result of this diversity in loads between buildings. However, this can require that the electrical infrastructure **behind the meter** be developed and maintained by the district (not the utility) and there may be implications regarding redundancy of service.

> *When utility rates include demand charges or time-based rate structures, energy cost savings are possible by shedding loads and shifting flexible and controllable loads from peak periods to off-peak periods.*

Peak Demand Savings and Load Shifting

When utility rates include demand charges or time-based rate structures, energy cost savings are possible by shedding loads and shifting flexible and controllable loads from peak periods to off-peak periods. Shifting loads may not save energy on a daily or annual basis, but it can affect when energy is consumed, such as reducing energy consumption during peak periods. In individual buildings, the best opportunities for load flexibility and load control are generally thermostatically controlled loads (e.g., air conditioning, electrically-driven heating, and water heating) and schedulable loads (e.g., appliances and EV charging). Districts present enhanced opportunities for load shifting, especially if they include electri-

5 doi.org/10.22361/jfmer/81612

6 If allowed by the utility and local laws and regulations; although the buildings may be grouped under a common meter for billing purposes, it is still useful to have energy submetering to understand individual buildings' energy consumption and end uses.

cally-driven district thermal systems and large central thermal storage systems. For example, it may be more cost-effective to handle chilled water storage in a large central tank than in many smaller tanks distributed in buildings throughout the district. Examples of strategies relevant to shifting cooling, space heating, and service/domestic water heating are shown in **TABLE 9**. Examples of strategies relevant to schedulable loads are shown in **TABLE 10**.

TABLE 9. Example Strategies Relevant to Shifting Space Cooling, Space Heating, and Service/Domestic Water Heating

Category	Description
Building thermal mass	Thermal mass enables building materials to absorb, store, and later release heat. For example, NREL's ZE Research Support Facility has precast thermal mass walls (3 inches of concrete on exterior, 2 inches of rigid insulation, and 6 inches of concrete on interior), which help moderate internal temperatures year-round. Nighttime purges in summer months paired with the high thermal mass walls trap cool air inside, keeping temperatures comfortable during warm summer days.
Chilled water storage	Water can be cooled by chillers during off-peak periods and stored in insulated tanks to meet later cooling needs. Smaller tanks can be distributed in buildings or installed in conjunction with central district thermal systems.
Hot water storage	For domestic hot water, larger storage tanks with dynamic temperature controls allow better matching of hot water production and renewable supply availability. Smaller tanks can be distributed in buildings or installed in conjunction with central district thermal systems.
Phase change storage	Phase change systems for thermal energy storage often have a smaller space footprint than chilled/hot water storage systems, because these materials store more energy in a given volume than other storage media.[7] One common example of a phase change material is water/ice; currently available commercial HVAC products use this strategy successfully. Phase change systems can be distributed in a building or installed in conjunction with central district thermal systems.

TABLE 10. Example Strategies Relevant to Schedulable Loads

Category	Description
Ventilation	In some cases, ventilation rates and timing can be controlled in ways that help to reduce peak consumption in buildings while meeting minimum ventilation requirements. For example, if a building is typically ventilated at 30% more than the minimum required rate to provide enhanced indoor air quality, there may be an opportunity to reduce to the minimum required ventilation rate during peak hours.
Appliances	Certain electric appliances can be scheduled to run during off-peak hours. For example, dishwashers with time delay features can be installed in multifamily buildings.
Electric vehicles	EV charging can contribute to peak loads, especially if many vehicles are charging at the same time. Scheduled and/or controlled charging can help manage the number of vehicles drawing power during certain time periods and help shift energy consumption to off-peak hours. A district may present unique opportunities for the coordinated control of large numbers of vehicles to help manage local renewable consumption/export, reduce **peak demand**, provide grid services, etc.

7 For example, melting 1 pound of ice requires about as much energy as heating 10 pounds of water by 14.4ºF (note that the 1 pound of ice only takes up about 9% more volume than 1 pound of water at near-freezing temperatures under standard atmospheric pressure).

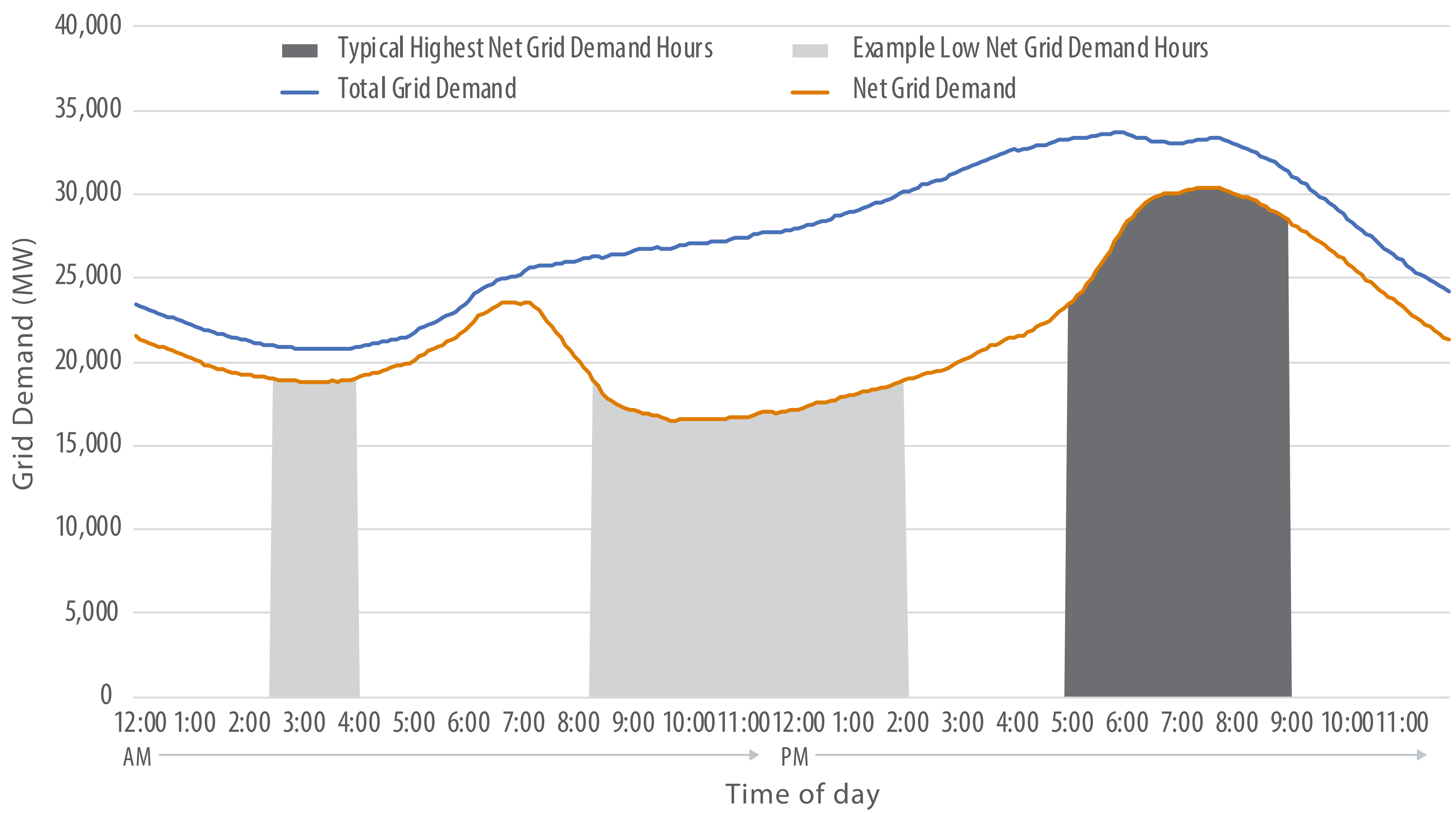


FIGURE 45. A typical day of total grid demand, net grid demand (total grid demand minus renewable generation), and highest net demand hours
(Note: The area between the total grid demand and net grid demand curves represents the renewable generation.)

Source: California Independent System Operator[8]

8 www.caiso.com/TodaysOutlook/Pages/default.aspx

Basic District-Scale Grid-Interactive Approaches

FIGURE 45 shows an example of how a large utility system's electric loads can vary over the course of a day, including typical highest cost and highest net demand hours as well as lowest-cost and lowest net demand hours. Net demand on the grid represents the nonrenewable grid-scale generation (total demand on the grid minus renewable generation on the grid). In this example, the grid would benefit from districts that can reduce or shift energy use away during the peak 5 p.m.–9 p.m. period.

The following is a set of building design and operations strategies for district-scale grid interactivity presented in qualitative priority order based on possible cost implications, synergies with other benefits, and conceptual ease of implementation:

- **General energy efficiency year-round.** Design for 30%–50% annual energy savings compared to local code in new construction to save energy at all times during the year, including peak hours
- **Efficiency strategies that target peak period savings.** Focus on saving energy during peak hours for the utility net load, often between 5 p.m.–9 p.m.
- **"No-regrets" applicable solar ready buildings.** Design building systems to more easily integrate PV systems in the future[9]
- **Passive demand flexibility strategies.** Use building strategies involving uncontrolled passive design strategies to shift and/or enable the shift[10] of electricity use from higher net demand periods to lower net demand periods
- **Active demand flexibility strategies.** Employ building strategies involving flexible and controllable loads that can automatically shift electricity use from higher net demand periods to lower net demand periods; automated and actively controlled dynamic design strategies that include flexible and controllable loads can enable load shifting based on local utility price and control signals.

Examples of related questions that district planners should consider in the early stages of planning include:

- What are the applicable/potential utility rate structures? Are the rate structures sensitive to demand

9 NREL Solar Ready Buildings Planning Guide: www.nrel.gov/docs/fy10osti/46078.pdf

10 For example, building thermal mass could passively shift the loads of a building relative to a lower thermal mass alternative design, but also could enable active shifting of loads when coupled with an active demand flexibility strategy, such as thermostat set point controls.

and/or timing of electricity consumption? Are there "opt-in" time-based rate structures?

- Is there, or could there be, a master electric meter?
- What are the "typical" load profiles and timing/magnitude of peak loads for different efficiency levels, building types, and program mixes being considered for the district?
- Is there or will there be a need/incentive within the district for:
  - **Peak demand** reduction
  - Load flexibility/shifting.
- To what extent do the annual energy efficiency strategies result in peak period savings? Are there additional efficiency strategies that are cost-effective when peak period savings are considered?
- Which building types/end uses in districts have the most potential for **peak demand** reduction and load flexibility/shifting? What is the timing of flexible loads relative to peak periods?
- Is there potential for stationary electrochemical (battery) storage?
- How does on-site PV generation affect load shapes and peak period energy consumption for individual buildings and the district as a whole?
- Are there opportunities for interactive controls, **microgrid**s, and/or enhanced **resilience**?

District design teams can explore these questions using a variety of approaches, including:

- Review of applicable local utility rate structures and **interconnection** rules/limits for batteries, PV, and other distributed energy resources
  - Contact/refer to utility for official rate information
  - Consult the Utility Rate Database.[11]
- PV/battery analysis and analysis of measured data from previously-constructed buildings/districts of similar type in similar climates (e.g., smart meter data from past projects in an owner's, builder's, developer's portfolio, when available)
  - Using PVWatts[12] enables users to estimate the energy production of grid-connected PV energy systems
  - Using the REopt Lite[13] with the Utility Rate Database enables users to input a building or district[14] load profile and calculate
    - The energy costs under different utility rates
    - The life cycle cost optimal PV and battery system sizes.
  - Using the System Advisor Model[15] with the Utility Rate Database enables users to perform economic analyses of energy systems, including PV and battery systems
  - Custom analysis of end-use level measured data to identify the potential for **peak demand**/load flexibility/load shifting.
- Building and district energy modeling
  - Analysis of energy efficiency strategies to identify and optimize peak period savings
  - Analysis of load shifting strategies to identify potential for **peak demand**/load flexibility/load shifting.

Commuters can park at the Peña Station Parking Facility and ride the mass transit train one stop to Denver International Airport.

Photo by Dennis Schroeder, NREL 48754

11 openei.org/wiki/Utility_Rate_Database
12 pvwatts.nrel.gov/pvwatts.php
13 reopt.nrel.gov/tool
14 This would require that the district could be master-metered rather than buildings being metered individually under the chosen rate. Confirm such assumptions with the utility.
15 sam.nrel.gov/

Example Analysis: Building and District Scale Grid Interactivity

For building and district energy modeling, simulation studies can be performed to understand differences in the average load profiles and the timing and magnitude of peak loads for different efficiency levels, building types, and architectural program mixes. This example analysis builds directly on the example EUI analysis described in Energy Use Intensities **page 64**. Assuming building energy models are developed for different building types in the district under business as usual and higher efficiency scenarios, and that the simulation platform used can generate hourly or subhourly electric energy use estimates for the simulated year (e.g., 8,760 hourly values in 1 year), then load profile estimates can be analyzed to gain some insights.

FIGURE 46 shows the average daily electricity load during the summer months (June 1–August 31) for the different higher efficiency (roughly 30%–50% more efficient than the ASHRAE 90.1-2013 baseline scenario) mixed fuel[16] building prototypes considered in the example analysis. The results are presented in watts per square foot (W/ft²) to more easily compare across the different building types, which can vary substantially in total square footage and load magnitudes. For the buildings considered in this example analysis, the food service building generally has the highest average electricity loads per ft² and peaks on average during the noon lunch hour.[17] The office and retail buildings peak on average between 4 p.m. and 5 p.m., while the multifamily and lodging peak on average between 6 p.m. and 10 p.m. Three different hypothetical districts were also simulated according to the square footage breakouts described in **Example Analysis: Energy Use Intensities on 64**, and the predicted average daily electric load profiles are shown in **FIGURE 47**. The example office park has the largest average hourly loads and also the highest ratio of maximum average hourly loads to the minimum average hourly loads (peak to valley) while the example multifamily district has the flattest average daily loads. The example live-work-play district is a mix of office, multifamily, and other building types and generally has average hourly loads between the office and multifamily districts.

16 Gas space and water heating was modeled.

17 Depending on the location and business type, other food service buildings might peak during the evening. Schedules and other simulation input variables that affect daily load profiles should be customized based on available information.

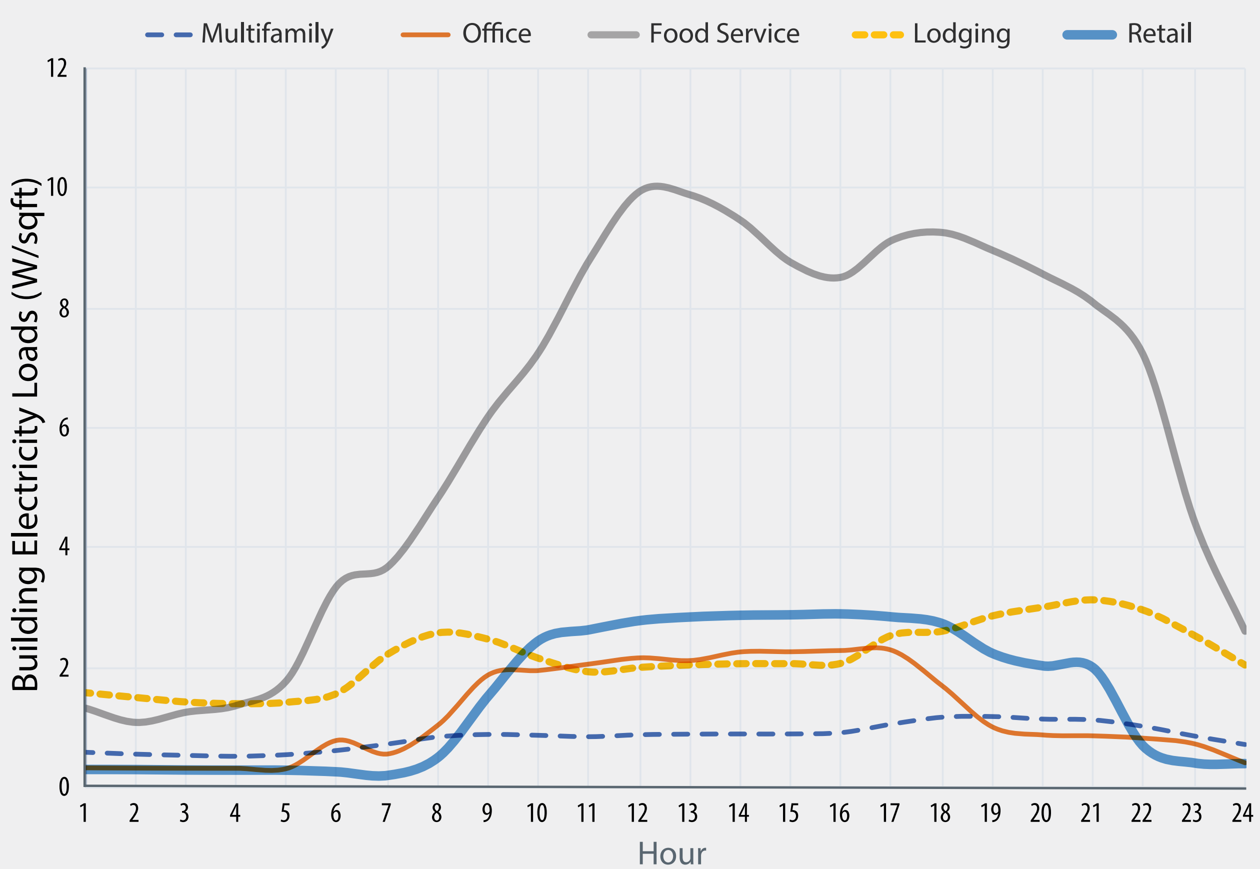
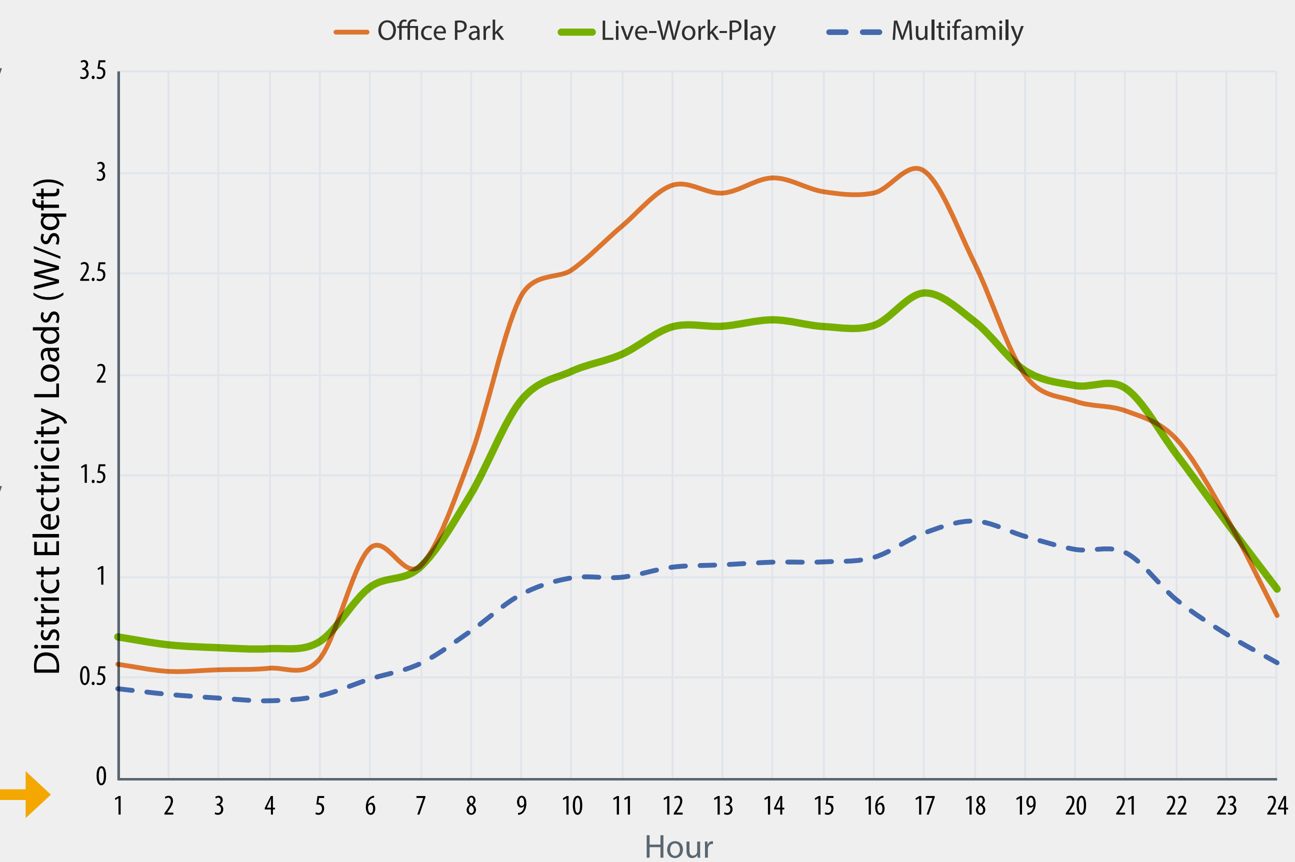


FIGURE 46. EXAMPLE ANALYSIS: Average daily summer electric load profiles for simulated higher efficiency buildings in Atlanta, Georgia

(IECC climate zone 3A)

FIGURE 47. EXAMPLE ANALYSIS: Average daily summer electric load profiles for simulated higher efficiency hypothetical districts in Atlanta, Georgia

(IECC climate zone 3A)



Many traditional annual energy efficiency strategies can also help reduce peak loads in a district. For example, **FIGURE 48** shows the average daily summer electric load profile for the mixed fuel example live-work-play district under the business as usual scenario and the higher efficiency scenario. This figure is one way to visualize how improving the annual energy efficiency of the buildings in the district can also help reduce the average daily electric loads. Although not shown in **FIGURE 48**, it is expected in buildings where summer peak electric loads are dominated by cooling energy consumption, targeted energy efficiency features (e.g., more efficient enclosures, lighting, and cooling systems) can help reduce the monthly 15-minute **peak demand** of the building (and thus reduce utility costs if demand charges apply). When analyzing the cost-effectiveness of energy efficiency measures for a district, analysts can attempt to quantify the cost savings that will occur under the applicable utility rate structure(s). For example, if a utility rate has both volumetric and demand charges, combinations of measures delivering cost-effective annual and **peak demand** savings can be identified.

