



Zero Energy Commercial Buildings: Research For the Next Generation

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Zero Energy Buildings Research Engineer

October 25, 2017

Next Generation of ZEBs will be...

- Taller
- District Scale
- High Load Building Types
- Grid Friendly
- More Resilient

- Required and everywhere...

National Renewable Energy Laboratory Snapshot

Only National Laboratory Dedicated Solely to Energy Efficiency and Renewable Energy

- Leading clean-energy innovation for 40 years
- 1740 employees with world-class facilities
- Campus is a living model of sustainable energy
- Owned by the Department of Energy
- Operated by the Alliance for Sustainable Energy
- Golden, Colorado Main Campus
 - Wind Technology Site



Scope of Mission

Sustainable Transportation

Vehicle Technologies
Hydrogen
Biofuels

Energy Productivity

Residential Buildings
Commercial Buildings

Renewable Electricity

Solar
Wind
Water: Marine Hydrokinetics
Geothermal

Systems Integration

Grid Integration of Clean Energy
Distributed Energy Systems
Batteries and Thermal Storage
Energy Analysis

Partners

Private Industry
Federal Agencies
State/Local Government
International

What We Do

Advanced Commercial Buildings Research, through applied research and demonstration, supports DOE's speed-and-scale goals to reduce building energy use.

Focus areas:

- Whole-building systems integration to reach net zero
- Comprehensive building energy modeling
- Cutting-edge energy efficiency technologies
- Systematic performance metrics and monitoring

Our team's key strength lies in combining all these tools to design well-integrated new buildings and cost-effective retrofits.

NZEB DEFINITION



Net Zero **Site Energy** Building



Net Zero **Source Energy** Building



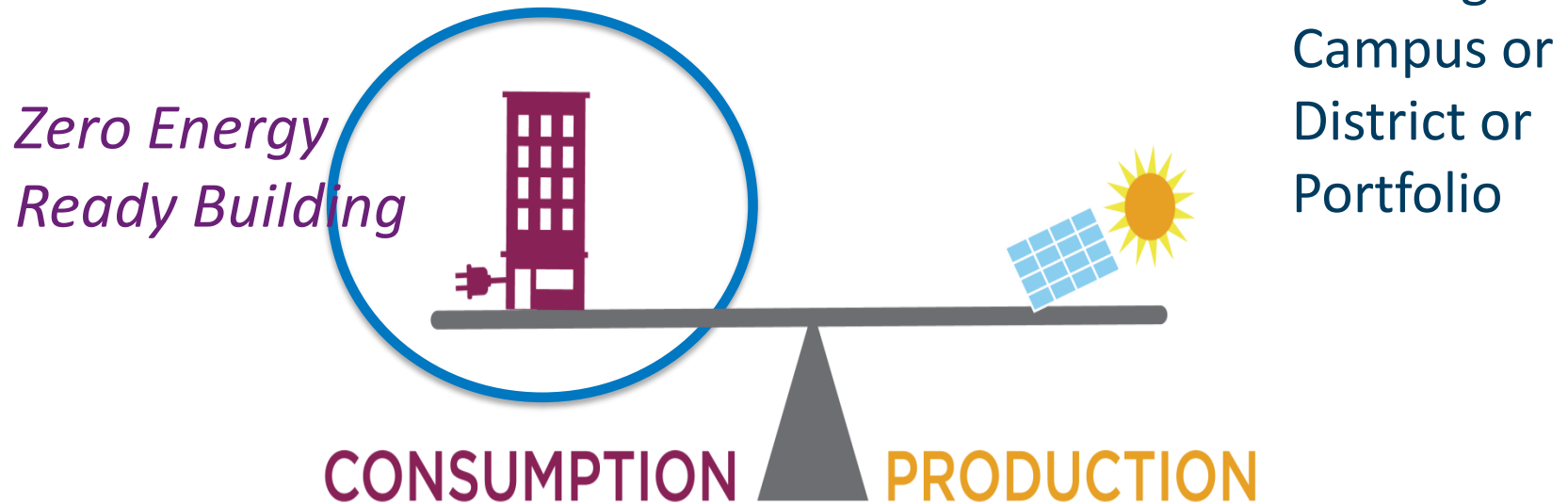
Net Zero **Energy Emissions** Building



Net Zero **Energy Cost** Building

Zero Energy Building (ZEB) Source Definition

An energy-efficient building, where on an annual source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy.



Home » DOE Releases Common Definition for Zero Energy Buildings, Campuses, and Communities

DOE Releases Common Definition for Zero Energy Buildings, Campuses, and Communities

September 16, 2015 - 5:38pm



- Buildings Home
- About
- Emerging Technologies
- Residential Buildings
- Buildings
- Standards
- Energy Codes



NREL Research Support Facility, photo credit: Bill Gillies, NREL

WASHINGTON, DC – Today the U.S. Department of Energy (DOE) reached a significant milestone in bringing the building community together by releasing a common definition for a zero energy building, or what is also referred to as a "net zero energy" or "zero net energy" building.

RELATED ARTICLES

[DOE Announces Webinars on an Energy Design Guide for Grocery Stores and Buildings of the Future](#)



[Happy Birthday Unmet Hours!](#)

[Department of Energy Announces the Launch of the Hospital Energy Alliance to Increase Energy Efficiency in the Healthcare Sector](#)

A Common Definition for Zero Energy Buildings

September 2015

Prepared for the U.S. Department of Energy by
The National Institute of Building Sciences



NREL Research Support Facility, photo credit: Bill Gillies, NREL

<http://energy.gov/eere/buildings/articles/doe-releases-common-definition-zero-energy-buildings-campuses-and>



Federal New Buildings Handbook for Net Zero Energy, Water, and Waste

[Home](#) » [Federal New Buildings Handbook for Net Zero Energy, Water, and Waste](#)

In 2015, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) defined zero energy buildings as "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."

This document is focused on applying EERE's definition of zero energy buildings to federal sector new buildings. However, it is not intended to replace, substitute, or modify any statutory or regulatory requirements and mandates.

California State Agency Zero Net Energy Definition

https://www.documents.dgs.ca.gov/osp/sam/mmemos/MM17_04.pdf

STATE ADMINISTRATIVE MANUAL

MANAGEMENT MEMO

SUBJECT:

ZERO NET ENERGY FOR NEW AND EXISTING STATE BUILDINGS

REFERENCES:

Executive Order (EO) B-18-12; Green Building Action Plan, AB 32, MM 15-04, SAM chapter 1815.31

NUMBER:

MM 17-04

DATE ISSUED:

OCTOBER 16, 2017

EXPIRES:

UNTIL INCORPORATED INTO SAM OR ON OCTOBER 1, 2018

ISSUING AGENCY:

DEPARTMENT OF GENERAL SERVICES

Purpose

This management memo (MM) provides state agencies and building professionals with the requirements for meeting zero net energy (ZNE), as well as the direction, strategies and procedures that will help them achieve ZNE for new building design and construction, and build-to-suit leases, as well as existing state-owned buildings.

This MM is part of a series of directives to state agencies designed to implement the Governor's Executive Order (EO) B-18-12 on energy and resource conservation in state buildings. See [State Administrative Manual \(SAM\) Section 1815.31](#) for more details and guidance.

Policy

[Executive Order B-18-12](#) requires the following actions to reduce the environmental impact of state facilities on climate change:

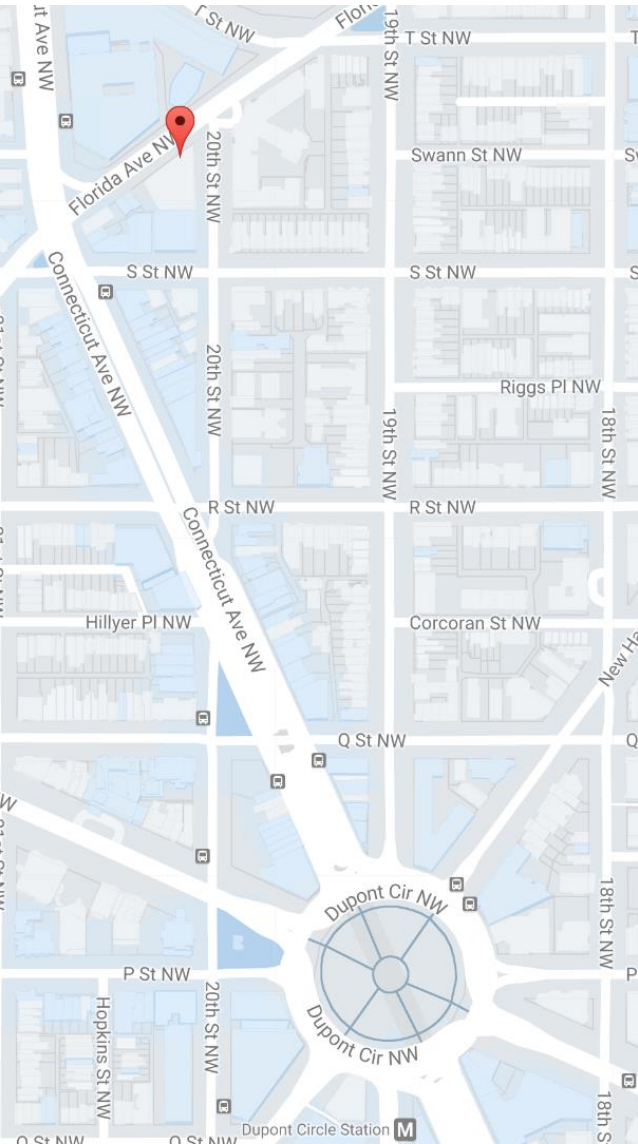
- All new State buildings and major renovations beginning design after 2025 shall be constructed as Zero Net Energy facilities.
- 50% of new facilities beginning design after 2020 shall be Zero Net Energy.
- State agencies shall also take measures toward achieving Zero Net Energy for 50% of the square footage of existing State-owned building area by 2025.
- To facilitate achieving these goals the following shall apply:



LARGE SCALE ZERO ENERGY

American Geophysics Union Net Zero Renovation in DC

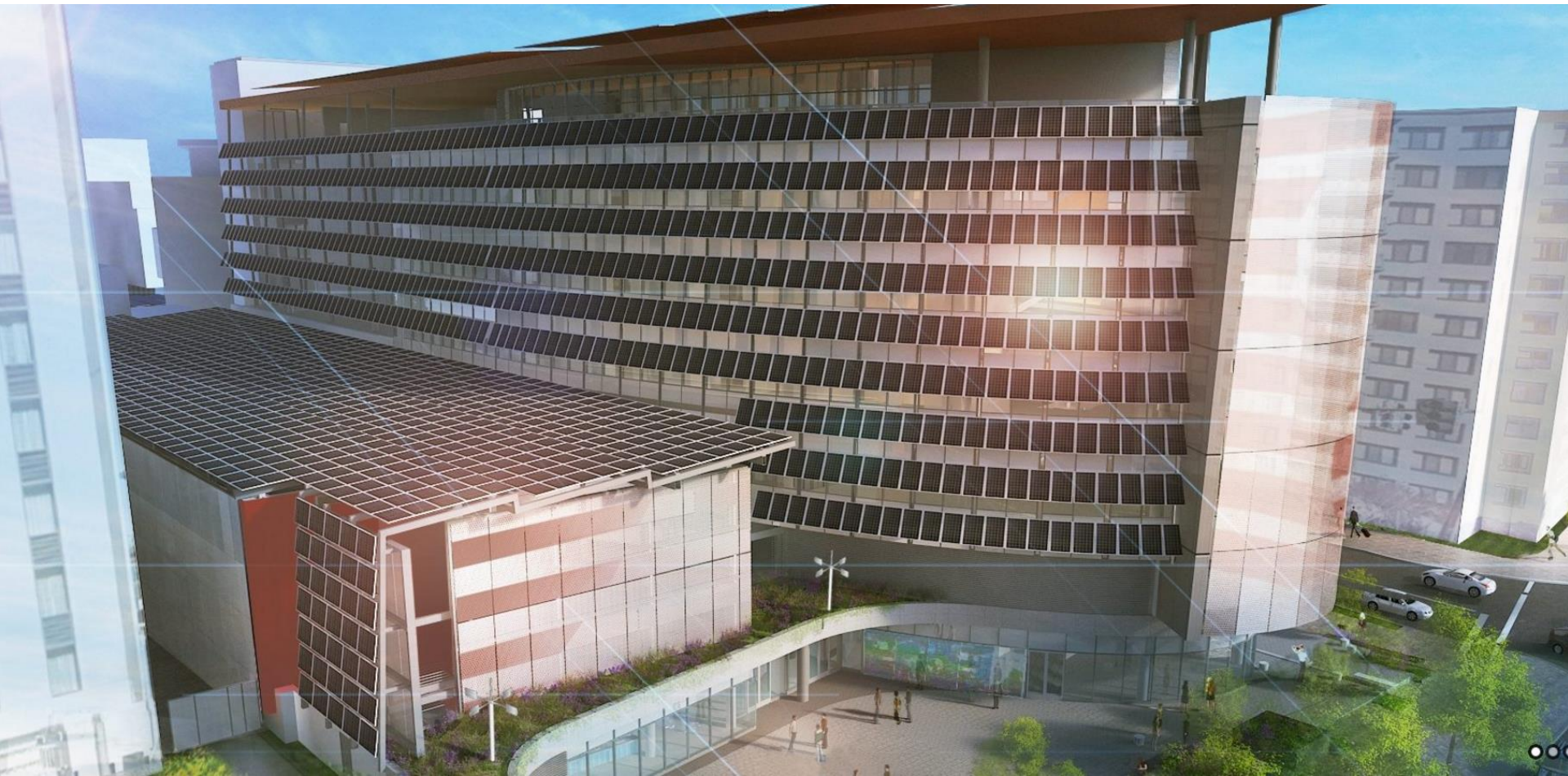
<http://building.agu.org/>



United Therapeutics Unisphere

Net Zero New Construction Goal, Silver Springs, MD

<http://utunisphere.com/>



Taller requires more creative PV integration

South Façade PV in Denver produces more than optimal tilt in Northeast...