Although load shifting analysis is not as mature as annual efficiency analysis using building energy simulation, there are some approaches analysts can use to better understand the opportunity. For example, **FIGURE 49** shows predicted electric loads in an all-electric multifamily building prototype for an example summer day in the IECC 3A climate zone (Atlanta, Georgia). End-use simulation output data were analyzed to estimate the maximum potential for shifting cooling and water heating electricity consumption outside of an assumed 5 p.m. to 9 p.m. peak period.[18] The "No Shifting" curve shows the whole-building electric load profile without any shifting. The "Shifted Cooling" curve shows the whole-building profile if all cooling electricity consumption occurring between 5 p.m. and 9 p.m. was shifted to other time periods outside of 5 p.m. to 9 p.m. with the lowest whole-building electricity consumption.[19] The "Shifted Cooling & Water Heating" shows the whole-building profile if all cooling and water heating electricity consumption occurring between 5 p.m. and 9 p.m. were shifted.[20]

18 Shifting may be possible for other end uses as well, but were not analyzed for this example analysis.

19 No on-site PV was assumed in this example scenario. If PV were present, loads could be shifted to periods with the lowest whole-building net electricity loads (building demand minus PV generation).

20 Heat pump water heaters were simulated in this high efficiency multifamily prototype.

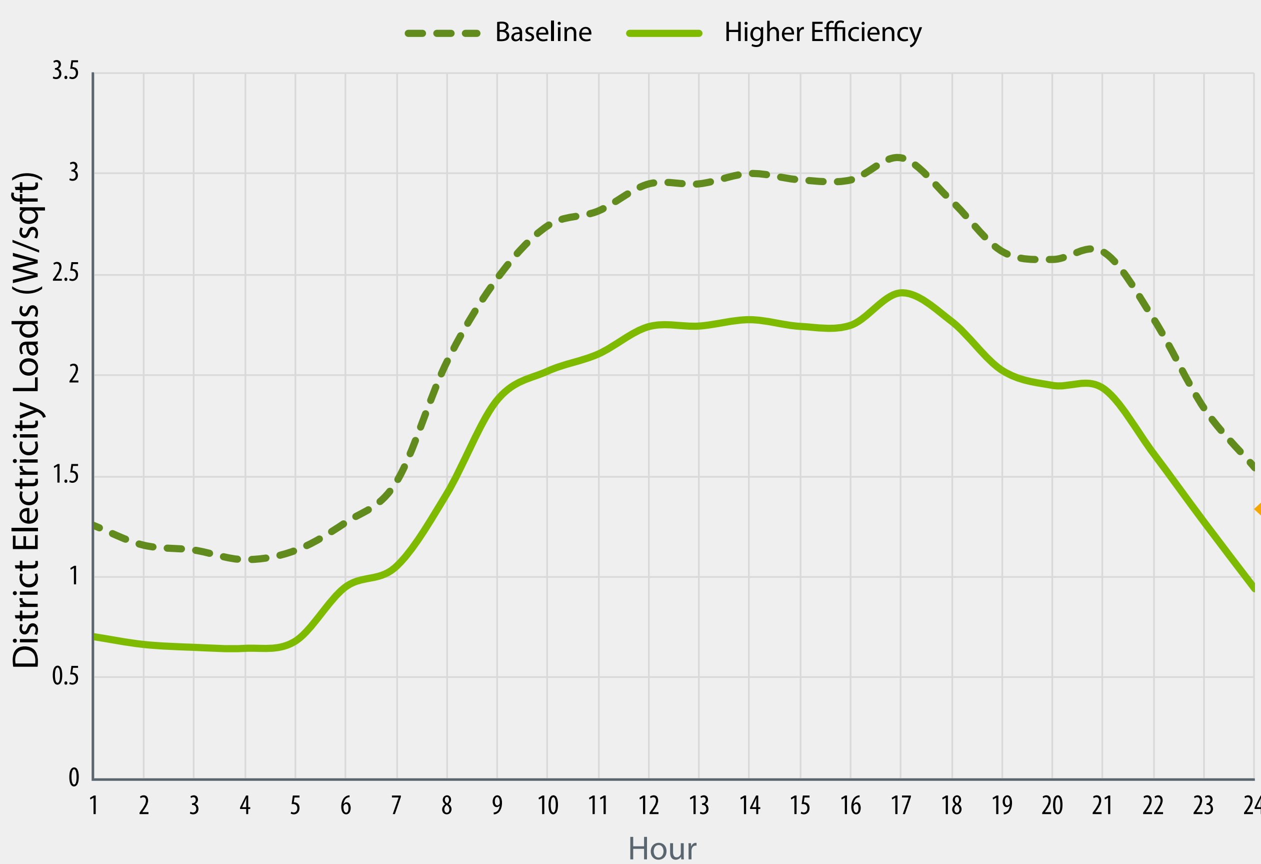
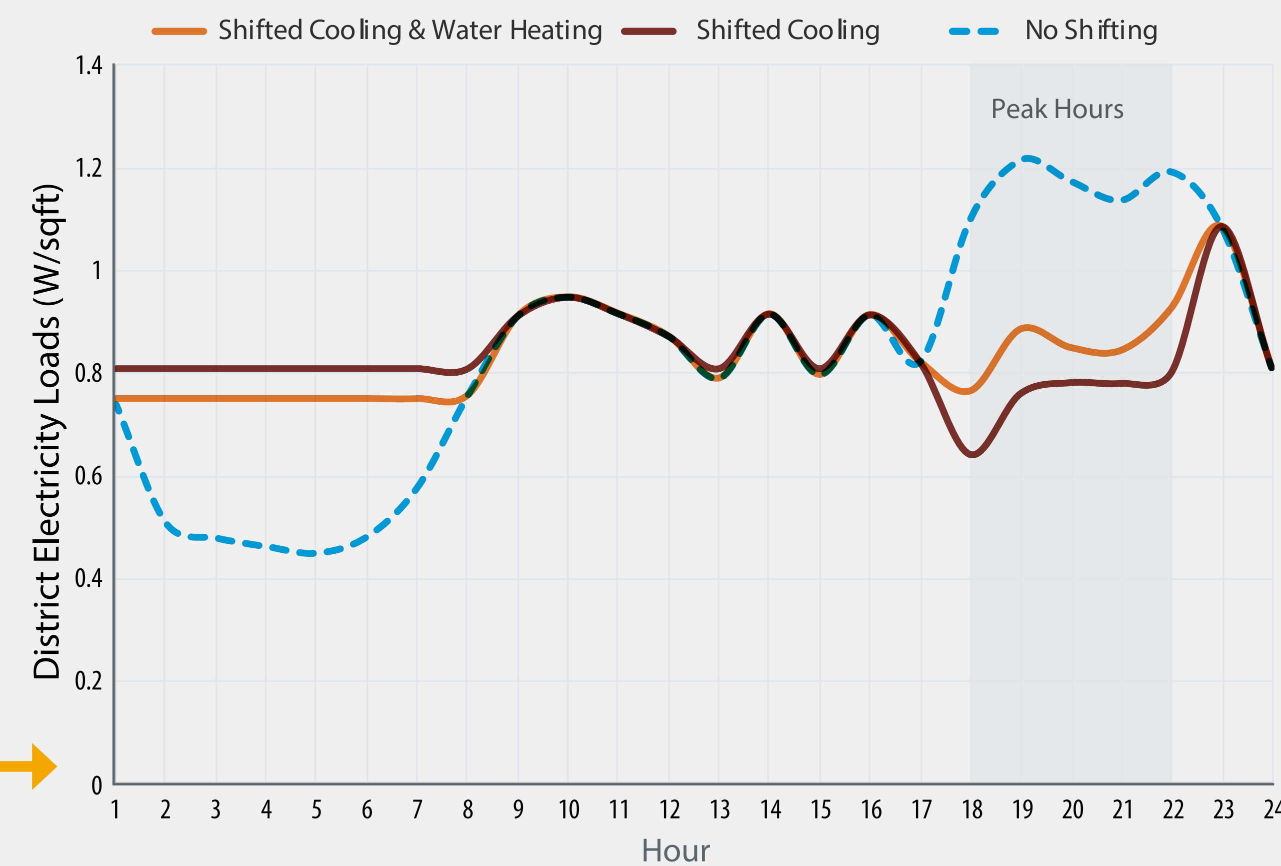


FIGURE 48. EXAMPLE ANALYSIS: Average daily summer electric load profiles for simulated baseline and higher efficiency "live-work-play" hypothetical district in Atlanta, Georgia

(IECC climate zone 3A)

FIGURE 49. Example summer day load shifting analysis



This type of analysis generally estimates an upper bound for the amount of energy that can be shifted outside the peak period for the end uses considered. It assumes there are no efficiency gains or losses in shifting the energy. In reality, shifting would be achieved through specific technologies such as ice storage, chilled/hot water storage, phase change materials, and building thermal mass. These technologies may result in increases or decreases[21] in annual efficiency. For example, ice storage systems have some standby losses and also require electricity to operate fans/pumps during periods when ice is being used for cooling. However, in certain climates it may be efficient to make ice during the night when it is cooler outside and heat can be rejected more easily. Specific efficiency results will depend on the exact system characteristics, control strategies, weather, and more. Although not pursued here, some of these strategies can be modeled explicitly with building energy simulation tools once specific end uses and system types are prioritized. Efforts are ongoing to increase the capabilities of simulation tools to model more load shifting technologies and strategies as time-based rate programs become more prevalent, driving the need for more complex "time-of-energy savings" analyses.

For building and district energy modeling, the effects of PV on load diversity and peak period demand can be analyzed. Assuming that the simulation platform being used can generate hourly or subhourly PV generation estimates in addition to electric energy use estimates for the simulated year (e.g., 8,760 hourly values in 1 year), then net load profile estimates can be analyzed to gain some insights.

FIGURE 50 shows the average hourly daily electricity net load during the summer months (June 1–August 31) for the different mixed fuel building prototypes considered in the example analysis with PV systems sized to achieve ZE.[22] **FIGURE 50** can be contrasted with **FIGURE 46** to understand the general impact of PV on average daily load profiles during the summer months. Positive loads indicate net imports of electricity from the grid while negative loads indicate net exports. The PV generation causes average daily loads during these summer months to change considerably in shape during periods of the day when there is PV generation. Average net loads are generally flat and positive (importing) in the early morning, ramp up slightly during the morning for some building types, and then become negative (exporting) during the peak PV generation hours of the day. In the afternoon and early evening as PV generation declines, net loads become positive again and reach peaks on average in the early- to mid-evening. Compared with the no solar scenario (see **FIGURE 46), FIGURE 50** shows average hourly loads peak later in the day as a result of the PV generation and exhibits a larger range of average values. See also the California "duck curve" load shape that describes a common challenge in integrating large amounts of PV into the grid.[23]

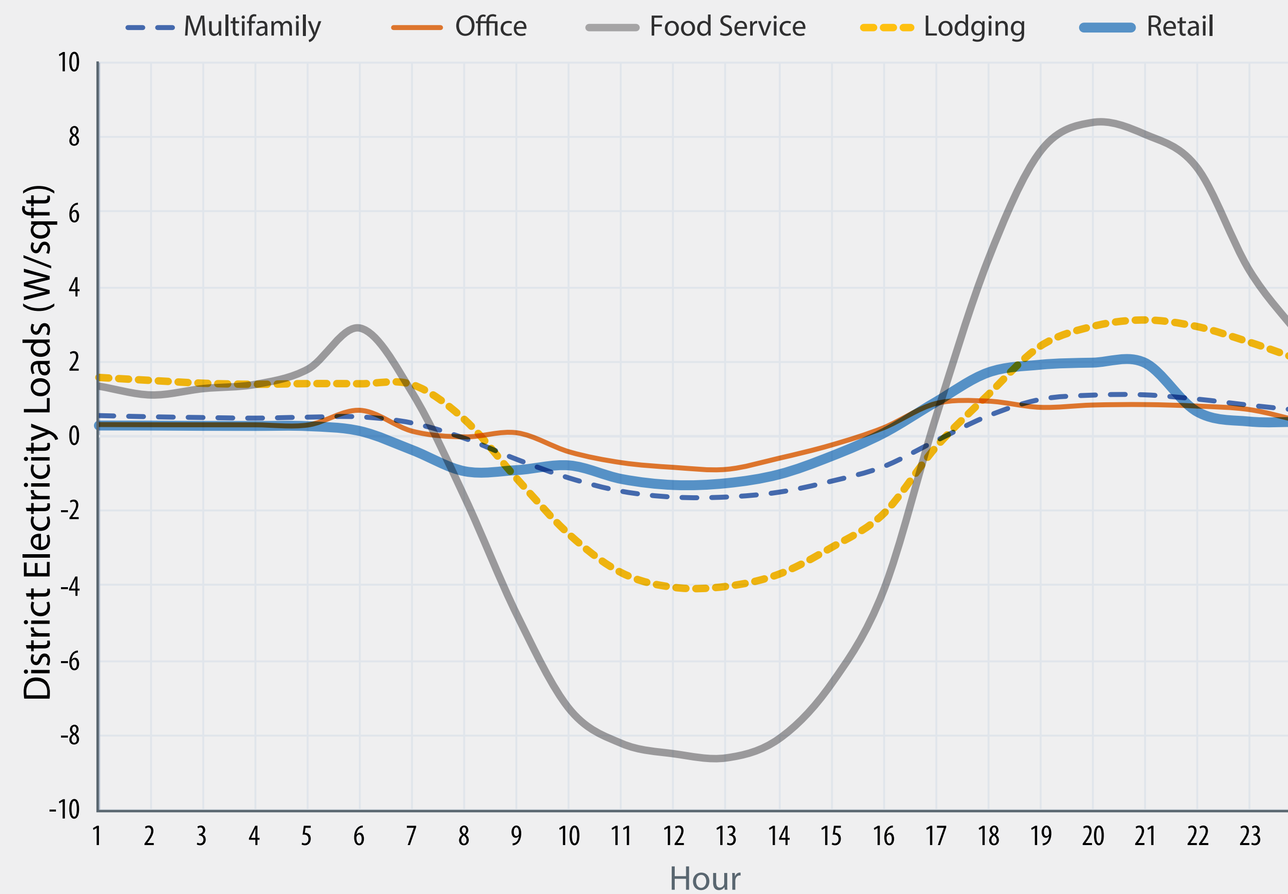


FIGURE 50. EXAMPLE ANALYSIS: Average daily summer electric net load profiles (building demand minus solar photovoltaic generation) for simulated higher efficiency mixed fuel buildings with solar photovoltaic systems sized to achieve **zero energy** in Atlanta, Georgia (IECC climate zone 3A)

21 E.g., high building thermal mass in climates with strong diurnal temperature swings could shift and reduce space conditioning energy consumption.

22 South-facing systems with 10° tilt were assumed and modeled in SAM using the same weather files that were used in OpenStudio/EnergyPlus.

23 www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Example Analysis: Electric Vehicle Infrastructure Planning and Charge Load Modeling

The following provides an example analysis linking the City and County of Denver's goals for EVs and charging infrastructure to a district's energy planning goals and approach. The example analysis demonstrates how a district could consider the energy impacts and planning goals for EV supply equipment (EVSE) within a district to answer specific planning questions such as:

- How much future electrical load could be expected for various EVSE infrastructure scenarios?
- What EVSE charging infrastructure location options and control strategies allow for a better alignment with local renewable energy generation?

In the Denver mayor's Climate Action Plan, Denver set the goal of reducing greenhouse gas emissions 80% by 2050.[24] The transportation sector is the second largest source of GHG emissions in Denver and the Climate Action Plan identifies EVs as one of the key strategies for reducing GHG emissions from vehicles. To achieve these objectives, Denver set a goal that by 2030, 30% of vehicles would be electric, growing to 100% of vehicles in 2050.[25] Specific guidance from Denver includes[26]:

> *To reach these ambitious goals, there will need to be significantly more charging stations available to Denver residents and drivers. The EVI-Pro tool developed by the Department of Energy,[27] estimates that Denver would need to have nearly 10,000 publicly available stations in 2030 and 25,000 charging stations in 2050 to support the vehicle electrification goals. Currently in Denver there are approximately 350 publicly available charging stations so there is a significant need for additional charging stations.[28] In 2018, electric vehicles made up 2.6% of vehicles sales in Colorado and in December of 2018, electric vehicles sales made up 5.36% of vehicles sales in the state. In Colorado, electric vehicle (EV) sales increased by 70 percent from 2017 to 2018. To serve all these new people and their associated jobs, the City's stock of residential and commercial buildings will need to increase significantly. Making sure all these new buildings are equipped to charge electric vehicles will help increase EV adoption and save consumers and businesses a lot of money. Because charging is most convenient where one is parked for long periods of time, it is important to make charging as easy as possible at residences. In particular, there are significant logistical barriers for residents of multi-family dwellings to upgrade existing electrical infrastructure and install new EV charging stations. Installing charging stations at multi-family properties has proven challenging. With just under half (44%) of its population living in multi-family properties, this is an especially important area for Denver to concentrate on. While updating the building code will not directly address existing multi-family properties, it should encourage the overall market to move in the right direction as existing properties compete with new properties for customers. . . . Due to their lower fueling and maintenance costs, electric vehicles can provide a substantial economic benefit to lower income populations, if they have access to charging stations. Lower income households spend twice as much of their income on transportation compared to higher income households and would benefit the most from access to charging. Without these requirements it will be even more unlikely that property owners and landlords will support the installation of charging stations at lower income properties.*

For a possible district energy planning effort in the city of Denver, the following example analysis demonstrates an approach to answer the EVSE questions for the district.

The future district will occupy a 300-acre site comprising more than 100 buildings. The development is anchored by a large corporate office park, with additional planned development that includes attached residential buildings, three-story multifamily apartment buildings, hotels, small offices, and retail buildings. The stretch goal of the development is to be ZE and include electrical infrastructure for future EVSE build-out goals. To assess the impact of the possible EV charging loads on the district's overall electrical load profile and the local distribution grid, an hourly end-use modeling analysis of the EV charging loads was performed using URBANopt and OpenStudio. URBANopt is an urban modeling platform originally created by NREL and now collaboratively developed by multiple national labs, universities, and industry partners. According to its developers, "the URBANopt platform uses the OpenStudio platform to perform detailed energy modeling at the individual building level using EnergyPlus." OpenStudio is a "cross-platform collection of software tools to support whole building energy modeling using EnergyPlus," and is developed collaboratively by five national laboratories (NREL, Argonne National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory). NREL constructed building energy models of the 100 planned buildings based on the district program using URBANopt. Then an OpenStudio measure was developed to add an EV charging load to a building energy model for various assumptions of EVSE users. Additionally, an EnergyPlus measure was developed for demand management control of the EV charging load in a building energy model.