- 1,000 kWh/kW+
- Also provides seasonal balance with winter peak production
- Image credit Bouldercommons.com



High Load Net Zero Labs

BRISTOL COMMUNITY COLLEGE

Image courtesy Sasaki Architects



NREL/DOE Research Support Facility

Location: Golden, CO

Primary Use: Office

Size: 360,000 ft²

Occupants: Approximately 1,325

LEED Rating: Platinum

Construction Cost: \$254/ft²

Energy Budget: 35 kBtu/ft²/yr

DOE Net Zero Energy Goal:

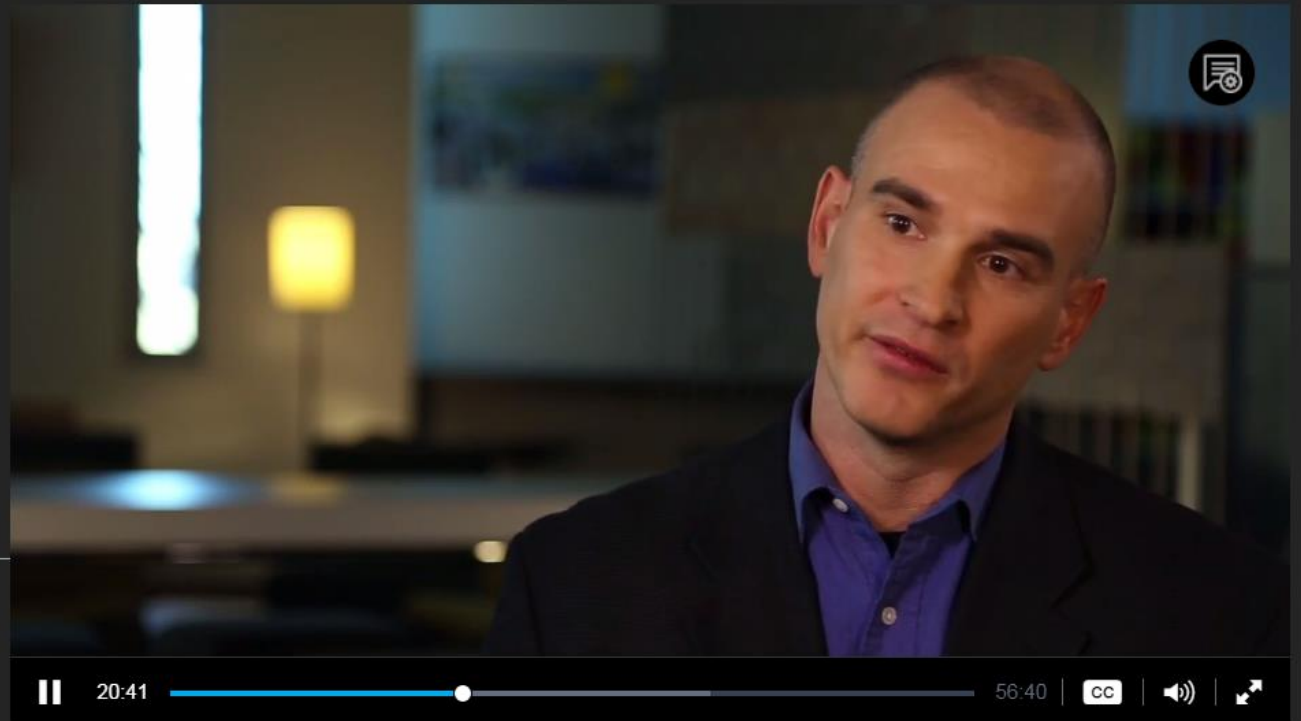
Offices, datacenter, and parking
with on-site PV

Utilize Design Build Contract,
warranty and incentive program to
ensure EUI targets met



Building Below Zero: The Net Zero Plus Transformation

Actor and environmentalist Ted Danson narrates this examination of the Net Zero Plus Transformation: buildings that produce and store more energy than they consume, lowering greenhouse gas emissions and potentially impacting global climate change.



Building Below Zero: The Net Zero Plus Transformation

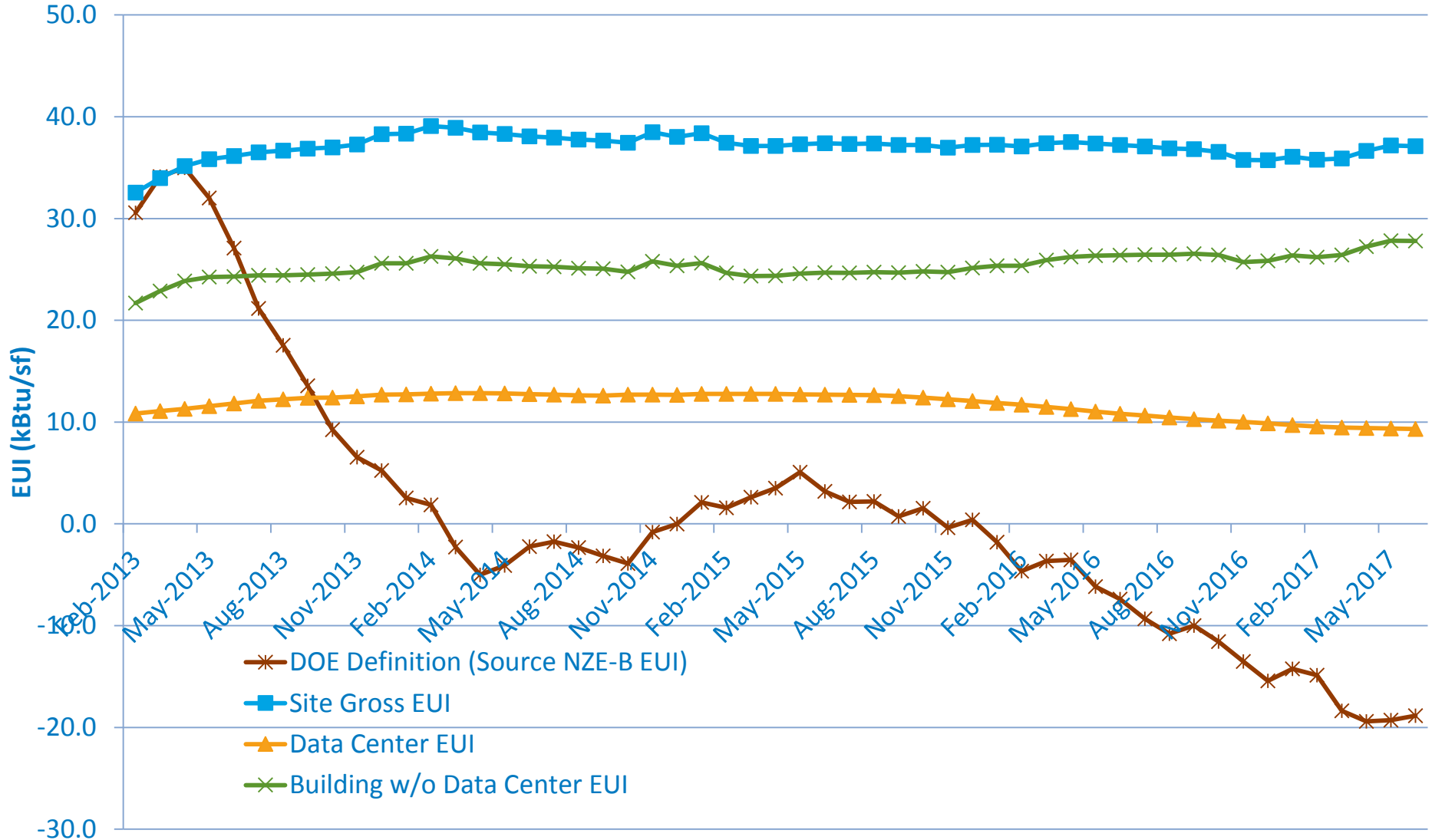
Aired: 10/19/2016 | 0:56:40

NREL CAMPUS



3 Years of Zero Net Energy Operations

RSF Trailing 12-month Energy Use Intensity



What Worked

- Vacancy sensors in daylit spaces
- Performance based design build with energy performance requirements on a firm fixed price
- Plug load efficiency
- Insulation and thermal mass
 - Attention to details
 - Ask for a continuous insulation system
 - Focus on envelope component junctions



What works (cont.)

- 0.5 W/ft² lighting power density with 100% LEDs
 - Daylighting controls with north windows
 - Passive glare control with overhangs and NO shades/blinds
- Systems to turn equipment OFF
 - Lights
 - Fans
 - Pumps
 - Plug loads
- Decoupled outdoor air with water hydronic heating and cooling
- Power purchase agreements for PV
- Passive and SIMPLE!