24 www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/80x50/DDPHE_80x50_ClimateActionPlan.pdf
25 www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/80x50/DDPHE_80x50_ClimateActionPlan.pdf
26 www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver_Building_Code/2019-code-update/iecc/(p129)_447_IECC-Chapter2_Final%20EV%20Ready.pdf
27 Projection Tool (EVI-Pro) Lite. afdc.energy.gov/evi-pro-lite
28 Alternative Fuels Data Center. 2019. Alternative Fueling Station Locator. afdc.energy.gov/stations/#/find/nearest

The OpenStudio measure is based on static profiles of power draw for EV charging. The profiles were generated from the EVI-Pro tool based on EVSE type and building occupancy profile assumptions. According to the tool's developers, "the fundamental assumption in EVI-Pro is that consumers prefer charging infrastructure that enables them to complete all their travels (based on current vehicle use) while minimizing operating cost." The charging profiles are divided into three types of charging stations: residential, public, and workplace. Residential and workplace charging stations were assumed to be Level 1 and Level 2 (see **Available Electric Vehicle Charging Infrastructure on 108**). Public building charging stations were assumed to be DC fast chargers. Each of the 100 buildings modeled for the district was assigned one of these types of charging stations for weekdays and weekends. The EV charging profiles at future build-out that were generated for this district assumed that 50% of the light-duty vehicles on the site were plug-in EVs, which amounts to about 10,000 during a typical weekday. Building occupancy was used as a proxy for vehicle population. The OpenStudio measure selects an EV charging power draw profile for a given building and a given set of conditions (charging behavior and charging control) and adds the EV charging load to the building electrical load.

EV charging profiles were developed for three different scenarios for charging behavior and three different scenarios for workplace charging flexibility:

- **Minimum delay.** EVs begin charging immediately upon arriving at work.
- **Maximum delay.** EVs are plugged in immediately but do not begin charging until necessary.
- **Minimum power.** EVs are charged at minimum rate over the parking event.

Plots of the EV charging load on a weekday under each of these scenarios are shown in **FIGURE 51**. The plots show district-wide EV loads for an average weekday, with disaggregation by home charging (Level 1 and Level 2), workplace and public charging (Level 1 and Level 2), and DC fast charging. A large workplace charging infrastructure combined with a load leveling power management control approach both reduces the overall average daily **peak demand** as well as best aligns with local midday solar production.

For more general analysis for EVSE infrastructure planning in districts, this example analysis demonstrates a workflow to allow energy planners to scale the level of EV user penetration for a generalized profile for the building type (work, retail, or home) across common demand management control strategies. This workflow, when integrated with the building energy modeling analysis for the district, enables EV infrastructure planning to be included in the full district energy analysis and feasibility studies.[29]

29 www.nrel.gov/docs/fy20osti/77438.pdf

The parking facility at Peña Station allows **electric vehicle** owners to park, leave their cars to charge, and ride the train to Denver International Airport.

Photo by Dennis Schroeder, NREL 48757

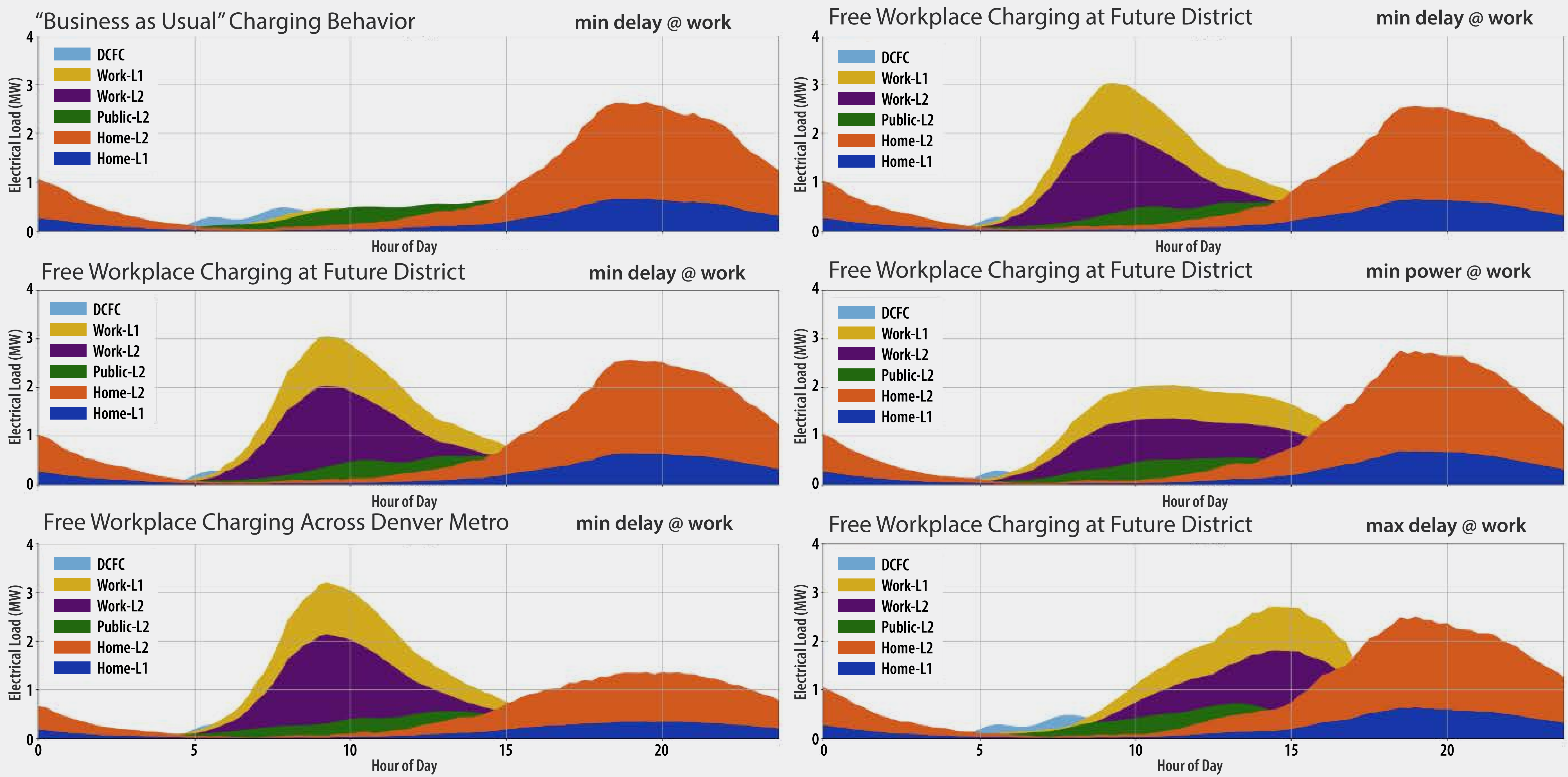


FIGURE 51. **Plots demonstrating how control and behavior scenarios affect the distribution and timing of electric vehicle charging and the magnitude and timing of peak power draw for charging.**

With "business as usual" charging behavior and the "min delay at work" control option, Level 2 home charging sets peak power draw in the evening. With "free workplace charging across Denver metro" behavior and "min delay at work" control, peak power draw is set by workplace charging around midday, better aligning with expected solar power production. "Max delay at work" moves workplace charging to later in the day and "min power at work" results in home charging setting peak power draw in the evening.

Key:
DCFC: DC fast charging
L1: Level 1 charging that uses a standard electrical outlet
L2: Level 2 charging that can add 12 to 25 miles of range per hour

Considerations

Stationary Batteries

Electrochemical (or battery) storage is another potential technology for load shifting and **peak demand** management in HPDs, whether batteries are located **behind the meter** in individual buildings or larger community-scale batteries are installed within the district (e.g., by the electric utility or an energy services company). Whereas energy generation technologies are often characterized by their power capacity (e.g., kW or MW), batteries are typically characterized by both their power capacity (maximum discharge rate, typically in kW or MW) and their energy capacity, the length of time the battery can sustain power output at its maximum discharge rate (typically hours).[30]

Various resources are available to help understand the economics of batteries. For example, the Rocky Mountain Institute published a report on "The Economics of Battery Energy Storage: How Multi-Use, Customer-Site Batteries Deliver the Most Services and Value to Customers and the Grid"[31] and NREL previously reported key basics of battery economics and potential energy storage value streams.[32]

Coordinated Controls

An emerging potential advantage of a district-scale approach is the coordinated control of connected devices in buildings as well as distributed energy resources such as stationary batteries, EV charging stations, and PV systems within a district. Traditional utility demand response programs have often relied on participating customers to take actions to reduce their loads during demand response events. Utilities have used direct load control approaches to turn off or modulate power to certain devices during these events per an agreement with the customer that can include financial incentives for participation. With the increasing number of internet-connected devices in buildings, the installation of advanced metering infrastructure, and other advances in data communication, processing, and analytics, there is a growing opportunity to coordinate the control of individual devices within buildings to achieve whole-building objectives.[33] For example, a building energy management system may centrally coordinate multiple flexible load technologies in a commercial building or home to shift loads and manage **peak demand**s in a way that delivers energy cost savings to the building owner while satisfying other preferences such as occupant thermal comfort.

For a district, additional opportunities may exist for expanding coordinated control beyond individual buildings to the collection of buildings within the district. In addition, shared energy infrastructure such as district thermal systems, community-scale energy generation and thermal or electric storage, and the electric distribution system offer control opportunities. Control strategies at these scales could take a variety of forms, such as a hierarchical control structure in which individual connected devices or building energy management systems are in two-way communication with a central aggregator or more distributed control structures such as transactive energy markets in which devices or individual building energy management systems are communicating and interacting with each other.

Approaches and technologies for coordinated control at building and larger scales are emerging and are the subject of ongoing research. However, district planners can explore the feasibility and potential benefits of advanced controls for their districts now and may consider partnering with researchers, technology companies, utilities, etc. to pilot advanced technologies and approaches. Important considerations include, but are not limited to, identifying potential financial mechanisms, incentives, and markets for such controls and understanding potential barriers related to data privacy and security.[34] A more detailed discussion of many of these concepts and potential benefits can be found in *Connected Communities: A Multi-Building Energy Management Approach*.[35]

Available Electric Vehicle Charging Infrastructure

An energy district development process takes time, so it is important to ensure adaptability in planning. This is particularly important in determining EV charging infrastructure needs, which are evolving rapidly. A district may deploy multiple kinds of EV charging systems based on the building type and connection to the energy system. The plan should first determine where single car chargers, multiple car chargers, fast chargers, etc. are best deployed. Understanding the existing definitions of EVs and charging infrastructure is the first step in this process. The Southwest Energy Efficiency Project definitions include[36]:

- **EV.** A motorized vehicle registered for on-road use, powered by an electric motor that draws current from rechargeable storage that is charged by being plugged into an electrical source

30 www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
31 rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf
32 www.nrel.gov/docs/fy16osti/66967.pdf. Specific potential value streams for a project will vary.
33 These advances are also enabling the creation and use of "digital twins," where digital replicas of physical systems are created and explored to improve operations and efficiency. www.forbes.com/sites/bernardmarr/2019/04/23/7-amazing-examples-of-digital-twin-technology-in-practice/#32c1991e6443
34 www.nature.com/articles/s41560-018-0257-2.pdf
35 www.nrel.gov/docs/fy20osti/75528.pdf
36 www.swenergy.org/transportation/electric-vehicles

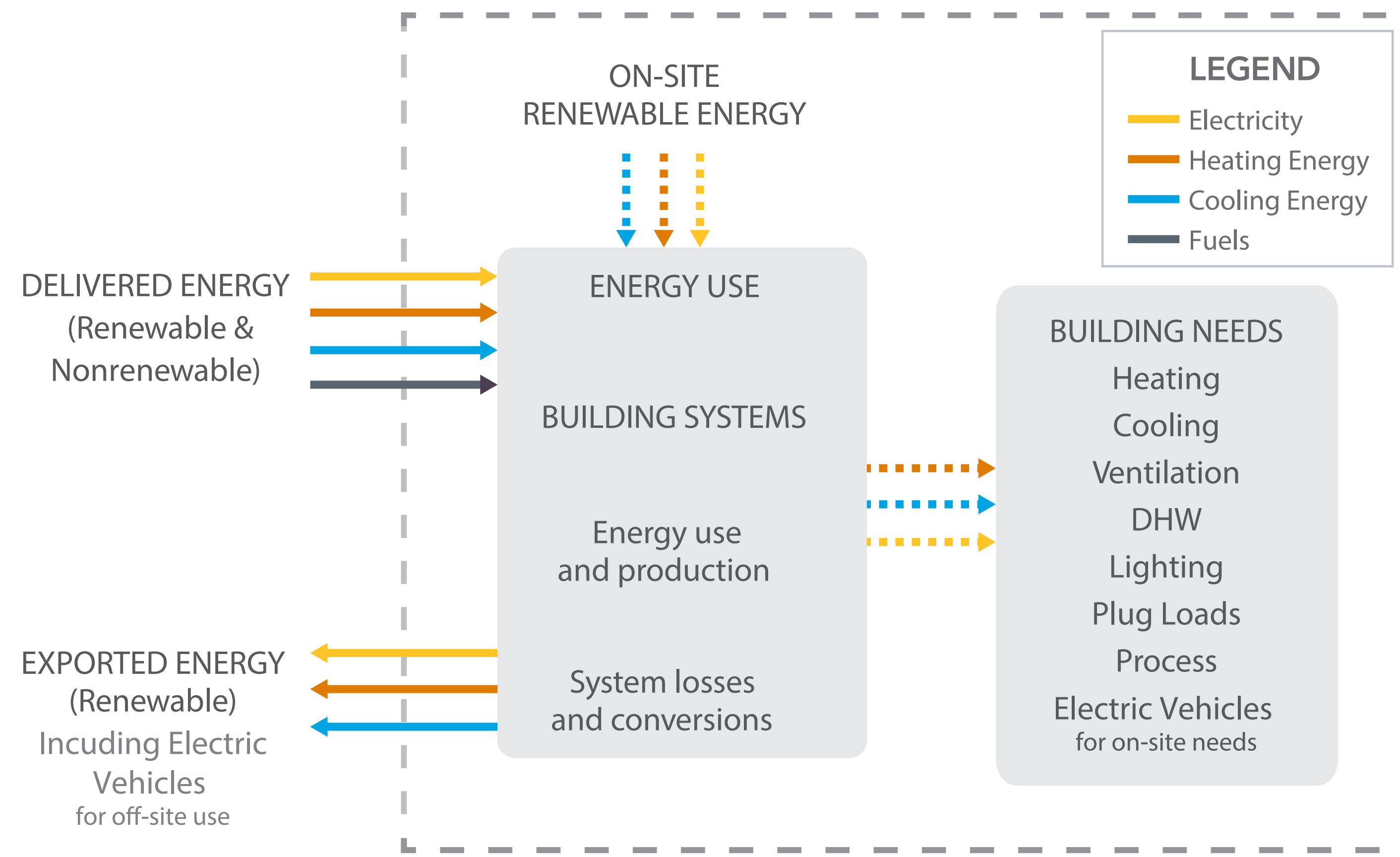
- **EVSE.** The electrical conductors and equipment external to the EV that provide a connection between an EV and a power source to provide EV charging, with varying levels of power delivery available
- **Level 1 EVSE**. Level 1 charging is provided by a standard electrical outlet and can be convenient for home use or extended parking sessions; it charges slowly, however, offering about 5 miles of range per hour of charging and a power output less than 1.5 kW at 120 volts
- **Level 2 EVSE.** Some home chargers and most public charging stations are Level 2, which can add 12 to 25 miles of range per hour, depending on the type of EV and its onboard charger at 3 kW to 7 kW at 208/240 volts; Level 2 EVSE is ideal for times when the vehicle will be parked for at least an hour, such as at work, restaurants, movie theaters, sporting events, or longer shopping trips
- **EV fast charger.** EV supply equipment with a minimum power output of 20 kW (EVSEs with outputs up to 350 kW are available as of this writing [October 2020]), often referred to as DC fast chargers; these devices enable a faster charge and are typically located in public areas with access for long distance trips (note that not all EVs have DC fast charge capabilities)
- **EV load management system.** A system designed to allocate charging capacity among multiple EVSE installations
- **EV capable space.** A designated parking space with conduit sized for a 40-amp, 208/240-volt dedicated branch circuit from a building electrical service panel to the parking space and sufficient physical space in the same building electrical service panel to accommodate a 40-amp dual-pole circuit breaker
- **EV ready space.** A parking space that is provided with one 40-amp, 208/240-volt dedicated branch circuit for EV supply equipment that is terminated at a receptacle, junction box, or Level 2 EVSE within the parking space
- **EVSE installed space.** A parking space with EVSE capable of supplying Level 2 with current at 40 amps at 208/240 V.

The DOE Zero Energy Building and Campuses Common Definition, as well as U.S. Green Building Council's LEED Zero Building certification program, provide specific guidance for how to treat EV charging loads in the ZE building accounting[37]:

> *ZEB energy accounting would include energy used for heating, cooling, ventilation, domestic hot water (DHW), indoor and outdoor lighting, plug loads, process energy, and transportation within the building. Vehicle charging energy for transportation inside the building would be included in the energy accounting. On-site renewable energy may be exported through transmission means other than the electricity grid such as charging of electric vehicles used outside the building.*

For a building or district that provides electricity to charge EVs used for transportation to and from the district, this load, if separately metered, is considered an export option rather than an additional load to offset with renewable energy. If the electricity used for charging is only for vehicles used in the buildings or within the district (such as an electric forklift or autonomous campus electric shuttle), it is considered a district scale load and would need to be offset with renewable energy to reach zero. The DOE ZE building definition graphic in **FIGURE 52** shows how EV loads are treated in the HP calculation.

37 www.energy.gov/sites/prod/files/2015/09/f26/A%20Common%20Definition%20for%20Zero%20Energy%20Buildings.pdf



Notes

1. The dashed lines represent energy transfer within the boundary
2. The solid lines represent energy transfer entering/leaving the boundary used for zero energy accounting

FIGURE 52. Zero energy definition energy use boundary with electric vehicles

Figure adapted from A Common Definition for Zero Energy Buildings (DOE 2015)

Aligning Electric Vehicle Charging with Distributed Renewables

In a recent Rocky Mountain Institute evaluation of the future of buildings and the grid, researchers identified key strategies for building systems and loads that could enable more cost-effective grid integration and the addition of renewables to the grid.[38] The researchers modeled the use of demand flexibility strategies to shift electricity consumption from times of the day with high demand but low renewable supply to times with high renewable supply. As shown in **FIGURE 53**, they identified EV charging loads as the largest opportunity to maximize the benefits of demand flexibility, suggesting that developing a grid-coordinated EV charging infrastructure could be a key strategy to reduce utility system costs and maximize alignment of loads with renewable generation.

38 rmi.org/wp-content/uploads/2018/02/Insight_Brief_Demand_Flexibility_2018.pdf

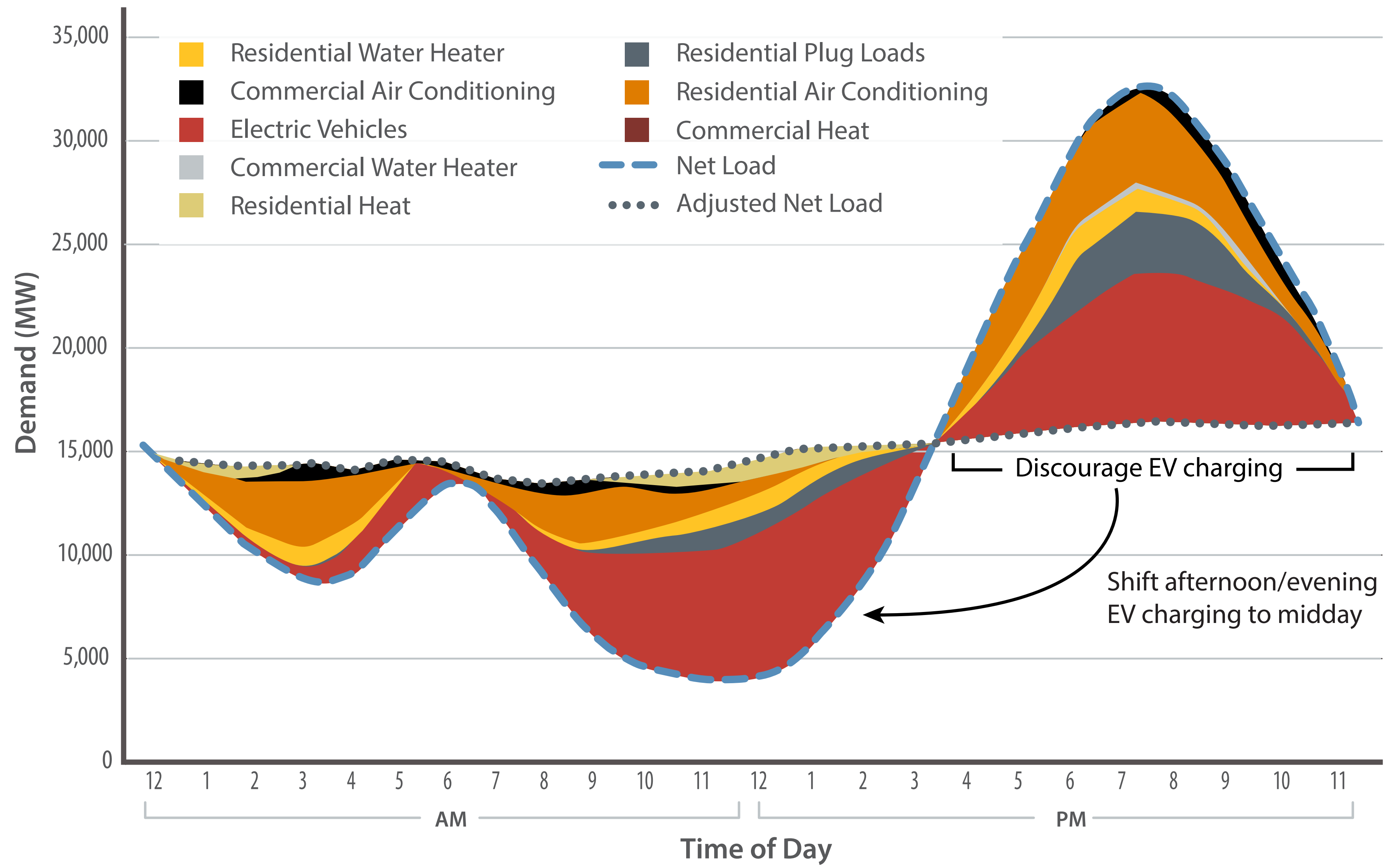


FIGURE 53. Electric vehicle charging loads provide an opportunity to maximize the benefits of demand flexibility

Graphic from Rocky Mountain Institute

Based on the possible locations for EV charging infrastructure, district energy planners can consider the following deployment scenarios to maximize alignment of this new load with renewables and reduce infrastructure and **peak demand** costs:

- **Charging at work in office buildings.** Daytime loads with Level 2 EVSE align well with the lowest-cost renewables. Demand charges can be mitigated with smart charging controls.
- **Charging at single family homes.** Lower power Level 1 EVSE and overnight Level 2 charging reduces overall peak loads and can be aligned with off-peak periods for TOU rates to minimize charging costs.
- **Charging in apartment and multifamily buildings.** Lower power Level 1 EVSE and overnight level 2 charging reduces overall peak loads and can be aligned with off-peak periods for TOU rates to minimize charging costs.
- **Strategic destination charging (hotels, park-and-rides, gyms, schools, etc.).** Provides charging infrastructure anywhere vehicles are parked for extended periods of time.
- **Fast charging (long distance travel and fleets).** Additional charging flexibility and demand management is possible with demand management controls on EV charging infrastructure.

Aligning with Local Proposed New Construction Codes by Building Type

According to the Southwest Energy Efficiency Project,[39] approximately half of all vehicles in the United States belong to residents of single-family or duplex homes with access to a dedicated off-street parking space such as a garage or driveway that could be used for overnight EV charging. The other half do not have reliable access to a dedicated off-street parking space at an owned residence, so there is a need to expand charging access to multifamily unit dwellings, workplaces, and commercial properties. In addition, the installation of an EV charging station is three to four times less expensive when the infrastructure is installed during initial construction rather than retrofitted in existing buildings.[40] Therefore, EVSE charging infrastructure new construction codes are being developed to ensure these EV charging capabilities become available as districts are built out over time.

As **FIGURE 54** indicates, new construction codes being implemented across the United States include requirements for EV capable, EV ready, and EVSE.

1. EV Capable

Install electric panel capacity with a dedicated branch circuit and a continuous raceway from the panel to the future EV parking spot.

Aspen, CO: 3% of parking is EV-Capable (IBC)

Atlanta, GA: 20% is EV-Capable (Ordinance)

2. EVSE Ready Outlet

Install electric panel and raceway with circuit to terminate in a junction box or 240-volt charging outlet (typical clothing dryer outlet).

Boulder, CO: 10% of parking is EV-Ready Outlet

3. EVSE Installed

Install a minimum number of Level 2 EV charging stations.

Palo Alto, CA: 10% of parking is EV-Installed

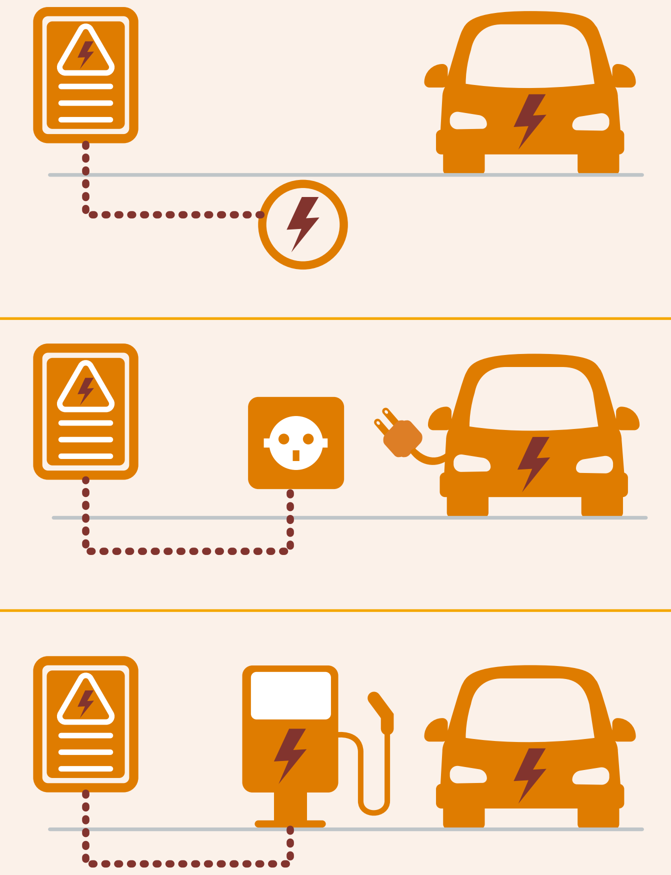


FIGURE 54. New construction codes across the United States include **electric vehicle** requirements

Key: EVSE=electric vehicle supply equipment

Sources: Aspen (Colorado) code,[41] Atlanta (Georgia) ordinance,[42] Boulder (Colorado) code,[43] Palo Alto (California) code,[44] and illustration adapted by Marjorie Schott, NREL

39 www.swenergy.org/cracking-the-code-on-ev-ready-building-codes

40 evchargingpros.com/wp-content/uploads/2017/04/City-of-SF-PEV-Infrastructure-Cost-Effectiveness-Report-2016.pdf

41 www.cityofaspen.com/DocumentCenter/View/243/Title-8-Buildings-and-Building-Regulations-1-2-PDF

42 drive.google.com/file/d/1sM2Y_ttE1vvVQrGbfdjxyY8DPiO4v4oL/view

43 assets.bouldercounty.org/wp-content/uploads/2017/03/building-code-2015.pdf

44 www.menlopark.org/DocumentCenter/View/14341/Staff-Handout---H6

Further, **TABLE 11** and **TABLE 12** indicate that the charging stations can be installed by building type. For example, Denver's new construction codes will likely include the following[45]:

- At least one EV ready space in every parking garage for single family homes and townhomes
- Charging stations in multifamily parking
- Commercial/workplace and parking lot/garage charging.

TABLE 11. Multifamily **Electric Vehicle** Infrastructure Denver Code Requirements (proposed in 2019 and passed in 2020)

	Number of EV Ready Spaces	Number of EV Capable Spaces	Number of EVSE Installed Spaces
1 space	1	None	None
2–9 spaces	1	20% of space	None
10 or more spaces	15% of spaces	Remainder of spaces	5% of spaces

TABLE 12. Commercial and Parking Garage **Electric Vehicle** Charging Infrastructure Denver Code Proposed Requirements

	Number of EV Ready Spaces	Number of EV Capable Spaces	Number of EVSE Installed Spaces
1 space	1	None	None
2–9 spaces	1	1	None
10 or more spaces	10% of spaces	10% of spaces	5% of spaces

Including Charging Infrastructure in Energy Plans and Design Guidelines

Once a district energy planner understands future EV growth projections, current and pending EVSE codes, and district EVSE infrastructure needs, then the EV capable, EVSE installed, and EVSE ready outlet provisions should be included in the parking design guidelines and transportation/mobility sections of the district's master plan. EVSE infrastructure requirements can be applied as a percentage of total parking spaces for each of the primary EVSE locations types:

- Single family/townhomes
- Multifamily and apartments
- Commercial office/workplace
- Retail and other commercial buildings
- Public shared parking lot spaces.

The following are examples from the Southwest Energy Efficiency Project of how EVSE requirements have been specified for inclusion in design standards and master plans[46]:

> *5% of total parking spaces are to be EV-capable for commercial building parking lots with more than 10 parking spaces*

or

> *Newly constructed one- or two-family dwellings and townhouses with a dedicated attached or detached garage shall facilitate future installation and use of electric vehicle chargers. For each dwelling unit, a Level 2, 40-amp minimum 208/240-volt individual branch circuit raceway shall be installed. The raceway shall originate at the main service or subpanel and shall terminate into a listed cabinet, box or other enclosure in close proximity to the proposed location of the electric vehicle charger.*

45 www.denvergov.org/content/dam/denvergov/Portals/696/documents/Denver_Building_Code/2019-code-update/iecc/P129_IECC-IRC_Chapter2_EVReady.pdf

46 www.swenergy.org/cracking-the-code-on-ev-ready-building-codes. Note that the Southwest Energy Efficiency Project's model EVSE residential and commercial codes provide further details for planning EVSE infrastructure in design guidelines and master plans.

Plug-in **electric vehicle** charging stations for staff at Alliant Energy in Madison, Wisconsin.

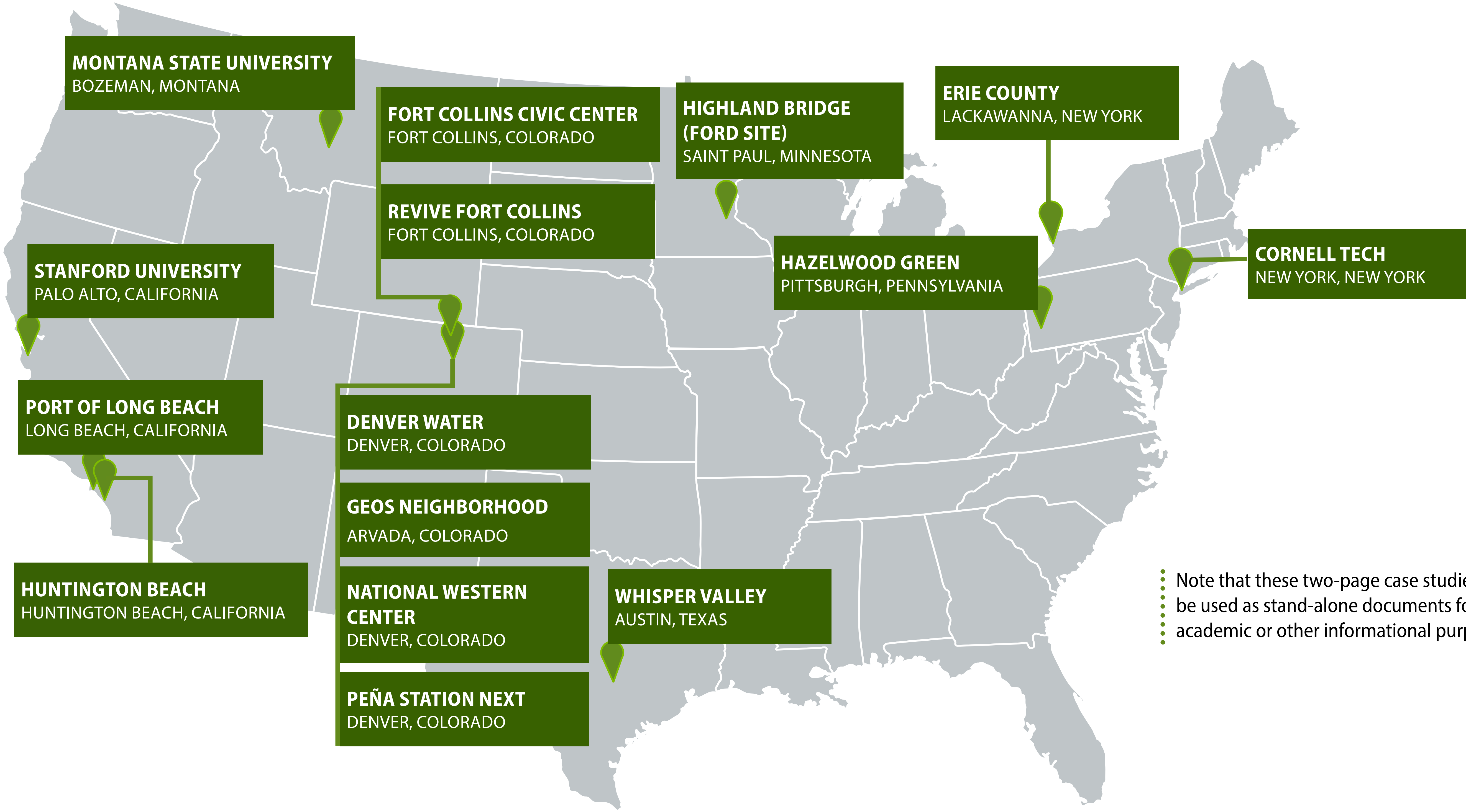
Photo from Alliant Energy, NREL 41419

CHAPTER 10

HIGH-PERFORMANCE DISTRICT CASE STUDIES

The rooftop solar photovoltaic system on the Mill 19 building at Hazelwood Green provides occupants with filtered daylight as well as power.

Photo from Ashley Koltonski, Cushman & Wakefield/Grant Street Associates, Inc.



Note that these two-page case studies can be used as stand-alone documents for academic or other informational purposes.

Photo from Lucas Blair Simpson for SOM

Cornell Tech

New York, New York

CASE STUDY

Location: **Roosevelt Island, New York, New York**

Size: **12.4 acres**[1]

Building/space types: **Educational (classrooms, instructional labs, lecture hall, huddle rooms, collaboration areas, conference rooms, cafe, open work areas, and shared spaces)**

Building area: **2 million square feet**

Master plan: **Skidmore, Owings & Merrill**

Master architect: **Skidmore, Owings & Merrill**

Urban design and site planning: **James Corner Field Operations**

Master developer: **Forest City Ratner Corporation**

Housing developer: **Hudson and the Related Companies**

Development strategy: **U3 Advisors**

Mechanical, electrical, and plumbing engineering: **AKF**

Structural engineering planning: **Robert Silman**

Civil and transportation engineering: **Philip Habib & Associates**[2]

Certifications, awards, standards:

- **Buildings built to LEED, Passive House, and zero energy standards**
- **Urban Land Institute, Finalist in Awards for Excellence in Development, 2019**
- **Society of American Registered Architects National Design Awards, 2019**
- **American Institute of Architects Regional & Urban Design Award,[3] 2020**

1 americas.uli.org/awards/cornell-tech-campus-framework-plan-and-phase-i-site-development-2019-global-awards-for-excellence-finalist/
2 Master architect through civil and transportation engineering: www.aia.org/showcases/6246330-cornell-tech-campus-framework-plan
3 www.architectmagazine.com/project-gallery/cornell-tech-campus-framework-plan_o

Description

The Cornell Tech campus is pioneering a new model for higher education in the United States. Located on Roosevelt Island in New York City, the campus is designed to encourage interactions between industry and academia rather than consign them to their respective silos. In addition to academic buildings, the development includes corporate colocation, offices, a hotel, a residential tower, and conferencing and assembly areas, with space remaining to accommodate future program requirements.

The campus is designed to be resilient and sustainable, with on-site energy generation and buildings built to LEED, Passive House, and **zero energy** standards. A New York City Economic Development Corporation analysis projected that the campus will generate more than $7.5 billion in economic activity and spur $23 billion in overall economic activity in the next 30 years. When fully built out, the campus will include 2 million square feet of state-of-the-art buildings and more than two acres of open space. It will also accommodate more than 2,000 graduate students and hundreds of faculty and staff.

At least one building, the 160,000 square foot Bloomberg Center, which opened in September 2017, is expected to achieve **zero energy** status, and the adjacent Bridge building will host additional solar photovoltaics to help The Bloomberg Center meet that goal. In addition, the first residential building on campus is also the world's first high-rise Passive House building. The Passive House designation requires that the building operate at a site **energy use intensity** of no more than 38.1 kBtu/ft^2·yr.

Cornell Tech is a partnership between the Technion-Israel Institute of Technology and Cornell University. The partnership secured the site by winning a New York City competition for the development of a campus on Roosevelt Island.

Project status (as of October 2020)

Three buildings—Tata Innovation Center, the House, and the Bloomberg Center—opened in September 2017 and the Verizon Executive Education Center and Graduate Hotel could be finished as soon as late 2020.[4] Campus build-out is projected to be complete by 2037.[5]

Key energy opportunities

The Bloomberg Center (**energy use intensity** of 29.3 kBtu/ft^2·yr[6]), the first academic building on the Cornell Tech campus and its main academic hub, is expected to be a **zero energy** building.
Features include[7]:

All-electric building: No fossil fuel is used in the building.

Ground source heat pump system wells: 80 closed-loop ground source heat pump system wells, each 400 feet deep, were drilled below the main campus public open space. The electrically powered ground source heat pumps are used to heat and cool the building in conjunction with an active chilled-beam system

Solar power: An acre-sized solar photovoltaic array on the roofs of The Bloomberg Center and the neighboring Bridge building generates solar power. Instead of locating solar systems off-site, The Bloomberg Center and The Bridge incorporate the panels as an integral design feature. The array on The Bloomberg Center provides shading while harvesting solar power.

Highly insulated façade: A unitized, continuously insulated rainscreen wall system covered by an iconic metal panel façade designed by Morphosis architects balances exterior views and daylight while maximizing façade insulation.

Smart building technology: Smart building features, designed by Morphosis and engineering firm Arup, links lighting control, occupancy sensors, security, and other building controls to provide on-demand power, respond to user needs and occupancy, and reduce energy use.

Green roof: A low-maintenance green roof incorporates native plant species along the southeast edge of the building to help cool the lower roof surface.

Innovative strategies

Cornell Tech began as an initiative of former New York City Mayor Michael Bloomberg's administration to make New York a tech innovation hub.[8] From the beginning of the process, the focus was on a **zero energy** development, with on-site renewable energy production to offset campus energy use. The early **zero energy** focus informed project participants' decision making as the development progressed. The district master plan included ensuring optimal solar access and locating the tallest buildings on the north side of the site so they do not shade other buildings within the district.

4 newyorkyimby.com/2020/08/exterior-work-finishes-on-verizon-executive-education-center-and-graduate-hotel-on-roosevelt-island.html
5 en.wikipedia.org/wiki/Cornell_Tech#Phase_1
6 www.arup.com/perspectives/publications/the-arup-journal/section/the-arup-journal-2018-issue-1, page 44; 31.9 according to NBI newbuildings.org/wp-content/uploads/2019/02/2019_SchoolsWatchlist.pdf, p. 12
7 tech.cornell.edu/news/cornell-tech-on-path-to-reach-net-zero-at-the-bloomberg-center/
8 www.arup.com/perspectives/publications/the-arup-journal/section/the-arup-journal-2018-issue-1, page 43

Photo from Frank Ooms for Denver Water

Denver Water

Colorado

CASE STUDY

Location: **Denver, Colorado**

Size: **34.6 acres**[1]

Building/space types[2]: **Administration building, equipment shops, fleet maintenance, warehouses, trade buildings, parking garage, and wellness building**

Building area: **345,000 square feet**[3]

General contractor: **Mortenson**[4]

Delivery method:
Construction manager at risk[5]

Architect: **Stantec**

Owner: **Denver Water**

Owner representative: **Trammell Crow**[6]

Master planner:
Stantec and Integral Group

Certifications, awards, standards:
Zero energy, LEED Platinum, One Water standards

1 www.denverwater.org/project-updates/denver-waters-operation-complex-redevelopment-project
2 www.denverwater.org/project-updates/denver-waters-operation-complex-redevelopment-project
3 www.stantec.com/en/projects/united-states-projects/d/denver-water-operations-complex-redevelopment
4 www.mortenson.com/denver/projects/denver-water-operations-complex-redevelopment
5 www.mortenson.com/denver/projects/denver-water-operations-complex-redevelopment
6 www.denverwater.org/project-updates/denver-waters-operation-complex-redevelopment-project

Description

Denver's water utility operations have been located on the same site since 1881 and an update was overdue. That update began in 2016 and was largely completed in 2019; the remaining work is expected to be complete by fall 2020.