How-to Guides for Cost Control



<https://buildingdata.energy.gov/cbrd/resource/1655>

Discusses the recommended strategies

Pairs strategies with industry examples of success in ZEBs and other high-performance buildings where possible

Describes how to balance key decision-making factors

Provides quick reference tables to help building owners and project teams apply the recommended strategies to their projects.

ZERO ENERGY IS ACHIEVABLE



Read about
ZE Schools

What do we mean by zero energy?

A zero energy building, or ZEB, is an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the onsite renewable exported energy.

<https://www.zeroenergy.org/>

DOE Zero Energy K-12 Schools Accelerator

Vision

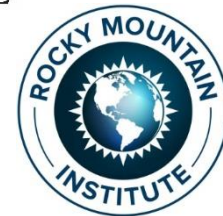
K-12 school buildings provide healthy, dynamic learning environments and resilient community assets that have zero to minimal energy costs

Accelerator Goals

- **Identify** strategies to overcome barriers to building ZE K-12 schools and realizing the associated health, savings, and resiliency benefits
- **Share** solutions, resources, and technologies that help schools achieve ZE goals
- **Develop** replicable road maps to build ZE schools and achieve associated benefits
- **Increase** visibility and replication of best practice approaches and successful models

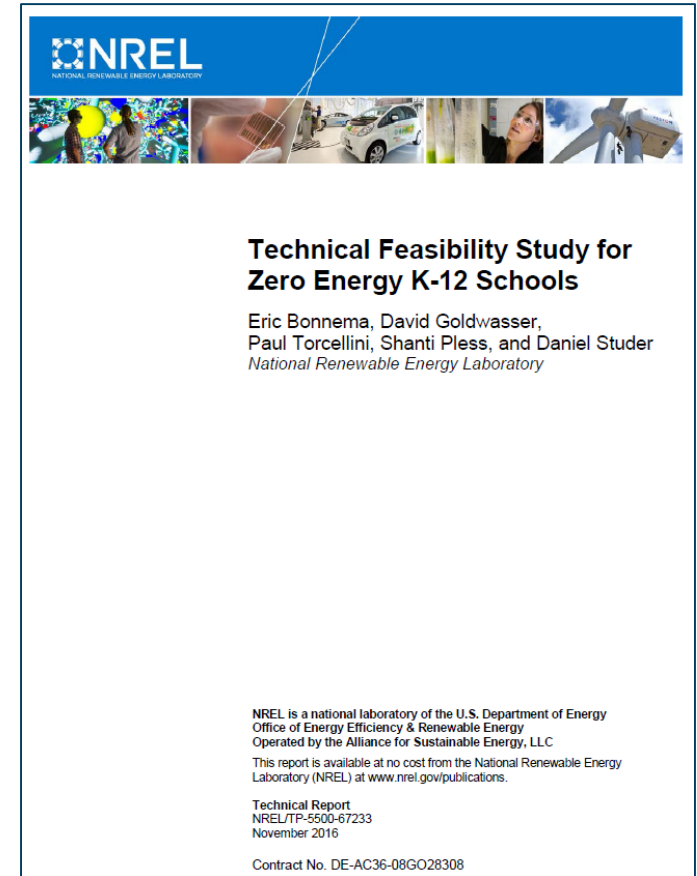
Current Accelerator Partners

- Implementing (Districts)
 - Hermosa Beach City School District
 - LA Unified School District
 - Arlington School District
 - Boulder Valley School District
 - Adams 12- Five star schools
- Implementing (States)
 - California, Minnesota
- National
 - NEED
 - NEEP
 - SoCalEd
 - TEC
 - NBI
 - NASEO
 - RMI
 - A4LE
 - U.S. Department of Education



Accelerator Will Demonstrate ZE/ZER Pathway

- Establish EUI targets to drive energy efficiency (approximately 50-70% savings) such that ZE/ZER is possible for schools through [Technical Feasibility Study for Zero Energy K-12 Schools](#)
- Show that ZE/ZER schools are possible within conventional construction budgets
- Work with school districts and states to identify barriers to ZE/ZER schools creating solutions to overcome these barriers
- Identify and create resources to accelerate the construction of ZE/ZER schools

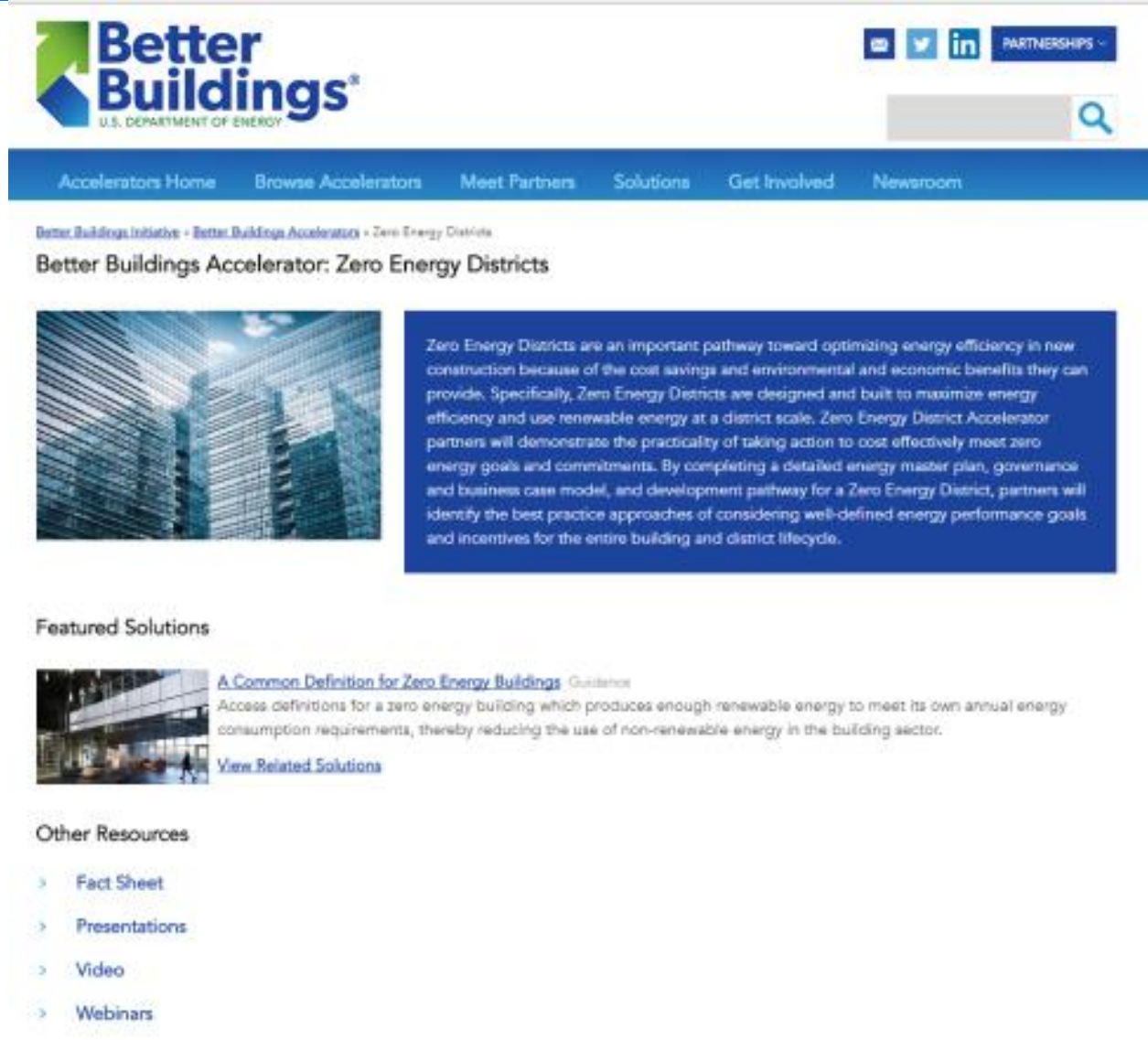


Zero Energy Districts Accelerator Launch 11/16/2016

DOE Building Buildings Accelerator

<https://betterbuildingsinitiative.energy.gov/accelerators/zero-energy-district>

<http://www.energy.gov/eere/articles/energy-department-announces-partnerships-under-new-better-buildings-zero-energy>