The new Denver Water Operations Complex is a showcase of energy efficiency and **resilience** strategies. The redevelopment includes eight new structures (seven buildings and a parking garage) as well as the renovation of the existing water distribution building and the historic Three Stone Buildings.[7] Eight of those buildings will be LEED-certified at levels ranging from Silver to Platinum. The administration building as well as the four new operations-based buildings—the warehouse, fleet services, trade shops, and meter shop—use radiant tubing in the floors for cooling and heating to reduce energy use and increase thermal comfort. An innovative central utility plant for the complex uses a large potable water distribution main as a heat source and heat sink, depending on the season.[8]

7 www.mortenson.com/denver/projects/denver-water-operations-complex-redevelopment
8 denverwatertap.org/2019/04/15/building-for-the-future-on-a-sustainable-foundation/

Furthermore, the administration building is targeting **zero energy** and One Water, a first of its kind holistic low water use strategy; rainwater capture; and an on-site water recycling initiative that expands local water law for more aggressive conservation strategies. The redeveloped campus will be more accessible to the public, with increased public outreach and water and energy educational resources.

Project status (as of October 2020)[9]

The first phase of construction began in 2016 with a focus on the operational facilities. The second phase, which was substantially completed in October of 2019 and finalized in October of 2020, focuses on the **zero energy** administration building, the parking garage, and the Three Stone Buildings.

Key energy opportunities

- Administration building designed to operate at an **energy use intensity** of 26 kBtu/ft^2·yr and pursuing **zero energy** and LEED Platinum certification
- Campus as a whole designed to have an **energy use intensity** of 25 kBtu/ft^2·yr, a step toward achieving the campus stretch goal of **zero energy**
- District hot water and chilled water district system linked to a central heat pump system connected to city potable water supply provides a free cooling resource
- More than 85% of the workspaces will have natural light during the day, and lighting controls adjust based on the amount of daylight coming through the windows and turn lights off when they are not needed[10]
- Rooftop solar photovoltaic systems on the administration building (290 kW) and the parking garage (690 kW).

Innovative strategies

- Design using health and wellness strategies included in WELL Building standards [11]
- Commit to One Water principles, which are strategies to manage water more holistically by shifting from the separate management of drinking water, wastewater, stormwater, and water for the environment to water management that provides multiple benefits[12]
- Analysis of energy-water nexus for the administration building to quantify energy savings from water system and water savings from energy systems
- Water used for distribution of thermal energy (radiant slabs and central utility plant), but no water evaporated for cooling.

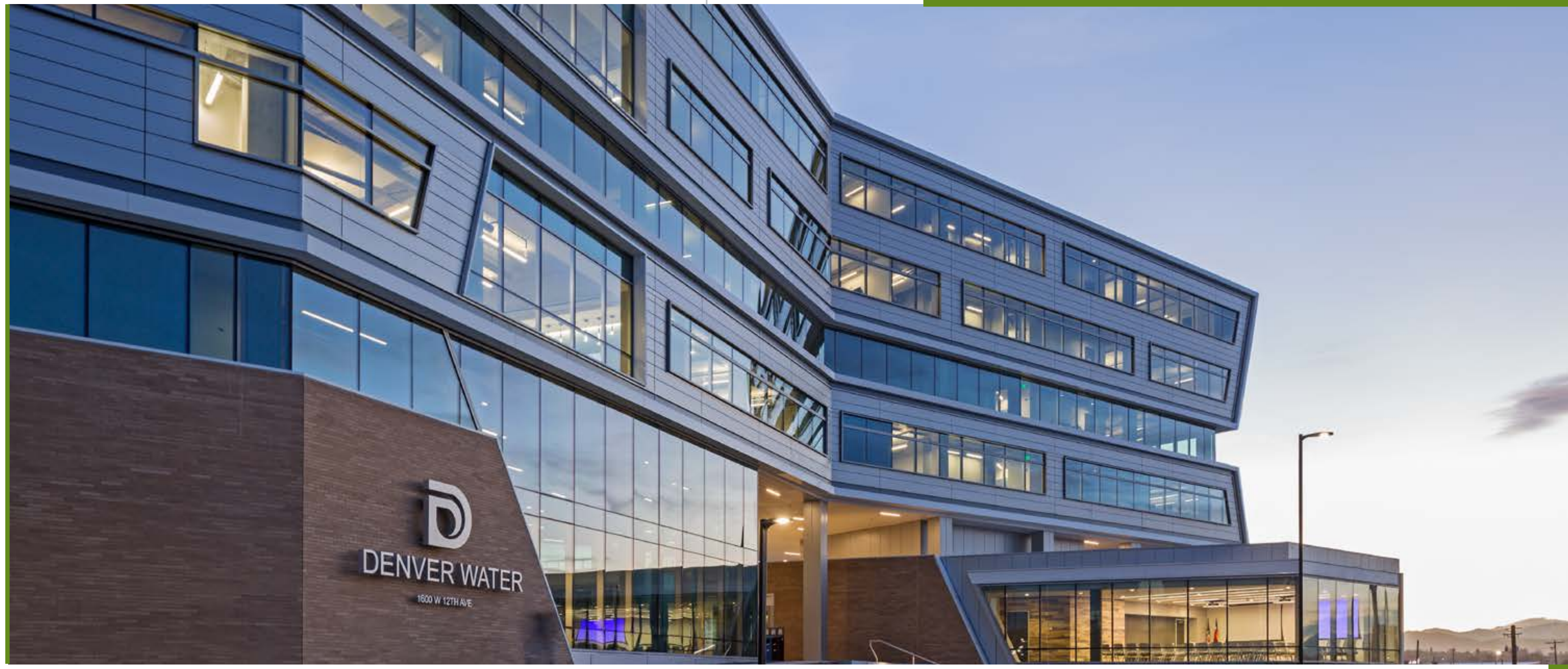
Links to additional materials

Master plan

- Energy Master Plan[13]

Denver Water's new six-story, 186,000-square-foot administration building is targeting LEED-NC Platinum certification and **zero energy** status.

Photo from Frank Ooms for Denver Water



9 www.denverwater.org/project-updates/denver-waters-operation-complex-redevelopment-project
10 denverwatertap.org/2019/04/15/building-for-the-future-on-a-sustainable-foundation/
11 www.wellcertified.com
12 ensia.com/features/one-water/
13 drive.google.com/open?id=1H5pBZDdcz3W7Ye9lroYJ8aAdm_gy-Q1I

Rendering from Graphic by HGA, ELEMENTA, and C&S Companies

Erie County

New York

CASE STUDY

Location: **Lackawanna, New York**

Size: **148 acres of industrial brownfield**

Building/space types**:**
Class A manufacturing and commercial office

Building area: **93,000 ft^2 for first building (manufacturing and commercial zero energy facility); total district area to be determined**

Owner(s): **Buffalo & Erie County Industrial Land Development Corporation, a 501(c)(3) nonprofit**

Architect: **HGA**

Engineer & energy consultant: **Integral Group**

Mechanical & energy engineering: **ELEMENTA**

Site & civil engineering: **C&S Companies**

Contractor (through design): **Turner Construction**

Site master planning consultant: **AECOM**

Delivery method: **Initially construction manager at risk, but due to funding delays the final delivery method expected to be design/bid/build**

Anchor tenant:
Interest from two potential manufacturing tenants

Funding source(s): **Grants, brownfield cleanup program, loans, partnerships, opportunity zone funding (a federal program designed to attract investment with capital gains benefits after a defined number of years)**

Certifications, awards, standards: **The initial building is designed to achieve "zero or better" in several sustainability categories: energy, carbon, water, waste, materials, and value**

Description

In 2017, the Erie County Industrial Development Agency acquired approximately 148 acres of the 994-acre Bethlehem Steel Redevelopment Area, the largest brownfield in the Buffalo, New York, region of western New York. The first project planned for the district is a large, **zero energy** light industrial manufacturing and commercial **zero energy** facility that will serve as a model to attract more **zero energy** development.

This initial building will advance sustainable building design and construction and tell a story of **resilience**, urban and industrial regeneration, and innovation. The building will feature approximately 93,000 ft^2 of mixed-use manufacturing and commercial office space and will be powered by solar, geothermal, and wind energy to produce as much energy as it consumes on an annual basis.

As the first certified **zero energy** manufacturing facility of its size in the state of New York, the project will be a state-of-the-art, dynamic facility that showcases new advances in **zero energy** design and construction. It will serve as a hub for construction education and performance testing, energy management, and workforce training for the remaining district build-out as well as the larger western New York region.[1] Located at the east end of Lake Erie and the southern border of the city of Buffalo, the site has easy access to Canada, all major highways, and mainline rail service.

The facility will be located at the north end of the site and serve as an example of sustainable building design and operations, allowing the manufacturers to—ideally—produce their products without incurring energy costs. There will be energy bills at times and energy credits at times that should zero out on an annual basis. Leases will include agreed-upon energy costs for each tenant; if they exceed that amount they will be charged for the overage to cover the expense of purchasing additional renewable energy and a noncompliance fee designed to encourage all parties to strive for usages at or below the agreed upon amount. The end goal is to operate at **zero energy** and to attract other sustainable development at the north end of the site.

Project status (as of October 2020)

Ready to begin the construction document stage for the initial building; a local development partner has been secured for the initial building and fundraising for project construction is underway.

Key energy opportunities

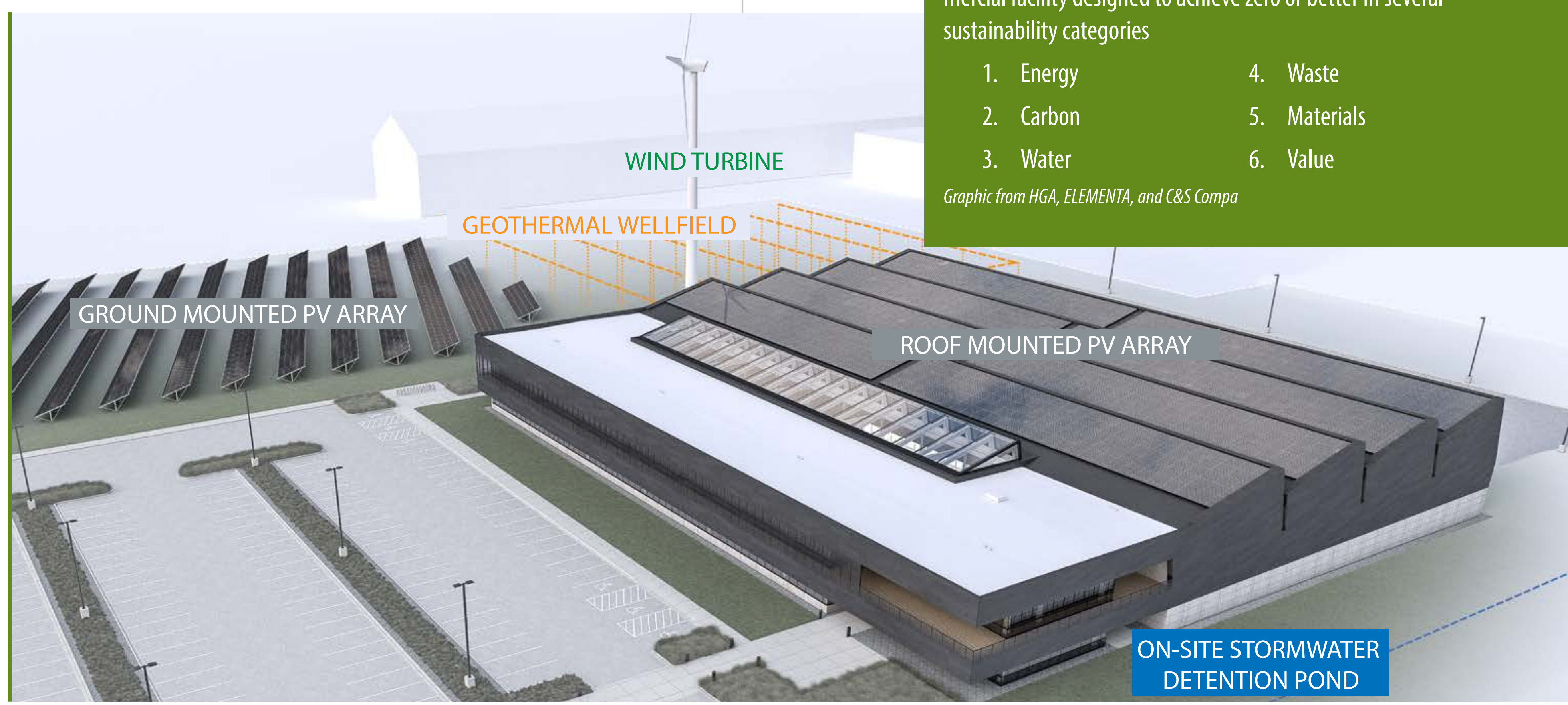
- Pursuing **zero energy** for light manufacturing building, with **zero energy** leases for tenants
- Using the initial **zero energy** light manufacturing building as a model project to demonstrate **zero energy** approaches
- Considering the potential for on-site wind because of the proximity to Lake Erie.

Innovative strategies

- Highlight innovative strategies employed on this project (e.g., leveraged commercial property-assessed clean energy [CPACE] to finance up-front cost of **zero energy** commercial buildings; public/private partnership)
- Use **zero energy** light manufacturing as the initial project to attract funding for more **zero energy** development
- Use **zero energy** lease language to ensure tenants are aware of projected plug load levels necessary to achieve **zero energy**.

Links to additional materials

- Net zero flyer[2]
- Erie County opportunity zone prospectus.[3]



A **zero energy** light industrial manufacturing and commercial facility designed to achieve zero or better in several sustainability categories

1. Energy
2. Carbon
3. Water
4. Waste
5. Materials
6. Value

Graphic from HGA, ELEMENTA, and C&S Compa

1 www2.erie.gov/exec/index.php?q=press/bethlehem-steel-agreement-heralds-new-age-historic-lackawanna-site
2 www.ecidany.com/documents/z7%20flyer042617.pdf
3 buffaloniagara.org/properties/opportunity-zones/

Graphic from RNL Design now Stantec

Fort Collins Colorado Civic Center

CASE STUDY

Location: **Fort Collins, Colorado**

Size: **Approximately 13.5 acres**

Building/space types: **Office, retail, multifamily residential**

Building area: **300,000 ft² of programmed building area (plus parking garages and future private development)**

Architect: **RNL Design (now Stantec) and AU Workshop**

Landscape Architect: **Logan Simpson Design**

Civil Engineer: **Northern Engineering**

Workshop Facilitation: **Institute for the Built Environment**

Energy Consultant: **Integral Group**

Mechanical, Plumbing, and Electrical Engineer: **MKK Consulting Engineers**

Certifications, awards, standards: **LEED v4 Platinum, zero energy ready**

Description

The Fort Collins Civic Center project envisions the creation of a **zero energy** campus for city government buildings that supports Fort Collins' sustainability and carbon emissions goals and provides healthy, comfortable, welcoming indoor and outdoor spaces for employees and residents. The city intends to reduce carbon emissions compared to 2005 levels by 20% by 2020, 80% by 2030, and 100% by 2050.

The master plan includes two downtown city blocks with some existing city government buildings in place and a master plan for the development of key city buildings and functions to be relocated to the new civic center site within the context of the downtown plan and design standards. A new city hall is the focal point of the two-block master plan.

The development of the **zero energy** district goal was integrated with the urban design and master planning process for the civic center. A 3-day planning **charrette** with project stakeholders was a key part of the integrative process. Research was conducted in preparation for the **charrette** that identified the program functions and areas for the civic center plan, but also energy use and energy generation targets for the program. In addition, site and climate considerations were analyzed and documented. Using this preparatory research, the **charrette** participants were able to cocreate an urban design concept for the two-block site that captured the civic character of Fort Collins, while also enabling the **zero energy** district goal.

The massing, orientation, and siting of the building's master plan enables individual buildings to use passive design strategies such as daylighting and natural ventilation. The mass and heights of the buildings provided enough roof area for solar photovoltaics to offset the overall energy use target for the civic center. The key urban planning feature of the site is an oval shaped civic green at the center of the two-block site. This civic green mirrors in form the green oval at the Colorado State University's campus that is directly south of the civic center. It provides a needed public gathering space for downtown Fort Collins as well as a site for a district ground source heat pump loop field, which will be located under the civic green. The plan also allows for electrical connections of multiple buildings so that they can operate as a **microgrid** with shared distributed energy resources during disruptive events.

Project status (as of October 2020)

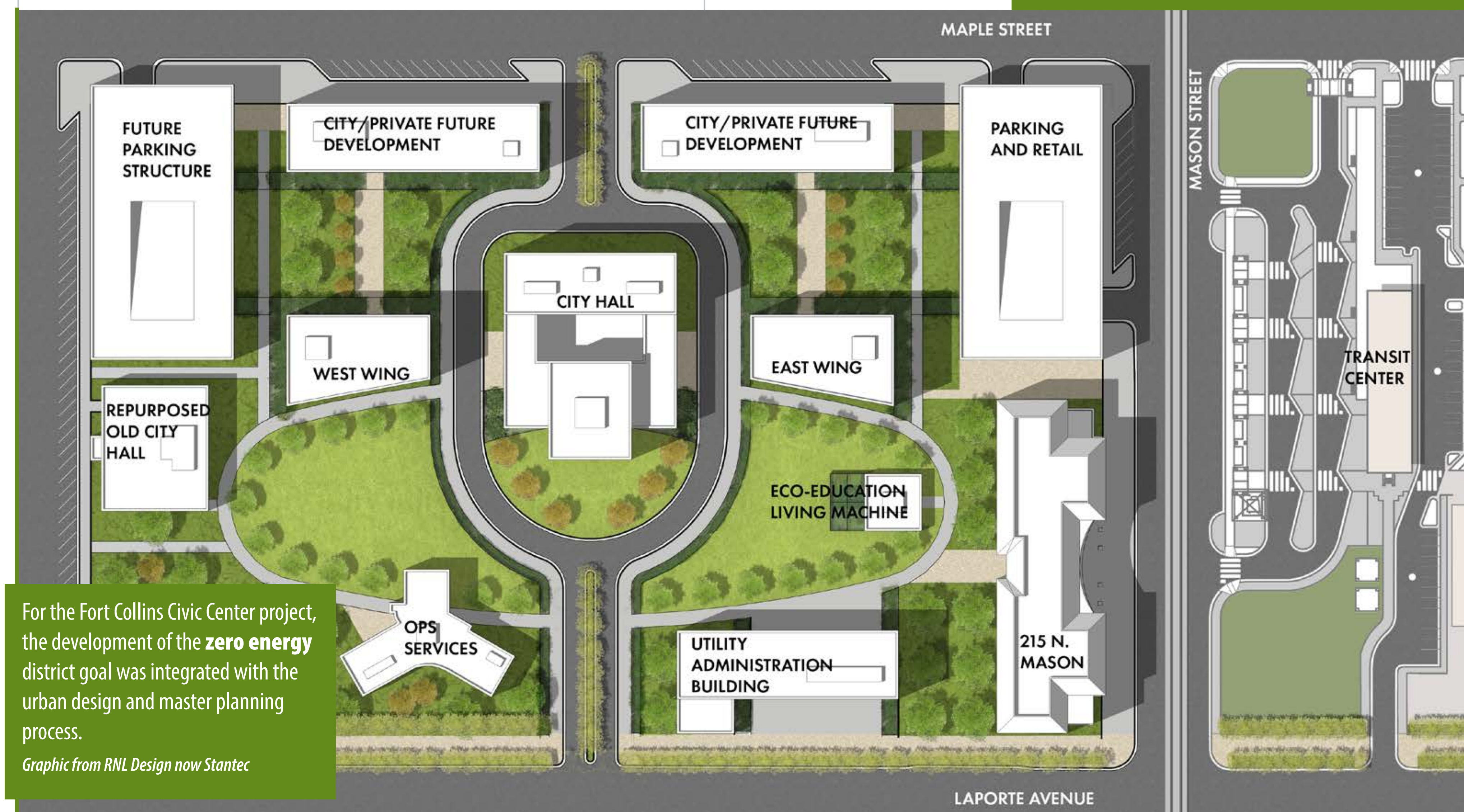
TThe first new building constructed on the civic center was the Fort Collins Utility Administration Building. Completed in 2016, this 37,500 ft^2 building was designed to allow future integration of a district ground source heat pump system. Energy strategies include building orientation, daylighting, a high-performance envelope, LED lighting, distributed water-loop heat pumps and energy recovery ventilation, high efficiency building transformers, energy monitoring, and on-site solar photovoltaics. An energy storage system was added in early 2020. The building is LEED v4 Platinum, **zero energy** ready, and operating at a measured 26.2 kBtu/ft^2·yr.

Key energy opportunities

- Building orientation and massing
- Passive design strategies
- High-performance envelope
- Energy targets per building
- Roof-mounted solar photovoltaics.

Innovative strategies

- Integrated design approach
- Integration of urban design and energy principles
- District ground source heat pump system ready
- Planning for **microgrid** and energy storage.



For the Fort Collins Civic Center project, the development of the **zero energy** district goal was integrated with the urban design and master planning process.

Graphic from RNL Design now Stantec

Photo from Philip Wegener for Geos Neighborhood

Geos Neighborhood

Arvada, Colorado

CASE STUDY

Location: **Arvada, Colorado**

Size: **25 acres**[1]

Building/space types: **A mix of single family homes, rowhomes, townhomes, duplexes, condos, a cohousing building, and small retail**

Building area: **Mixed use residential, with up to 250 dwelling units (100 detached, 100 attached, and 50 condos) at build-out**

Master developer: **Norbert Klebl**

Building technologies specialist: **Sustainably Built, Adam Stenftenagel**

Architect/landscape architect: **Sun Studio; Michael Tavel AIA, David Kahn ASLA**

Civil engineer: **JeHN Engineering**

General contractor: **Cornerstone Homes**

Certifications, awards, standards: **All homes certified by RESNET® (Residential Energy Services Network) HERS® (Home Energy Rating System) certified**

1 discovergeos.com/wp-content/uploads/2014/03/Tavel-GeosArticle-2010.04.30-PortlandUrbanResearchLab.pdf

Description

The Geos Neighborhood combines traditional neighborhood living with advanced sustainable design and building practices. Community members enjoy a pedestrian lifestyle with front porches, tree-lined sidewalks, community gardens, fruit trees, corner stores, and neighborhood services. The plan is to leave 40% of the site as green space and protect the 100-year-old trees on the property during construction. Mixed use zoning allows small home businesses to operate within the neighborhood. The neighborhood is laid out to make the best use of Colorado's climate and environment. It is designed to take advantage of solar gains in the winter and minimize exposure to the sun in the summer. Walls and windows are so tight, and appliances so energy-efficient, that rooftop solar photovoltaic systems provide all the power needs of the homes and can also charge electric cars as needed. Dwelling units are built to many Passive House standards, are HERS® certified, and have very small heating and cooling loads. Depending on the size of the unit, those loads are met with a combination of a CERV (conditioning energy recovery ventilator), geothermal technology, mini-split air source heat pump, and a heat pump water heater. The cost of Geos' Energy Plus homes is comparable to conventional homes. During the first 3 years these homes were occupied, they have consumed only 25% of the energy of ENERGY STAR®-certified homes.

Geos Neighborhood in Arvada, Colorado, is designed to take advantage of solar gains in the winter and minimize exposure to the sun in the summer.

Photo from Philip Wegener for Geos Neighborhood

Project status (as of October 2020)

Phase 1 in Block 10 includes 37 homes (13 single family homes and 24 homes with at least one shared wall). Only nine more homes are to be built in this phase, and the entry building will have a ground-level commercial space occupied by a coffee shop. The next phase of four future blocks across the street will include 40 detached homes and 47 attached homes.

Key energy opportunities

- **Zero energy** homes that have proven to produce surplus energy based on EnergyPlus™ models)
- Very tight building envelopes
- Passive solar design
- Solar photovoltaics
- Ground source heat pumps
- Air source heat pumps
- Heat pump water heaters
- Very energy-efficient appliances and lighting.

Innovative strategies

- All homes certified by the Residential Energy Services Network (RESNET®) Home Energy Rating System (HERS®)
- "Checkerboard" neighborhood layout offsets buildings from one another, providing each building with solar exposure where it is needed and preventing unwanted shading of solar photovoltaic systems and passive solar features
- Homes incorporate many Passive House principles,[2] but will not be certified to control costs.

Links to additional materials

Master plan

- Master Declaration of Covenants, Conditions, and Restrictions of Geos Neighborhood[3]
- District Energy Master Plan[4]
- District Energy Strategies[5]

2 discovergeos.com/passve-house-priniciples/
3 discovergeos.com/wp-content/uploads/2016/02/Geos-Declaration-2-8-16-1.pdf
4 drive.google.com/open?id=18wSRMMc4p8Q-KasE97kY8-xisvhvhsa9
5 drive.google.com/open?id=1w-YbzD9bBnpxQ7-jZBGMWTda_E0rLJvz

RIDC's Mill 19 at Hazelwood Green comprises three buildings within the superstructure of a former steel rolling mill.

Photo from Ashley Koltonski, Cushman & Wakefield/Grant Street Associates, Inc.

Hazelwood Green

Pittsburgh, Pennsylvania

CASE STUDY

Location: **Pittsburgh, Pennsylvania**

Size: **178 acres**[1]

Building/space types: **Light industrial, office, residential, retail**

Building area at build-out: **6–10.7 million square feet**

Primary landowner (165 acres): **Almono LP**[2]

Site manager: **Almono LLC**[3]

Project director and site manager authorized agent: **U3 Advisors**[4]

1 drive.google.com/file/d/1G7_0TCE9ZsvmlSasZt_UYeKQcm_2eTGz/view
2 www.hazelwoodgreen.com/owners
3 www.hazelwoodgreen.com/owners
4 www.hazelwoodgreen.com/owners

Mill 19

Developer and landowner (13 acres): **Regional Industrial Development Corporation (RIDC)**

Master architect (core and shell, all phases): **MSR Design, Minneapolis, Minnesota**

Building A interiors: **Renaissance 3 Architects, Pittsburgh, Pennsylvania**

Building B Interiors: **Desmone Architects, Pittsburgh, Pennsylvania**

Engineering (core and shell, all phases): **BALA and BALA Structures**

General contractor (site work and core/shell Building A): **Turner Construction Company**

General contractor (core/shell Building B): **Jendoco Construction Corporation**

Solar contractor: **Scalo Solar Solutions**

Plaza designer: **Gustafson Guthrie Nichol**

Roundhouse designer: **GBBN**

Certifications, awards, standards: **Hazelwood Green is being built to LEED-ND, Living Community Challenge, WELL Community, and Pittsburgh's p4 Performance Measures standards.**

Mill 19, the first phase of the Hazelwood Green development, is expected to achieve LEED Gold certification. Awards for Mill 19 (as of September 2020) include:

- Best Office/Retail/Mixed Use Project, Engineering News Record Mid Atlantic, 2020
- Placemaking Award for Visionary Excellence, Urban Land Institute Pittsburgh, 2019
- National Association of Industrial and Office Partners Pittsburgh, Green Building Award, 2019
- March of Dimes Pittsburgh, Building Project of the Year, 2020.

The Roundhouse is pursuing LEED Gold certification.

Description

The mixed use development of Hazelwood Green, a riverfront property along the Monongahela River in Pittsburgh, Pennsylvania, is based on four principles—advancing human well-being, regenerating the local ecology, inspiring innovation, and creating resilient spaces. The site was originally named Almono after the first syllables of Pittsburgh's rivers—the Allegheny, Monongahela, and Ohio.

As part of the effort to regenerate this brownfield site and create a resilient neighborhood, the owner, Almono LP, aspires to **energy positive** building performance site-wide. In support of the **energy positive** goal as well as the principle of creating resilient spaces, Hazelwood Green features on-site renewable energy systems.

Mill 19, the first phase of the development, comprises three buildings (A, B, and C) built within the skeleton of a former Jones and Laughlin steel mill. The building includes a rooftop solar photovoltaic array that, as of summer 2020, was the largest single-sloped solar array in the country.[5] Buildings A and B are complete and Building B is fully leased. Owner RIDC is in the process of leasing the remaining 20,000 square feet of Class A office space. Building C is in design and will have more than 100,000 additional square feet when complete.

The Plaza is an outdoor public space designed to be the civic heart of Hazelwood Green, incorporating local artists' work as well as materials recycled from the steel mill. Its solar canopy will generate power for the site and provide visitors with shade and protection from the elements.[6] A tree nursery is also planned. The Plaza is under construction and expected to be completed in fall 2020.

The Roundhouse, built in 1887 to turn and stabilize railroad engines to be serviced, is being remodeled into a technology accelerator and coworking space.[7] The building is designed to achieve LEED Gold certification and is expected to be occupied in 2021.

The development plan is flexible to accommodate future uses and market changes. Planners anticipate that, given the range of potential densities and intensity of uses, the total building area at build-out will be between 6 and 10.7 million square feet. To meet its sustainability goals, Hazelwood Green is pursuing LEED-ND Plan certification. In addition, the project will exceed LEED-ND requirements by integrating elements of the Living Community Challenge and the WELL Community Standard as well as Pittsburgh's own p4 Performance Measures[8] into the process of evaluating development proposals.

Project status (as of October 2020)

Mill 19 Buildings A and B are complete and Building C is in design. The Plaza is expected to be completed in fall 2020 and the Roundhouse should be completed in 2021.[9]

Key energy opportunities

The owners' plan is to make Hazelwood Green a national model for district energy integration. The primary site owners have not yet chosen a master developer, but some of the possible development strategies include:

- Procuring an integrated energy services provider that will be responsible for delivering financed building efficiency retrofits, district heating and cooling systems, and renewable energy
- Exploring a combination of biomass, ground source heat pump, solar, wind, **microgrid**, and electrical storage technologies at the building and site-wide scale
- Metering each building and tenant for heating, cooling, electrical energy, and renewable energy
- Implementing solar photovoltaic installations across the site's rooftops and several common areas and pursuing off-site renewable energy only if the site's **energy use intensity** becomes too high to reasonably offset with on-site renewables.

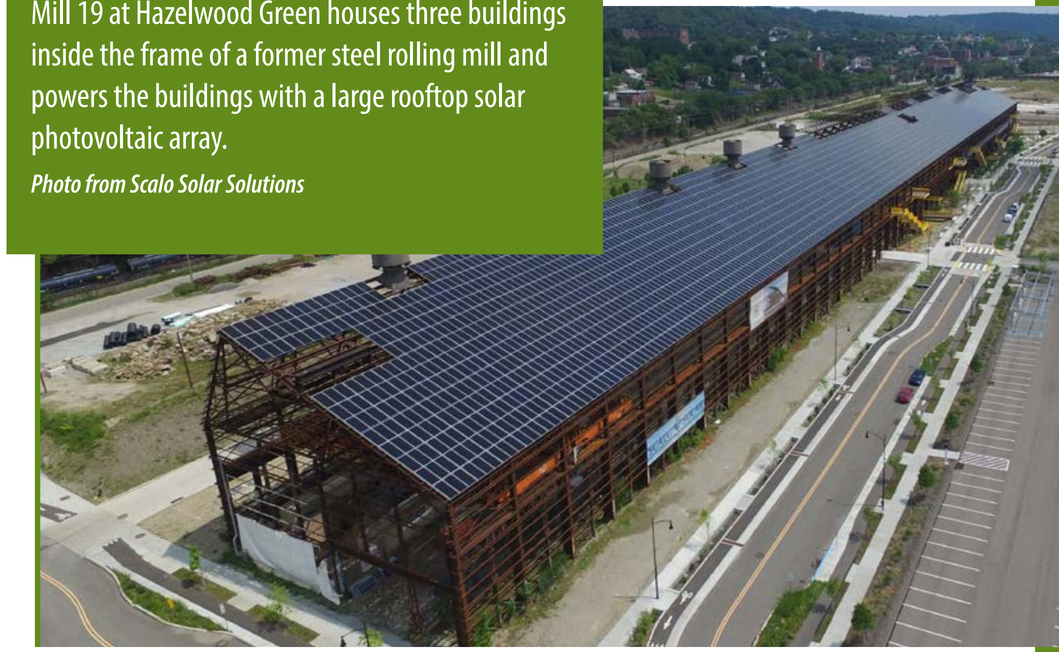
The specifics of the energy systems will be developed by the integrated energy services provider, in collaboration with the master developer and Almono LLC, the site manager.

Innovative strategies

To meet its sustainability goals, Hazelwood Green is pursuing LEED-ND certification. In addition, the development will exceed LEED-ND requirements by integrating elements of the Living Community Challenge and WELL Community Standard as well as Pittsburgh's own p4 Performance Measures[10] into the process of evaluating development proposals. Almono LLC will track the site's actual performance over the course of development and build-out using a combination of these standards and goals.

Links to additional materials

- Master plan—Hazelwood Green: Preliminary Land Development Plan[11]



Mill 19 at Hazelwood Green houses three buildings inside the frame of a former steel rolling mill and powers the buildings with a large rooftop solar photovoltaic array.

Photo from Scalo Solar Solutions

5 www.scalo-solar.com/project/mill-19/
6 www.hazelwoodgreen.com/the-plaza
7 www.gbbn.com/news/the-future-of-the-historic-roundhouse-revealed/
8 p4pittsburgh.org/media/W1siZilsIjIwMTgvMDIvMDUvMmg1ZmptcWQ2dV9wNF9QZXJmb3JtYW5jZV9NZWFzdXJlc18yMDE4LnBkZiJdXQ/p4_Performance_Measures_2018.pdf
9 www.hazelwoodgreen.com/site
10 p4pittsburgh.org/media/W1siZilsIjIwMTgvMDIvMDUvMmg1ZmptcWQ2dV9wNF9QZXJmb3JtYW5jZV9NZWFzdXJlc18yMDE4LnBkZiJdXQ/p4_Performance_Measures_2018.pdf
11 www.dropbox.com/s/7xu9s3p609j014m/HGPLDP_08.30.2018_Approved.pdf?dl=0

Rendering from Ryan Companies

Highland Bridge (Ford Site)

Saint Paul, Minnesota

CASE STUDY

Location: **Saint Paul, Minnesota**

Size: **122 acres**

Building/space types:
Limited single-family residential; small, medium, and large multifamily residential; office; retail; civic; limited industrial

Building area: **Approximately 415,000 square feet plus approximately 3,800 dwelling units**

Master developer: **Ryan Companies**

Description

Highland Bridge (also known as the Ford Site; renamed Highland Bridge by Ryan Companies in July 2020) is 122 acres of land along the Mississippi River and the former home of Ford Motor Companies' Twin Cities Assembly Plant. Over its lifetime, workers at the plant produced vehicles ranging from the Model T to armored vehicles and light tanks for use during World War II to the Ranger truck. After the closure of the plant was announced in 2007, the City of Saint Paul and multiple partners spent a decade engaging with the community, studying environmental impacts, and approving a final plan for the site's redevelopment.

Ryan Companies, as master developer of the site, has been charged with executing the city's plan of a new connected, livable, mixed use neighborhood with clean technologies and high quality design for energy, buildings, and infrastructure. Highland Bridge will be woven into the existing community; support walking, biking, and transit; and provide services, jobs, and activities that every generation can enjoy.

Highland Bridge will be developed with a goal of being a **zero energy** district. The vision for the site is a connected, livable, mixed use neighborhood that looks to the future with clean technologies. In addition to

zero energy, energy goals for the project include **resilience**, innovation, energy efficiency, and cost-effectiveness. The site will be redeveloped from scratch, starting with the installation of new utilities, streets, sewers, and water. This provides an unprecedented opportunity to design and install cutting edge technologies and systems appropriate to site conditions. Development of buildings on the site will proceed in phases, with total site build-out expected to take 12–20 years.

Project status (as of October 2020)

Infrastructure construction is underway and vertical development will begin in fall 2020.

Key energy opportunities

- Electricity from 100% carbon-free and renewable sources, including hydroelectric and the largest urban solar array (~1 MW) in the Twin Cities located adjacent to the site
- ENERGY STAR® and LEED certified row homes that offer an all-electric option
- Buildings that use an estimated 30% less indoor water and 50% less outdoor water than is typical
- Transit options that provide reduced or zero emission alternatives for residents
    - A minimum of 100 **electric vehicle** charging stations
    - All building entries within a quarter mile of public transit
    - Shared transport options such as a car sharing hub, scooters, and other modes of transit
    - 10 miles of pedestrian and bike paths as well as ample bike parking stalls and infrastructure.

Innovative strategies

- Compliance with the Saint Paul Sustainable Building Ordinance
- Reduction of energy consumption by 80% from baseline[1] through compliance with the SB2030 energy standard[2]
- LEED certification for all buildings, which requires setting **energy use intensity** targets as well as energy benchmarking and reporting
- Central stormwater system that aggregates the site's stormwater and treats it through a variety of elements including a two-acre central water feature combining recreation with passive water quality treatment and management.

Links to additional materials

- Saint Paul Sustainable Building Ordinance[3]
- Highland Bridge/Ford Site Zoning and Public Realm Master Plan[4]
- Highland Bridge/Ford Site Energy Study Report[5]
- Highland Bridge/Ford Site Energy Study[6]
- Highland Bridge/Ford Site: A 21st Century Community.[7]

The Highland Bridge development will feature electricity from 100% carbon-free and renewable sources.

Image from Ryan Companies

1 www.b3mn.org/wp-content/uploads/2017/07/SustainableBuilding2030factsheet.pdf
2 www.b3mn.org/2030energystandard/
3 library.municode.com/mn/st._paul/codes/code_of_ordinances?nodeId=PTIIIADCO_TITIVPOPR_CH81SUBU
4 www.stpaul.gov/sites/default/files/Media%20Root/Planning%20%26%20Economic%20Development/Ford%20Site%20Zoning%20and%20Public%20Realm%20Master%20Plan%20FINAL.pdf
5 www.stpaul.gov/sites/default/files/Media%20Root/Planning%20%26%20Economic%20Development/Ford%20Site%20Energy%20Study%20Report%20-%20FINAL%20and%20Appendices%2012-4-15.pdf
6 www.stpaul.gov/departments/planning-economic-development/planning/ford-site-21st-century-community/ford-site-energy
7 www.stpaul.gov/departments/planning-economic-development/planning/ford-site-21st-century-community

Photo by Dr. Laura Novoa, University of California, Irvine

Huntington Beach

California

CASE STUDY

Location: **Huntington Beach, California**

Size: **660 acres**

Building/space types: **Multifamily, community center, industrial, education, commercial**

Building area: **1.8 million square feet (estimated)**[1]

Prime contractor and manager[2]: **Advanced Power and Energy Program at the University of California, Irvine**

Site provider and outreach coordinator: **City of Huntington Beach**

Engineering and renewable energy planning: **Altura Associates**

Energy modeling: **National Renewable Energy Laboratory**

Electric energy service provider: **Southern California Edison**

Gas service provider: **Southern California Gas Company**

1 www.energy.ca.gov/2019publications/CEC-500-2019-047/CEC-500-2019-047.pdf, page 64

2 www.huntingtonbeachca.gov/residents/sustainable-hb/advanced-energy-community/

Description

The California Energy Commission selected Oak View,[3] a low-income community in Huntington Beach, California, as a good candidate for an Advanced Energy Community demonstration project and funded a Phase I feasibility study. The goal of the Oak View project was to improve grid reliability and **resilience** by achieving **zero energy** through deep energy efficiency, on-site renewables, and storage paired with advanced community scale energy system control. Oak View consists of mostly multifamily residential rental properties. Phase One of the project involved producing a scalable feasibility study; reaching out to the community; and performing an economic analysis, including exploration of sustainable business models. In addition, the project explored the potential for workforce development. A primary goal of the project was to develop tools to help plan and design an integrated set of energy infrastructure technologies and advanced energy technologies in a Huntington Beach community. The research aimed to

3 www.nrel.gov/docs/fy18osti/71841.pdf, page 8

integrate new energy innovations with the existing community electric grids, infrastructure, and buildings to maximize the cost-effective use of renewable energy sources, reduce emissions in the community, and reduce the life cycle cost of energy consumption for ratepayers.

Project status (as of October 2020)

Phase I Energy Master plan is complete; Phase Two implementation proposal was not selected, but, as of January 2020, a separate California Energy Commission-funded ongoing project in Oak View focuses on using **microgrid** technologies to simultaneously improve the environmental performance and resiliency of the local electric infrastructure.