The screenshot shows the website for the Better Buildings Accelerator, specifically the Zero Energy Districts section. The header includes the Better Buildings logo (U.S. Department of Energy) and social media icons for YouTube, Twitter, and LinkedIn, along with a 'PARTNERSHIPS' dropdown menu. A search bar is located on the right. The main navigation bar contains links for 'Accelerators Home', 'Browse Accelerators', 'Meet Partners', 'Solutions', 'Get Involved', and 'Newsroom'. Below the navigation, there is a breadcrumb trail: 'Better Buildings Initiative > Better Buildings Accelerators > Zero Energy Districts'. The main heading is 'Better Buildings Accelerator: Zero Energy Districts'. A large image of modern glass skyscrapers is on the left. To the right, a blue box contains text explaining that Zero Energy Districts are an important pathway toward optimizing energy efficiency in new construction because of the cost savings and environmental and economic benefits they can provide. Below this, a section titled 'Featured Solutions' includes a link to 'A Common Definition for Zero Energy Buildings' with a 'Guidelines' sub-link, a small image of a building at night, and a description: 'Access definitions for a zero energy building which produces enough renewable energy to meet its own annual energy consumption requirements, thereby reducing the use of non-renewable energy in the building sector.' Below this is a 'View Related Solutions' link. At the bottom, an 'Other Resources' section lists: 'Fact Sheet', 'Presentations', 'Video', and 'Webinars'.

Better Buildings
U.S. DEPARTMENT OF ENERGY

Accelerators Home Browse Accelerators Meet Partners Solutions Get Involved Newsroom


Better Buildings Initiative > Better Buildings Accelerators > Zero Energy Districts

Better Buildings Accelerator: Zero Energy Districts



Zero Energy Districts are an important pathway toward optimizing energy efficiency in new construction because of the cost savings and environmental and economic benefits they can provide. Specifically, Zero Energy Districts are designed and built to maximize energy efficiency and use renewable energy at a district scale. Zero Energy District Accelerator partners will demonstrate the practicality of taking action to cost effectively meet zero energy goals and commitments. By completing a detailed energy master plan, governance and business case model, and development pathway for a Zero Energy District, partners will identify the best practice approaches of considering well-defined energy performance goals and incentives for the entire building and district lifecycle.

Featured Solutions



[A Common Definition for Zero Energy Buildings](#) Guidelines
Access definitions for a zero energy building which produces enough renewable energy to meet its own annual energy consumption requirements, thereby reducing the use of non-renewable energy in the building sector.

[View Related Solutions](#)

Other Resources

- > Fact Sheet
- > Presentations
- > Video
- > Webinars

Accelerator Vision and Goals

Vision

Communities with energy efficient, resilient, cost-effective buildings and infrastructure are common throughout the U.S.

Goals

1. Support early adopters of ZE districts at two targeted and critical juncture points:
 - **Master planning** - including optimal district configurations and layout, building efficiency, renewable integration, utility partnerships, and district energy systems
 - **Financing and ownership structure** – including how to plan for, navigate and manage joint ownership structures, financing, and operations
2. Develop case studies, best practices, and pilot examples to support the replication of ZE districts

District Partners



Sun Valley Neighborhood
Denver, CO



Peña Station
Denver, CO



National Western Center
Denver, CO



Advanced Energy Community
Huntington Beach, CA



Advanced Energy Community
Fresno, CA



Old Ford Assembly Site
St. Paul, MN



Old Bethlehem Steel Site
Buffalo, NY

URBANopt

- Example web application built on modeling framework
- Using with partners to validate the modeling framework
- Demonstrate value of modeling framework to third-parties

Create Geometry

Manage input data

Building ID	Building Name	Year Built	Number of Stories	Number of Stories Above Street	Building Height	Number of Energy Modules	Height (ft)	Number of Modules	Number of Modules
1	Office	1980	10	8	100	10	100	10	10
2	Office	1980	10	8	100	10	100	10	10
3	Office	1980	10	8	100	10	100	10	10
4	Office	1980	10	8	100	10	100	10	10
5	Office	1980	10	8	100	10	100	10	10
6	Office	1980	10	8	100	10	100	10	10
7	Office	1980	10	8	100	10	100	10	10
8	Office	1980	10	8	100	10	100	10	10
9	Office	1980	10	8	100	10	100	10	10
10	Office	1980	10	8	100	10	100	10	10

Home Projects Admin Welcome, test@red.gov Sign out

URBANopt

Scenario Results: High Efficiency - District

Render By Variable: Min Max Units
 Net_Emb_Energy: -1.032E+7 2.036E+7 kWh

Visualize Results

Monthly Net Energy (kBtu)

Typical Buildings
 Annual Net Energy: 1077 (kBtu)

High Efficiency - Gas
 Annual Net Energy: 4770 (kBtu)

High Efficiency - All Electric
 Annual Net Energy: -687 (kBtu)

Compare Scenarios

URBANopt

BUILDINGS TOOLS

- File
- Select
- Draw
- Resize
- Rotate
- Move
- Zoom to Features
- Map Settings



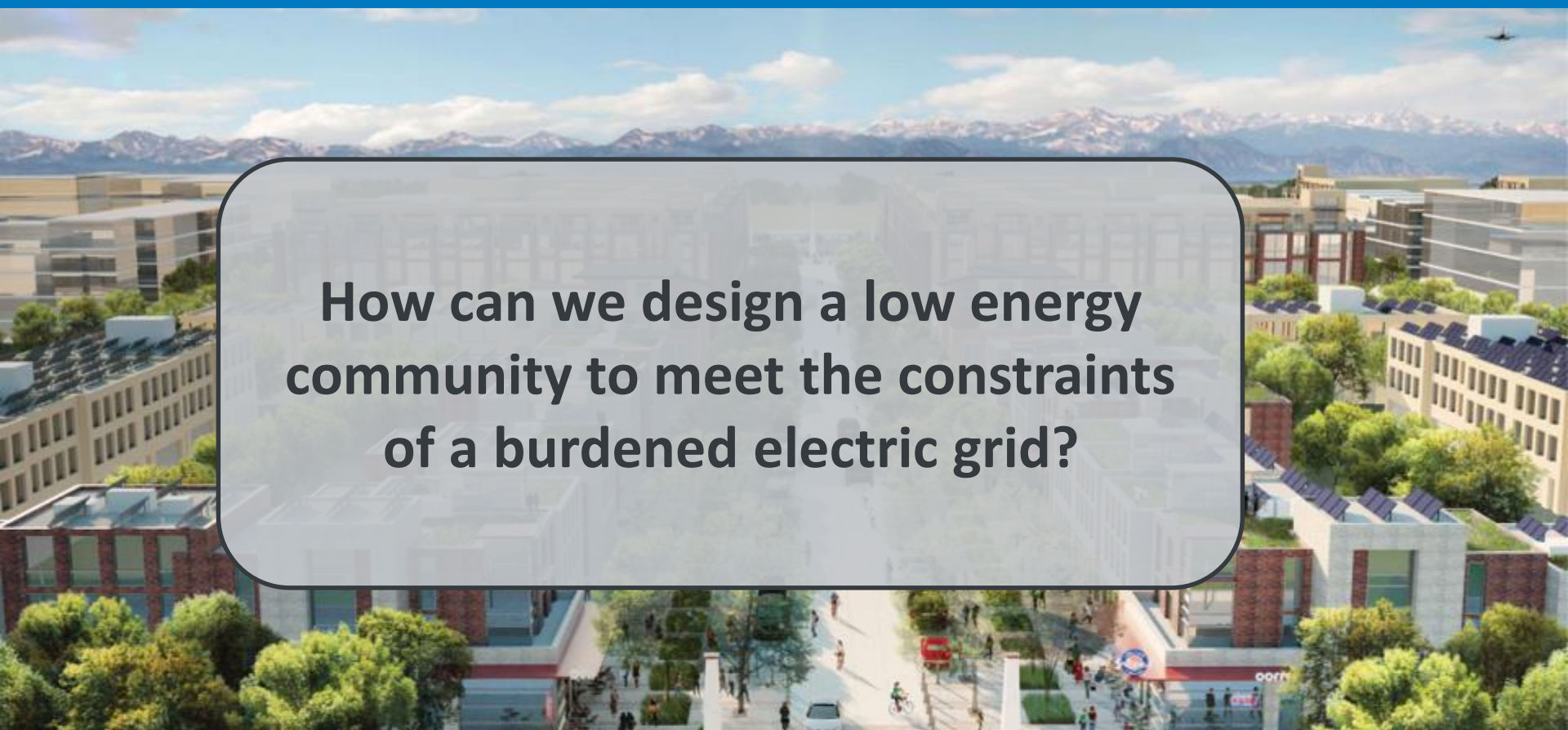
Building Properties Building Design Alternatives **Map Render Modes**

- NORMAL VIEW **RENDER BY BUILDING TYPE**

Render by Building Type

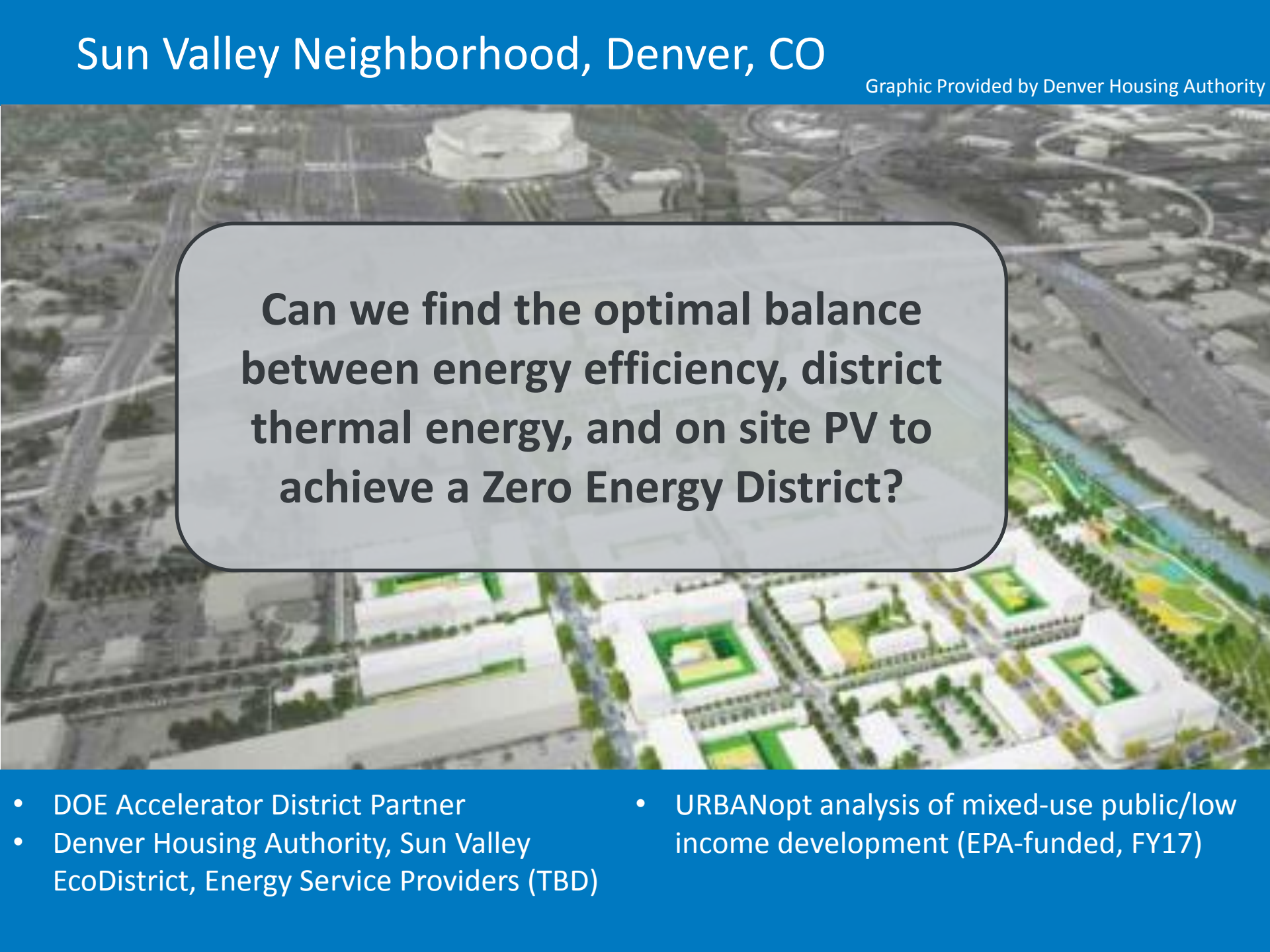
- | | | |
|---|---|--|
| ■ Single-Family | ■ Multifamily (2 to 4 units) | ■ Multifamily (5 or more units) |
| ■ Mobile Home | ■ Vacant | ■ Office |
| ■ Laboratory | ■ Nonrefrigerated warehouse | ■ Food sales |
| ■ Public order and safety | ■ Outpatient health care | ■ Refrigerated warehouse |
| ■ Religious worship | ■ Public assembly | ■ Education |

Peña Station Next, Denver, CO



How can we design a low energy community to meet the constraints of a burdened electric grid?