Key energy opportunities

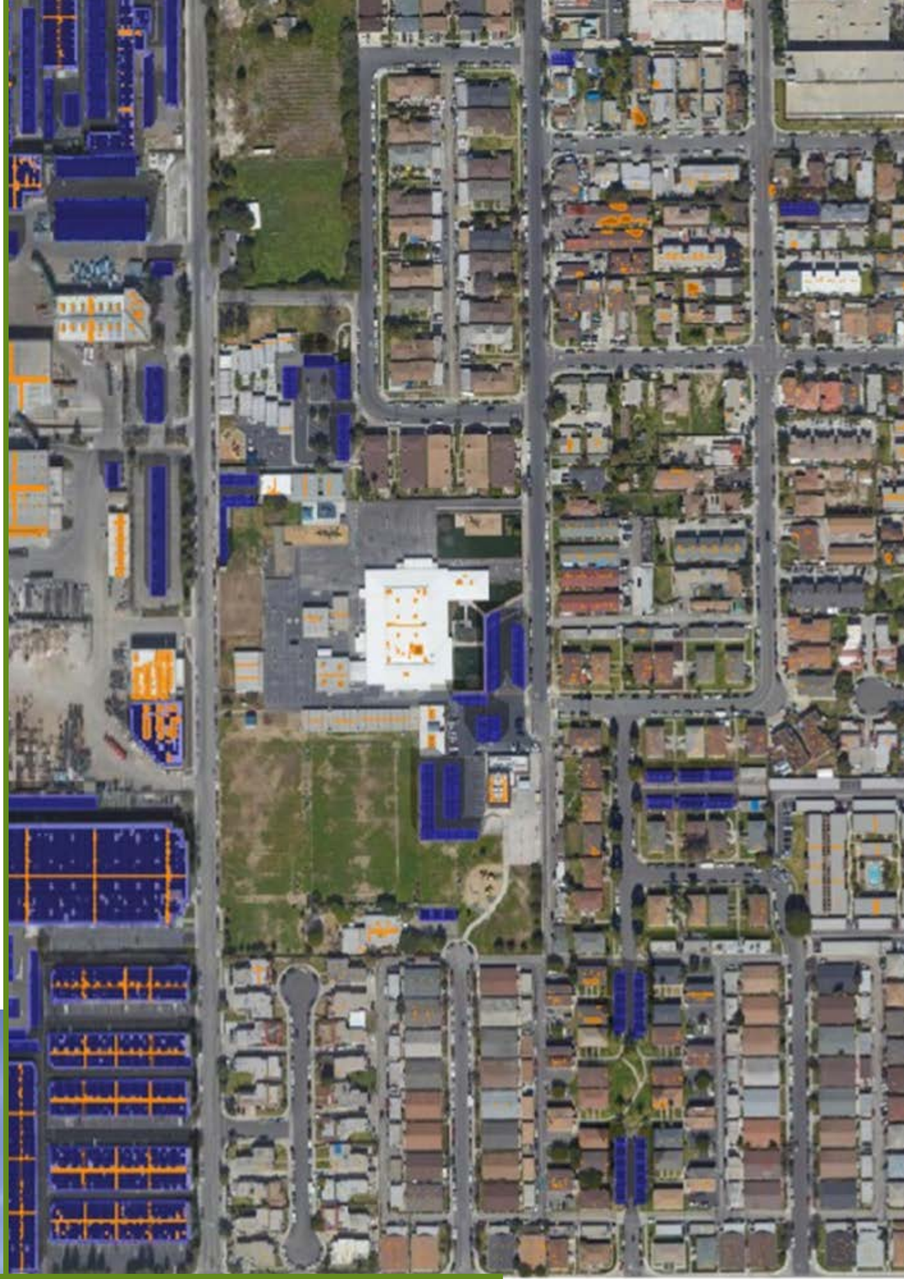
- Pursuing dramatic energy upgrades for a disadvantaged community
- Exploring the possibility of addressing grid reliability concerns with battery storage and fuel cell integration.

Innovative strategies

- Establishing and maintaining relationships with the many Oak View community organizations from the beginning of the process
- Developing design tools for reducing commercial and industrial energy use early in the process
- Developing community-scale technical tools to predict interactions between technologies and ensure that the benefits of reduced energy use and renewable energy production accrue to all utility customers
- Establishing quantifiable criteria for development decisions, supported by tools like URBANopt[4] and DERopt.[5]

Links to additional materials

- Phase 1 final project report: "Advanced Energy Community Blueprint"[6]



The Oak View Advanced Energy Community focuses on developing community-scale technical tools to ensure that the benefits of reduced energy use and renewable energy production accrue to all utility customers.

Image above from Yanchen Wu and Dr. Laura Novoa , University of California, Irvine

The Oak View neighborhood consists mainly of multifamily rental housing.

Photo to the left from Robert Flores , University of California, Irvine

4 www.nrel.gov/buildings/urbanopt.html
5 Novoa, Laura, Robert Flores, and Jack Brouwer. "Optimal renewable generation and battery storage sizing and siting considering local transformer limits." *Applied Energy* 256 (2019): 113926.
6 ww2.energy.ca.gov/2019publications/CEC-500-2019-047/CEC-500-2019-047.pdf

Rendering from Mike Munson, Munson Studios; ThinkOne Architects; Dennis Sun Rhodes, TSP/Great Horse Group

Montana State University

Bozeman, Montana

CASE STUDY

Location: **Bozeman, Montana**

Size: **956 acres with most of campus concentrated on about 210 acres**

Building/space types: **Academic, research, residence halls, dining halls, public gathering spaces**

Building area: **Approximately 5 million square feet**

Owner/occupant: **Montana State University**

Project team: **The multiple energy district projects involve multiple design and construction firms**

Design firms: **A&E Architects, ACE Engineers, AEI Affiliated Engineers, ARUP, Comma Q, Cushing Terrell, Energy One, Great Horse Group, Hennebery Eddy Architects, Morrison Maierle, MMW Architects, RDG Planning and Design, ThinkOne Architects, TSP Architects, ZGF Architects**

General contractors: **4G Mechanical, Dick Anderson Construction, Martel Construction, Swank Enterprises**

Delivery method: **Each building project in the district uses a specific contracting mechanism; most were delivered by general contractor/construction manager contracts**

Funding sources: **Project funds are specific to the building projects and consist of a mix of private donations and state funds**

Certifications, awards, standards: **Each building integrated into the energy districts has a LEED certification, usually Gold or Platinum, with Silver being the minimum acceptable.**

Description

Montana State University (MSU) is committed to a "reduce, reclaim, and renewable" energy strategy that involves first reducing energy use through resource conservation and integrated design. Then, as part of MSU's district energy development, previously wasted energy is reclaimed wherever possible, and, finally, renewable and low carbon energy systems are integrated into building and utility infrastructure systems. This energy strategy has allowed the campus to achieve a 17% decrease in greenhouse gas emissions since 2008, even with a 32% increase in population and a 9% increase in gross square footage during the same period. MSU continues to experience significant campus growth, with five major projects currently under construction. Coupling the proven energy strategy with lessons learned during the last decade, MSU anticipates excellent energy performance in these buildings and continued progress toward reducing greenhouse gas emissions.

MSU's energy strategy started with a conventional approach to energy retrofits and steam-based cogeneration. Although these efforts produced incremental improvements in efficiency, it soon became apparent that a more transformational approach was required to develop a practical path toward a low carbon future. During the design of an energy retrofit of Leon Johnson Hall, an academic and research facility in the core of campus, MSU developed the inaugural energy strategy that has since achieved significant gains in energy efficiency and reductions in carbon emissions. By combining a central heat pump plant to produce a heating and cooling stream simultaneously with exhaust air heat recovery and modernized HVAC, MSU was able to reduce energy consumption through efficiency gains while reclaiming significant heat previously treated as waste.

Finally, geothermal assets were added to the plant in a later phase.

MSU's commitment to reducing energy use and carbon emissions got a boost in 2011 when Jake Jabs, an MSU alumni, made a substantial donation to finance a new building, Jabs Hall. The donation opened the possibility of expanding the heating and cooling system of Leon Johnson Hall as part of its retrofit.

By making the Leon Johnson central heat pump plant big enough to serve multiple buildings, MSU could taking advantage of the benefits of sharing one system rather than having separate HVAC equipment in each building. In addition to itself, the Leon Johnson plant now supplies three other buildings with a combination of heating and/or chilled water for use by various heating and cooling systems. From 2007 to 2017, there was a 40% drop in the measured **energy use intensity** in these buildings, resulting in annual savings of roughly $130,000.

Since Jabs Hall was completed in 2015, the use of low temperature water systems in combination with heat pump technology has become a cornerstone of MSU's mission to achieve very low energy and carbon intensity. Among other projects, the new Norm Asbjornson Hall and American Indian Hall as well as the renovated Romney Hall all incorporate heat pump technology integrated with geothermal resources as well as active and passive solar strategies.

The basic principles of Norm Asbjornson Hall's heating and cooling system are similar to those pioneered in the Leon Johnson energy district, with the addition of unglazed transpired solar collectors that cover much of the south face of the building and cutting edge envelope technology including thermochromic glazing on the southern exposures. This building also includes a 216 kW rooftop solar photovoltaic array and a distributed heat pump system with 70 smaller units, each serving a room or hallway. These design concepts have already informed MSU's next buildings—the renovation of Romney Hall and the construction of American Indian Hall.

The new Norm Asbjornson Hall, the renovation of Romney Hall, and the reconstruction—after part of the roof collapsed during a historic snowstorm—of the Marga Hosaeus Fitness Center are included in the initial plan for a second energy district at MSU. This South Campus energy district concept was developed using lessons learned from the Leon Johnson energy plant. Unlike the Leon Johnson energy plant, this future energy district will more closely follow a distributed heat pump model; buildings will be connected for energy sharing using a low temperature heat pump loop.

Project status (as of October 2020)

The South Campus energy district continues to make progress with the addition of eighty-eight 700 foot deep geothermal bores in fall 2020, for a total of nearly 200 bores and more than 40 miles of installed vertical heat exchanger. American Indian Hall and Romney Hall are under construction with completion anticipated in 2021 and 2022 respectively.

Key energy opportunities

- Minimization or elimination of the direct use of fossil fuels
- Integrated design to achieve building energy goals
- Innovative site and building integrated photovoltaics
- Low energy ventilation strategies using unglazed transpired solar air collectors
- The use of modestly-sized geothermal assets for district level use.

Innovative strategies

- Buildings as energy producers and shared energy resources
- Campus-level low carbon energy district planning and development
- Retirement of high levels of deferred maintenance while achieving very high energy performance
- Reduce, reclaim, renewable strategy that couples the conventional with the transformational
- A road map to carbon neutrality for northern climate campuses
- Unique application of unglazed transpired solar collectors
- Use of thermochromic glazing to optimize solar gain.

Links to additional materials

Case studies

- *Mountains and Minds,* "Reinventing energy"[1]
- MSU News, "New geothermal system for Romney Hall to be one of MSU's biggest energy conservation projects"[2]
- *High Performing Buildings*, "Montana State University (MSU) Campus, Bozeman, Montana"[3]

1 www.montana.edu/news/mountainsandminds/18845/reinventing-energy
2 www.montana.edu/news/19588/
3 www.hpbmagazine.org/montana-state-university/

Rendering from Mayor's Office of the National Western Center

National Western Center

Denver, Colorado

CASE STUDY

Location: **Denver, Colorado**

Size: **250 acres**

Building/space types:
Event centers, arenas, office, education

Building area: **2.8 million square feet**

Energy project team: **EAS Energy Partners, led by Enwave, a global district energy leader, and including AECOM Technical Services and Saunders Construction**

Description

The National Western Center (NWC) is located on the historic grounds of the Denver Union Stock Yard Company, which currently hosts the annual National Western Stock Show. The redevelopment project is a partnership between the City and County of Denver, the National Western Center Authority, the Western Stock Show Association, and Colorado State University, and will transform the area, doubling its footprint, with the goal of creating a sustainable, multipurpose campus that attracts visitors year-round. The project is aiming for a **zero energy** campus to include energy-efficient buildings and the development of on-site renewable resources by 5 years after full build-out.

In August 2020, the NWC entered into an agreement with EAS Energy Partners, led by Enwave and including AECOM Technical Services and Saunders Construction, to develop an innovative, technically and financially feasible campus-wide energy system. An underground sewer pipeline will provide recycled thermal energy, and, when complete, the 3.8 MW system will be the largest sewer heat recovery system in North America. The system is expected to meet nearly 90% of campus heating and cooling loads.[1]

1 milehighcre.com/national-western-center-to-source-recycled-thermal-energy-to-meet-clean-energy-goals/

Project status (as of October 2020)

Construction on horizontal infrastructure (roads, bridges, water and wastewater pipes, railways, landfills, water and wastewater treatment plants, power transmission lines, sidewalks, and public spaces, for example[2]) started in the spring of 2019. In August 2020, NWC formed a partnership with EAS Energy Partners to provide nearly 90% of campus heating and cooling needs with a sewer waste heat recovery system. That system will be complete by 2022 and the larger NWC project will be completed in 2024.

Key energy opportunities

- District-scale sewer heat recovery from city-wide sewer system
- Potential for advanced building controls that adapt to variable use of event and conference spaces
- Large rooftops available for solar photovoltaics
- Opportunities to engage with the private sector to form a public-private partnership to design/build/finance/operate the energy systems infrastructure for the campus.

Innovative strategies

- LEED Gold minimum sustainability goals
- District waste heat recovery with integrated energy services partner
- Rooftop solar photovoltaics
- Community **resilience** center opportunities.

Links to additional materials

- Master plan[3]
- City and County of Denver. 2018. "National Western Center"[4]
- The Solutions Journal[5]

Aerial graphic showing the overall layout of the National Western Center.

Rendering from Mayor's Office of the National Western Center

2 www.governing.com/blogs/view/col-sustainable-infrastructure-envision-rating-system.html
3 nationalwesterncenter.com/about/the-redevelopment-process/master-plan/
4 citycountydenver-stage.adobecqms.net/content/denvergov/en/north-denver-cornerstone-collaborative/national-western-center.html
5 www.thesolutionsjournal.com/article/national-western-center-sun-valley-ecodistrict-infusing-large-scale-urban-development-projects-sustainability/

Rendering from Fulenwider

Peña Station NEXT

Denver, Colorado

CASE STUDY

Location: **Denver, Colorado**

Size: **382 acres**[1]

Building/space types: **Corporate offices, restaurants and retail, entertainment, health and wellness, multifamily residential, and hospitality and conference**[2]

Building area: **To be determined**

Master developer: **L. C. Fulenwider, Inc., in partnership with Panasonic and the real estate division of Denver International Airport, DEN Real Estate**[3]

1 solar-media.s3.amazonaws.com/assets/Pubs/Younicos%20White%20Paper.pdf
2 penastationnext.com/vision/strategic-advantages/
3 www.fulenwider.com

Description

The Peña Station NEXT district in Denver, Colorado, will be a mixed use community located on a commuter rail line at the first stop west of Denver International Airport (DIA). Among other groups, the project is a collaboration between Panasonic, electric utility Xcel Energy, land developer L.C. Fulenwider, and the City and County of Denver through DIA.

Peña Station NEXT is a transit-oriented development, a type of planned community comprising housing, office, retail, and/or other amenities integrated into a walkable neighborhood and located within a half mile of public transportation.[4] The project is expected to be the one of the more efficient and carbon neutral **zero energy** infrastructure developments in the United States and features Colorado's first **microgrid.** The **microgrid** consists of a 1.6 MW carport solar photovoltaic system located on a DIA parking lot and carport structure and a 259 kW rooftop solar photovoltaic array installed on the roof of the Panasonic Enterprise Solutions Company's building. This system uses Panasonic HIT modules and a Younicos 1 MW/2 MWh lithium-ion battery system with inverter and controls integrated into Younicos' innovative Y. Cube system. The DIA solar photovoltaic system is owned and operated by Xcel Energy under lease to the airport. Panasonic's Denver operations hub building serves as the initial anchor load for the **microgrid.**[5]

4 www.reconnectingamerica.org/assets/Uploads/ctod5yearbrochure.pdf
5 www.businesswire.com/news/home/20170201005496/en/Panasonic-Xcel-Energy-Younicos-White-Paper-Shares/?feedref=JjAwJuNHiystnCoBq_hl-fqXyBvmekC3Xq1G1wQ7hjMFbZM1ntlKeK-8bUzJqFSVSfe41V1BKA-b6v2ZVrSSNs-dUYKiDvY7XniNSqv88QcY1Ge_vf9QIMZ4alzlf_0HlyE0C4hZhHVlTvKnn0d0vQ%3D%3D

Project status (as of October 2020)

The 112,500-square-foot Panasonic Enterprise Solutions Company facility is the first vertical construction project at Peña Station NEXT. Among other functions, this facility serves as a 24/7 network operations center that monitors a nationwide network of large-scale solar photovoltaic installations. The site also currently includes a DIA parking lot with shaded parking, a solar photovoltaic installation, and a battery energy storage system.[6] The resulting installation can be operated as a **microgrid** and can provide backup power in emergencies. In August 2020, KDC, which develops corporate build-to-suit campus projects, teamed up with Fulenwider to add 1 million square feet of build-to-suit office.

Key energy opportunities

The **microgrid** can feed power into the utility grid as well as provide backup power in emergencies.

Innovative strategies

- Researchers from NREL are providing technical assistance by modeling building energy consumption and the dynamic flow of distributed energy resources within the entire district.
  - Specifically, NREL researchers are modeling energy consumption in corporate offices, retail spaces, multifamily dwellings, a hotel, parking, and street lighting.
  - The data will be integrated into Xcel Energy's grid distribution modeling tools to help the utility analyze rate and payment structures.[7]
- Participants are exploring the possibility of having the entire community be a large, islandable **microgrid**.[8]

Links to additional materials

- Case study Microgrid[9]
- Master plan[10]
- Energy planning analysis
  - Denver's Peña Station NEXT: This Way to Energy Utopia?[11]
  - *Journal of Renewable and Sustainable Energy*, "Toward a subhourly net zero energy district design through integrated building and distribution system modeling."[12]
  - NREL + PANASONIC: Developing a Zero Energy, Transit-Oriented Campus in Denver, Colorado.[13]

The Peña Station development will be a walkable community.

Rendering from Fulenwider

6 www.xcelenergy.com/staticfiles/xe-responsive/Energy%20Portfolio/CO-Panasonic-Pictorial-Sheet.pdf
7 microgridknowledge.com/pena-station-next/
8 microgridknowledge.com/pena-station-next/
9 solar-media.s3.amazonaws.com/assets/Pubs/Younicos%20White%20Paper.pdf
10 business.flydenver.com/bizops/documents/PSN_DesignStandardsGuidelines.pdf
11 microgridknowledge.com/pena-station-next/
12 aip.scitation.org/doi/full/10.1063/1.5093917
13 www.nrel.gov/docs/fy17osti/68998.pdf

Photo from Port of Long Beach

Port of Long Beach

California

CASE STUDY

Location: **Port of Long Beach, California**

Size: **3,200 acres**

Critical Facilities Microgrid Location: **Joint Command and Control Center**

Building/space types: **Command Center for the Port**

Project team: *Primary Consultant* **Schneider Electric**

Partners:

- **California Energy Commission**
- **Long Beach City College**
- **National Renewable Energy Laboratory**
- **Southern California Edison**
- **International Brotherhood of Electric Workers**
- **Advanced Power and Energy Program, University of California, Irvine**

Description

The Port of Long Beach (POLB) adopted a Clean Air Action Plan in 2017 that provides a framework to achieve zero emissions by 2030 for its terminal equipment. As part of the plan, POLB has identified a series of demonstration projects to achieve this ambitious goal, including the development of a **microgrid** for its critical operations and management facilities. Other elements include **electric vehicle** charging infrastructure and electric cargo handling equipment. The POLB has received $80 million from the California Energy Commission and $50 million from the California Air Resources Board to support these projects.

The **microgrid** demonstration project is planned for the POLB Joint Command and Control Center (JCCC), which is the central operations hub for harbor patrol, first responders, and computer and security systems. In addition to the JCCC building, the **microgrid** will serve an adjacent company, Jacobsen Pilot Service, which drives all the ships in the POLB. The project cost estimate is $7.1 million, funded in part by $5.2 million of the California Energy Commission grant. The JCCC was chosen as the pilot because it will increase POLB's

resilience in case of a natural or manmade (terrorism) disaster, which could result in millions of dollars in lost revenue as well as impacts to goods moving along the West Coast. As the heart of POLB, the JCCC building is essential to its operations. Creating an islandable **microgrid** will allow POLB to operate uninterrupted during grid outages as well as increase reliability, cybersecurity, and **resilience**.

Some of the key challenges the project had to overcome include:

- Limited land availability for renewables and storage
- Regulatory hurdles related to power sharing across property lines
- Port customer concerns that the changes—especially moving to all-electric—would impact operational efficiency.

Project status (as of October 2020)

The project is scheduled to break ground in October 2020 and be completed in August of 2021. It was delayed by the decision to provide additional power to an adjacent owner, a conflict with current utility rules requiring a regulatory variance by the California Public Utilities Commission.[1]

Key energy opportunities

The **microgrid** will include the following elements:

- Installation of a 300 kW solar photovoltaic system
- 250 kW **microgrid**-extending mobile battery energy
- 500 kW diesel generator
- **Microgrid** controls to allow demand response, peak shaving, and islanded operations for energy **resilience**
- 330 kW power output and 670 kWh capacity stationary battery energy storage system.