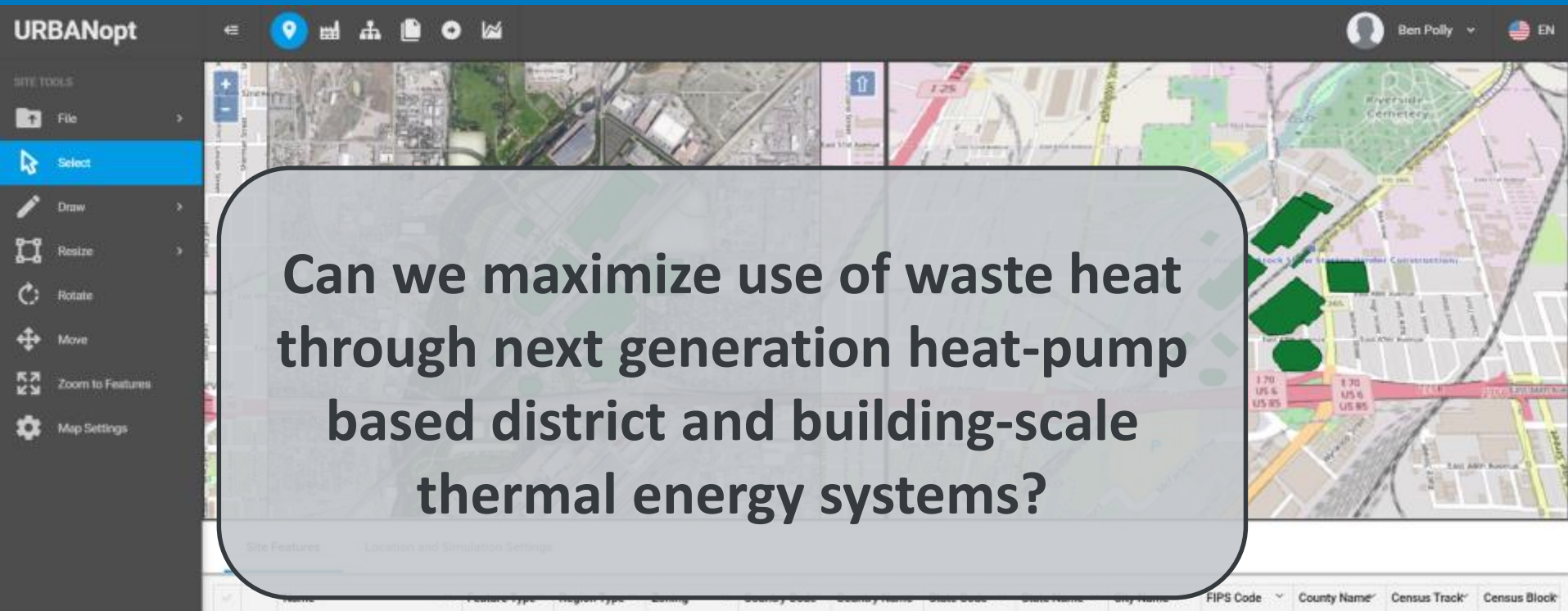
- DOE ESIF High Impact Project (FY17/18)
- 3-Way CRADA: Xcel Energy, Panasonic, DOE/NREL
- URBANopt and distribution system modeling (OpenDSS) to assess “non-wired” solutions
- Early results for baseline and energy-efficient cases for over 100 buildings



Can we find the optimal balance between energy efficiency, district thermal energy, and on site PV to achieve a Zero Energy District?

- DOE Accelerator District Partner
- Denver Housing Authority, Sun Valley EcoDistrict, Energy Service Providers (TBD)
- URBANopt analysis of mixed-use public/low income development (EPA-funded, FY17)

National Western Center, Denver, CO



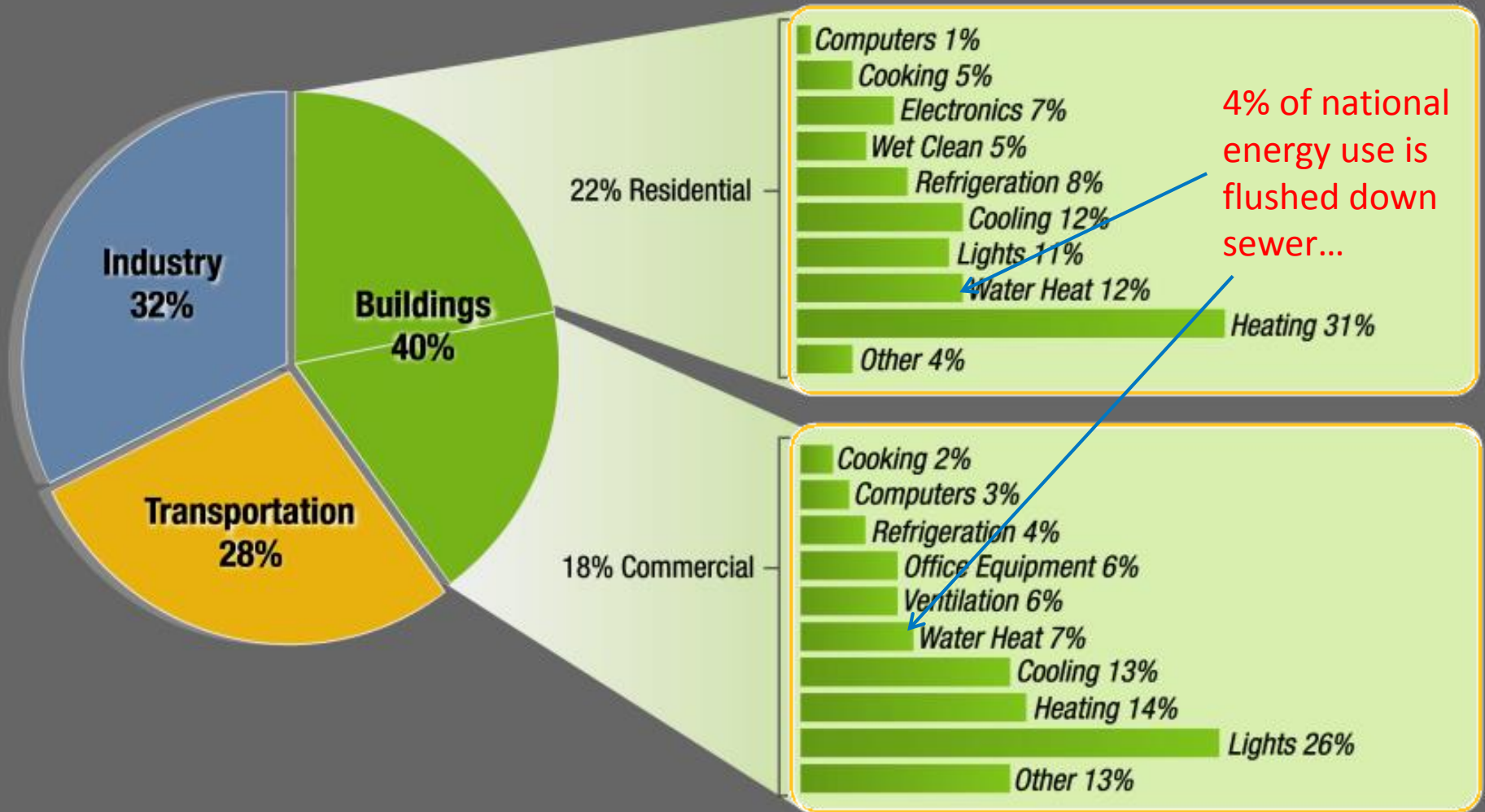
Can we maximize use of waste heat through next generation heat-pump based district and building-scale thermal energy systems?



Rendering Provided by City and County of Denver

- DOE Accelerator District Partner
- City of Denver, Colorado State University, Xcel Energy, CH2M,
- URBANopt development/workflow validation through NREL LDRD project (FY16/FY17)
- URBANopt helping set EUI targets; potential for OS modeling to evolve into Xcel EDA program modeling