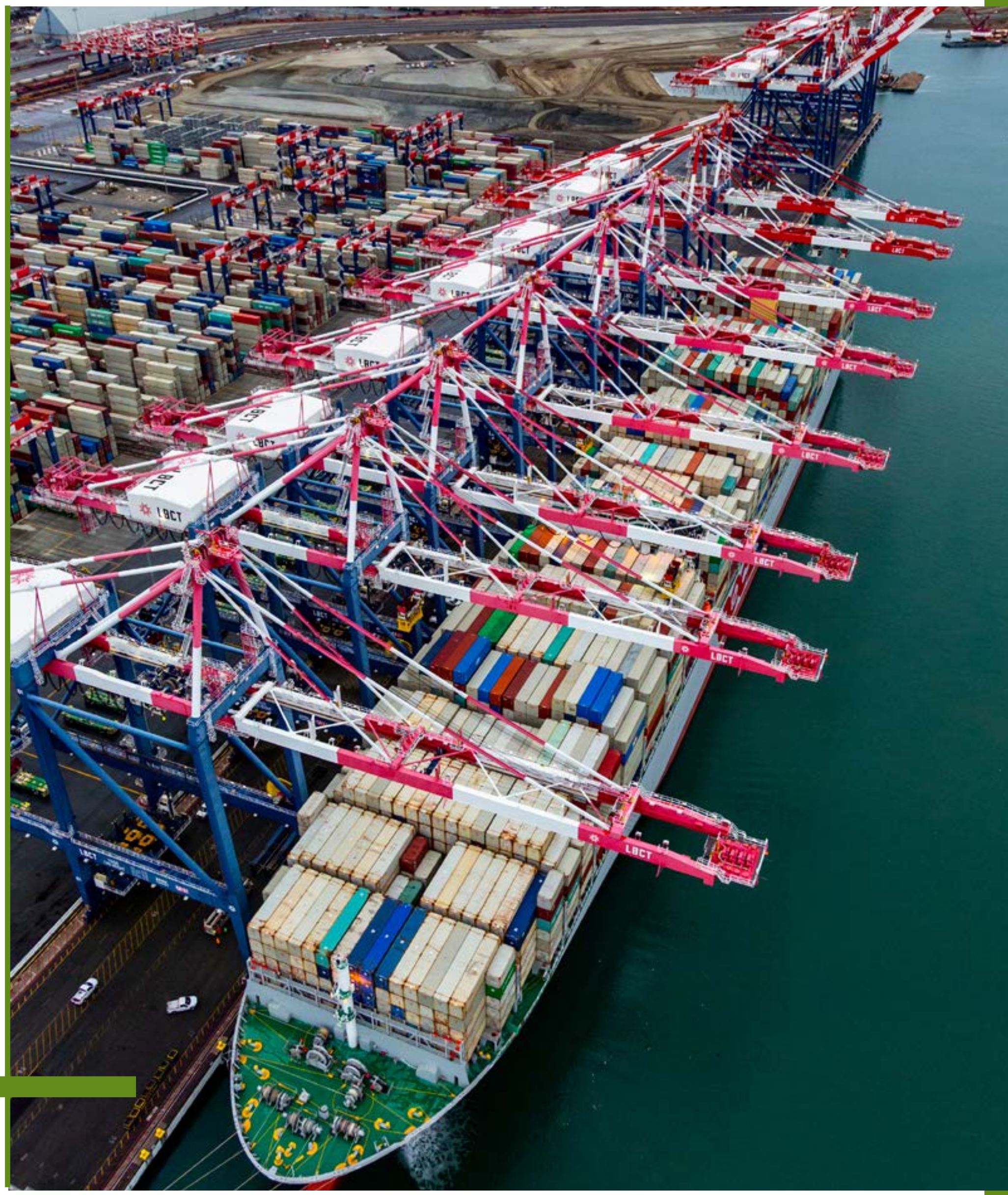
Innovative strategies

- Install a 300 kW solar photovoltaic carport over the command center parking lot to save land space and increase on-site renewable energy capacity
- Install an energy control center with **microgrid** controls and a 670 kWh stationary battery energy storage system
- Install a mobile battery energy storage system that can serve the command center, container ships that require emergency power, or other important infra-structure systems
- Monitor and assess 12 months of performance data
- Partner with Long Beach City College and the International Brotherhood of Electrical Workers to strengthen local workforce development and training initiatives and provide paid on-the-job training to apprentices during construction.

Links to additional materials

Master plan

- Port of Long Beach program details[2]
- Schneider Electric Microgrid to Service Long Beach, California Community by Creating Energy Resilience at Port[3]



The Port of Long Beach, California, is targeting zero emissions by 2030 for its terminal equipment.

Image from Port of Long Beach

1 www.greentechmedia.com/articles/read/california-ports-turning-to-microgrids-for-energy-security-demand-flexibility

2 www.polb.com/environment/our-zero-emissions-future#program-details

3 www.se.com/us/en/download/document/PR-10Oct2018-Long_Beach_Port/

Photo from Revive Properties, LLC Susan McFaddin

Revive Fort Collins

Colorado

CASE STUDY

Location: **Fort Collins, Colorado**

Size: **10 acres**

Building/space types: **37 townhouses, 18 single-family homes**

Building area: **7 acres**

Developer: **Revive Properties**[1]

Builder: **Philgreen Construction**[2]

1 revivefc.com
2 philgreenco.com

Certifications, awards, standards:[3,4]

DOE Housing Innovation Award in 2016, 2017, 2018, 2019[5]

DOE Zero Energy Ready Home Program—100% Commitment[6]

ENERGY STAR® Certified Homes Version 3.1[7]

Home Energy Rating System (HERS)[8] **ratings of 2 or less in all homes in 2018; the lowest HERS rating was -11 the lower the rating, the more energy-efficient the home**

U.S. Environmental Protection Agency Indoor AirPlus[9]

U.S. Environmental Protection Agency WaterSense[10]

2015 and 2018 Northern Colorado Parade of Homes Greenest Home Award

2018 City of Fort Collins Integrated Design Assistance Award

Meets insulation requirements of the 2012 (or 2015) International Energy Conservation Code.[11]

3 www.innovationews.com/Fort-Collins-developer-receives-DOE-Housing-Innovation-Award-/
4 www1.eere.energy.gov/buildings/residential/pdfs/doe_ch_case_studies/2018hiawinner_Revive_102418_HR.pdf
5 www1.eere.energy.gov/buildings/residential/pdfs/doe_ch_case_studies/2018hiawinner_Revive_102418_HR.pdf
6 www.energy.gov/eere/buildings/zero-energy-ready-homes
7 www.energystar.gov/newhomes/homes_prog_reqs/national_page
8 www.hersindex.com/hers-index/interactive-hersindex/
9 www.epa.gov/indoorairplus
10 www.epa.gov/watersense
11 www.iccsafe.org/products-and-services/i-codes/2018-i-codes/iecc/

At Revive Fort Collins, solar photovoltaics are not optional—rather than incentivizing upgraded finishes or other amenities, the partners incentivize solar.

Photo from Revive Properties, LLC Susan McFaddin

Description[12]

For the past four years, the partnership of Revive Properties and Philgreen Construction in Fort Collins, Colorado, has received DOE's Housing Innovation Award for its successful **zero energy** home development. For example, solar photovoltaics is not optional; rather than incentivizing upgraded finishes or other amenities, the partners incentivize solar. In addition to supporting the Fort Collins Climate Action Plan's ambitious carbon emissions reduction goals—a 20% reduction goal by 2020, an 80% reduction by 2030, and a 100% reduction by 2050 compared with a 2005 baseline—the partners create comfortable, healthy, beautiful homes with reduced life cycle costs. Fort Collins is a supportive community for sustainability efforts; it reached its 2020 emissions reduction goal 3 years early in 2017 and has also set a goal of 100% renewable electricity by 2030.[13] The units include extremely energy-efficient building envelopes and windows, careful air sealing, and many energy- and water-saving features. In addition to supporting local climate change mitigation goals, the development has revitalized a previously undesirable urban renewal district. The area is now home to retail businesses and cultural centers as well as a new restaurant and movie theater. The Revive development is credited with catalyzing this revitalization.

Key energy opportunities

- Ground source heat pump system provides heating, cooling, and domestic hot water; ground source heat pumps connect each home to an underground heat-exchange-loop infrastructure system consisting of 350-foot deep boreholes[14]
- PV systems provide electricity
- All lighting is LED; strategically placed windows provide daylighting, even in closets, bathrooms, and garages
- ENERGY STAR® appliances
- Energy modeling maximized daylighting while reducing heat loss and uncontrolled solar gain
- Energy recovery ventilation ensures good indoor air quality.

Ben Washa (owner's agent), Chad Adams (owner), Susan McFaddin (development consultant), Todd Adams (owner), Dave Phillips (builder), and Karen Goot and Linda Vescio (HOA members) at Revive Fort Collins

Photo from Revive Properties, LLC Susan McFaddin

Innovative strategies

- All townhomes are sold with solar installed; the developer sells solar at its cost
- Energy modeling maximized daylighting while reducing both heat loss and uncontrolled solar gain
- Energy- and water-saving features—savings of more than 50% on indoor water using Water Sense indoor water distribution strategy
- Building techniques and finishes enhance indoor air quality and comfort
- On-site ground source heat pump heating, cooling, and domestic water heating; solar electricity production
- Garages prewired for **electric vehicle** charging station.

Links to additional materials

Case study

- Revive Properties/Philgreen Construction—Green Leaf Street, Fort Collins, Colorado[15]

12 www1.eere.energy.gov/buildings/residential/pdfs/doe_ch_case_studies/2018hiawinner_Revive_102418_HR.pdf
13 www.coloradoan.com/story/news/2019/02/04/fort-collins-government-operations-hits-carbon-reduction-goal-early/2772916002/
14 www.proudgreenhome.com/press-releases/bosch-equips-revive-community-in-ft-collins-colorado-with-efficient-geothermal-comfort/
15 https://www1.eere.energy.gov/buildings/residential/pdfs/doe_ch_case_studies/2018hiawinner_Revive_102418_HR.pdf

Photo from Robert Canfield

Stanford University

California

CASE STUDY

Location: **Palo Alto, California**

Size: **360 buildings served by combined heating and cooling district thermal system**

Building/space types: **University/campus buildings**

Building area: **11 million square feet served by district thermal system**

Developer: **Stanford University**

Certifications, awards, standards:[1]

Acterra Business Environmental Award, Environmental Project, 2016

Alliance to Save Energy, Energy Efficiency Visionary Awards, 2016

American Institute of Architects, 2016 Honor Award, 2017 Committee on the Environment Top Ten Projects

American Institute of Architects, Portland Chapter, 2015 Architecture Awards

American Institute of Architects, San Francisco Chapter, 2016 Honor Award

APPA: Leadership in Educational Facilities, Effective and Innovative Practices Award (2013)

Engineering News-Record, Editors' Choice and Best Energy/Industrial Project 2015; Global Best Project: Green Project Category, 2015

Engineering News-Record California, 2015 Best Project: Energy/Industrial

Governor's Environmental and Economic Leadership Awards Program [California], Award in the climate change category, 2016

Green Power Challenge, U.S. Environmental Protection Agency, 2019 Pac-12 Champion

Green Power Leadership Award, U.S. Environmental Protection Agency, 2017 Direct Project Engagement category

Structural Engineers Association of Northern California, 2016 Excellence in Structural Engineering Awards: Award of Merit, Infrastructure Category

Stanford University's Central Energy Facility uses a innovative heat recovery system that takes advantage of Stanford's overlap in heating and cooling needs and is powered completely by electricity.

Photo from Robert Canfield

1 sustainable.stanford.edu/campus-action/energy/stanford-energy-system-innovations-sesi/new-central-energy-facility/news

Description

Stanford has aggressive campus-wide energy and emissions reductions goals, including reducing greenhouse gas emissions 80% from the historic peak by 2025 and achieving carbon neutrality by 2050. As outlined in the Stanford University Energy and Climate Plan,[2] the university is taking an approach to meet these goals that balances energy conservation in existing buildings; energy efficiency in new building design; and clean electrification of its power, heating, cooling, and transportation systems.

Related to energy supply, the Stanford Energy System Innovations project developed a new clean electrification-based district heating, cooling, and electricity system that provides significant energy and cost savings to the university. The system replaced a natural-gas fired combined heat and power plant that was set to be decommissioned in 2015.

The process began with an evaluation of existing heating and cooling loads that identified substantial (>75% during the course of a year) simultaneous heating and cooling in the campus buildings and thus an opportunity for heat recovery. A combined heating and cooling system was designed and constructed that recovers waste heat from the chilled water loop and uses it for space heating and domestic hot water production. Combined with on-site and off-site renewable energy procurement, the Stanford Energy System Innovations system has already reduced emissions by 72% from the historic peak as of 2019 and will achieve the university's 80% reduction goal in January 2022—3 years early. At that time, Stanford's second large solar power project will be operational and the decarbonization of Stanford's electricity supply will be complete.

The Stanford team has identified opportunities for substantial heat recovery in other district energy systems that have a cooling component. The heat recovery opportunity has totaled at least 50% at the sites they examined, from cold northern climates to warmer southern climates. The reason for this large opportunity for heat recovery across climates for the sites examined is that 100% of system heating needs in summer (primarily domestic hot water); 25% to 75% in spring and fall (mix of domestic hot water and space heating); and 5% to 30% in winter (continuous space heating and domestic hot water) can typically be met by waste heat recovery from the cooling system. Taken together, the large summertime waste heat recovery combined with moderate potential in spring and fall and modest potential in winter typically total more than 50% for the year even in the very cold climates examined.[3]

Project status (as of October 2020)

- The electricity powered combined heating and cooling system was implemented and has been operational since March 2015
- The combined heating and cooling system alone has reduced campus emissions by 50%, while decarbonization of the university's electricity supply has already added another 22% and will grow to 30% for a total 80% campus greenhouse gas reduction by January 2022; at this point, the completion of a another solar plant will make Stanford's electricity supply carbon-free
- It is estimated that the Stanford Energy System Innovations System project will save $530 million in reduced energy costs over 35 years.

Key energy opportunities

- Natural gas-fired combined heat and power plant was set to be decommissioned in 2015
- Diverse mix of buildings on campus showed substantial simultaneous heating and cooling and thus opportunity for heat recovery.

Innovative strategies

- Combined heating and cooling district thermal system that recovers waste heat from cooling; 88% of the heating load on campus is met with waste heat
- Substantial hot and cold water thermal energy storage
- Retrofitted existing buildings run on hot water instead of steam
- Model-predictive control system (invented and patented by Stanford for Stanford Energy System Innovations) provides optimal planning, design, and day-to-day operation of the system.

Links to additional materials

- Case studies
  - Stanford Energy System Innovations[4]
  - Stanford Energy System Innovations Fact Sheet[5]
  - *EPRI Journal*, Electric University[6]
  - Stanford University's "fourth-generation" district energy system—combined heat and cooling provides a path to sustainability[7]
- Stanford University Energy and Climate Plan.[8]

2 sustainable.stanford.edu/sites/default/files/E%26C%20Plan%202016.6.7.pdf
3 Personal communications, Joseph Stagner, Stanford University, June and July 2020.
4 sustainable.stanford.edu/campus-action/stanford-energy-system-innovations-sesi
5 sustainable.stanford.edu/sites/default/files/SESI_Condensed_factsheet2017.pdf
6 eprijournal.com/electric-university/
7 sustainable.stanford.edu/sites/default/files/IDEA_Stagner_Stanford_fourth_Gen_DistrictEnergy.pdf
8 sustainable.stanford.edu/sites/default/files/E%26C%20Plan%202016.6.7.pdf

Photo from Rob Aldridge for Whisper Valley

Whisper Valley

Austin, Texas

CASE STUDY

Location: **Austin, Texas**

Size: **2,062 acres**

Developer:
Taurus Investment Holdings, LLC[1]

Independent energy system provider:
EcoSmart Solution

Building/space types: **7,500 single and multifamily homes plus retail and office space**

Building area: **7,500 residential units and more than 2 million square feet of retail and office space**

Certifications, awards, standards:

City of Austin Municipal Building Code zero energy standard for all new home construction

Gold Nugget Awards, Merit Award winner for the Best Innovative Energy Design Award, 2018[2]

Sustainable Community of the Year, Green Builder Media, 2019[3]

1 www.whispervalleyaustin.com/about/developer/
2 www.whispervalleyaustin.com/blog/2018/07/03/whisper-valley-wins-national-award-for-innovation-at-2018-gold-nugget-awards/
3 www.whispervalleyaustin.com/2019/02/18/whisper-valley-recognized-as-sustainable-community-of-year-ecosmart-solution-wins-green-innovation-award/

Description

Whisper Valley is a new housing development in Austin, Texas, that will eventually have 7,500 single and multifamily homes as well as more than 2 million square feet of retail and office space. All the structures will be equipped with solar and a ground source heat pump system capable of achieving the **zero energy** (or carbon neutral) standard adopted by the City of Austin Municipal Building Code for all new home construction.

The project is the result of an innovative joint venture between the developer and an independent energy system provider called EcoSmart Solution. The EcoSmart team identified a number of important benefits of their approach:

- The district infrastructure is critical to consider from the beginning of the process, not just the buildings
- It was about 50% less expensive to do the ground source heat pump system at the district level than it would have been one house at a time
- The district ground source heat pump system can be optimized as a whole, aggregating savings and energy loads as needed rather than attempting to optimize each bore hole

- Building a large new development is key to the success of the project; retrofitting existing buildings would be much more difficult
- Ensuring that the home appraisals included and valued the solar infrastructure was essential to the project and allowed homeowners to buy their systems as part of their mortgage at a reasonable cost; this relieved the developer of the infrastructure cost so they could focus on the ground source heat pump district-wide system
- The business model allows for a single simple fee for homeowners—no complicated ownership agreements.

Having the Whisper Valley EcoSmart Solution center on-site is a promising high-performance district operations practice. This local expert organization provides coaching for homebuilders and homeowners on the innovative energy systems, using **zero energy** ready and HERS requirements for home builders and including these costs in the homeowner's mortgage (with the appropriate home value appraisal). They manage the financial thermal utility model to bill homeowners for the connection and monthly use of the district shared ground source heat pump system as well as initially providing nationally prequalified HVAC vendors and subcontractors to install the more innovative systems.

Project status (as of October 2020)

- Phase I is complete, providing 237 homesites for buyers and a community center.
- The ground source heat pump district system and Google Fiber network are in place and operational.
- Phase II is underway, with 267 buildable lots completed in summer 2020 and made available to builders, who are building model homes.[4]

Key energy opportunities

The team was able to realize the high-performance district vision by:

- Fully integrating a ground source heat pump system with the individual building heat pumps, solar systems, and energy efficiency measures to supply 100% of all of the buildings heating and cooling needs
- Effectively engaging the communities' real estate appraisers to ensure that the new homes' advanced energy systems are appropriately valued in the appraisals, allowing for increased mortgages, higher resale values, and homeowner (rather than developer) ownership of the solar systems
- The energy system builders are part of the development team, not merely a contractor, and are fully invested in the project, managing the infrastructure into the future.

Innovative strategies

- EcoSmart Solution organization is set up for local operations coaching on **zero energy** design, district ground source financing, and ongoing billing and **zero energy** operations support
- District ground source heat pump system for affordable below market average new home costs
- Energy efficiency and solar photovoltaics included in new home construction standards according to U.S. Department of Energy Zero Energy Ready Home requirements,[5] with appraisals to document additional value to be included in home mortgages.

Links to additional materials

- Case Study[6]
- Master Plan[7]
- Whisper Valley EcoSmart[8]

Whisper Valley in Austin, Texas, is a development of thousands of homes as well as retail and office space; all the structures are designed to achieve the **zero energy** or carbon neutral standard adopted by the City of Austin Municipal Building Code for new home construction.
Photo from Rob Aldridge for Whisper Valley

4 www.whispervalleyaustin.com/blog/2020/08/28/homebuilding-ramps-up-at-massive-east-austin-community-as-tesla-moves-earth-nearby/
5 www.energy.gov/eere/buildings/guidelines-participating-doe-zero-energy-ready-home-program
6 www.rehau.com/us-en/themes/whisper-valley
7 www.whispervalleyaustin.com/lifestyle/master-plan-community-concept/
8 www.whispervalleyaustin.com/living-ecosmart/

Mill 19 is the first phase of the Hazelwood Green high-performance development in Pittsburgh, Pennsylvania.

Photo from Turner Construction

NREL Transforming ENERGY

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