Sewer Renewable Heat Mining



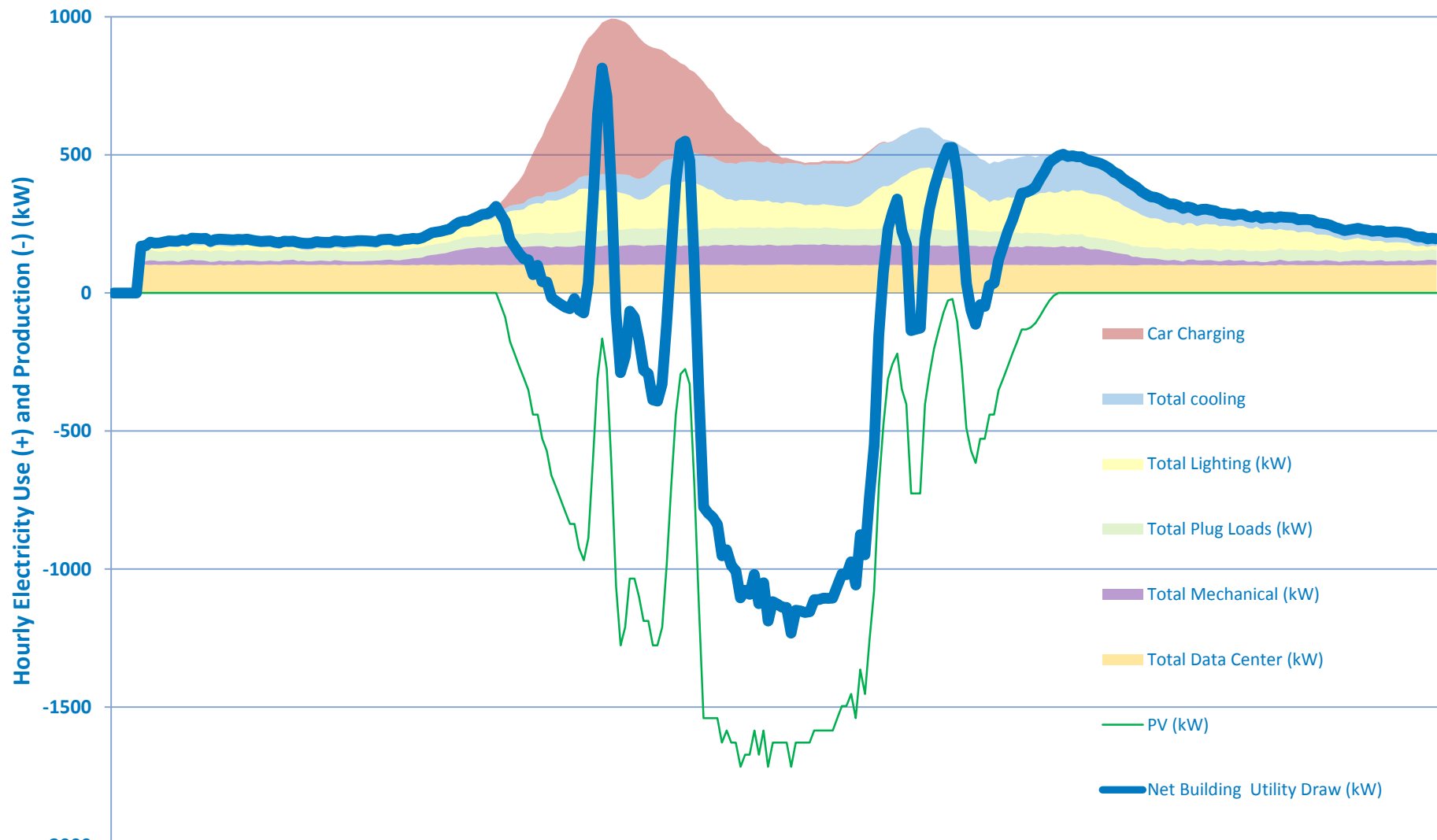
National Western Center

Image and Graphic Provided by City and County of Denver



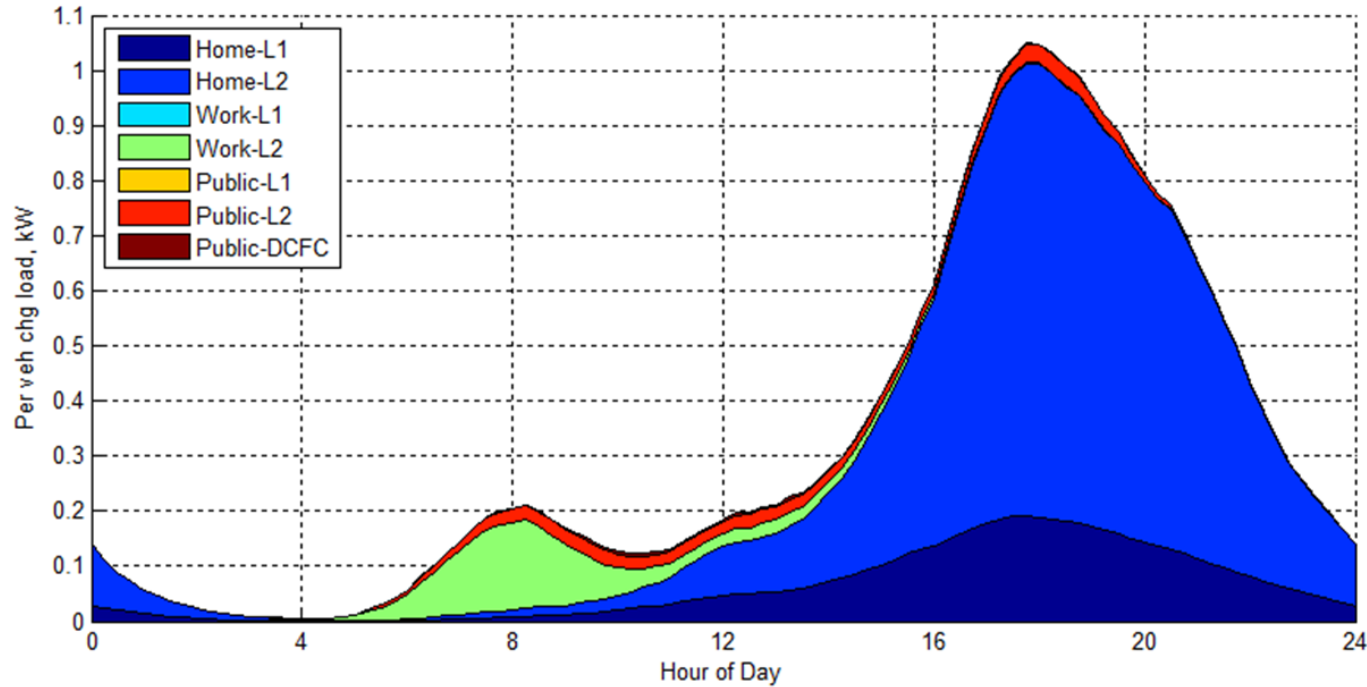
Potential for sewer heat recovery system tied to heat-pump based district and building systems

Uncontrolled Load Profile for a Zero Office Building



Optimal EV Charging Load Shapes?

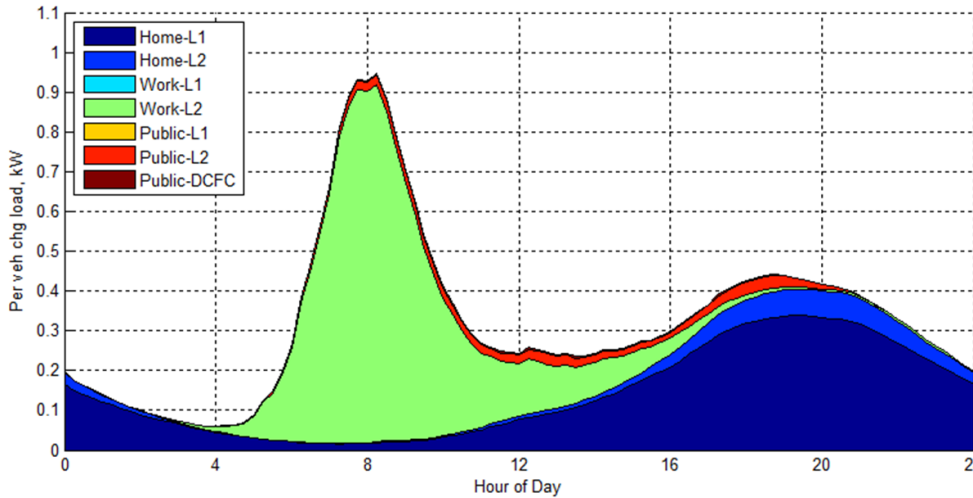
Home Dominant



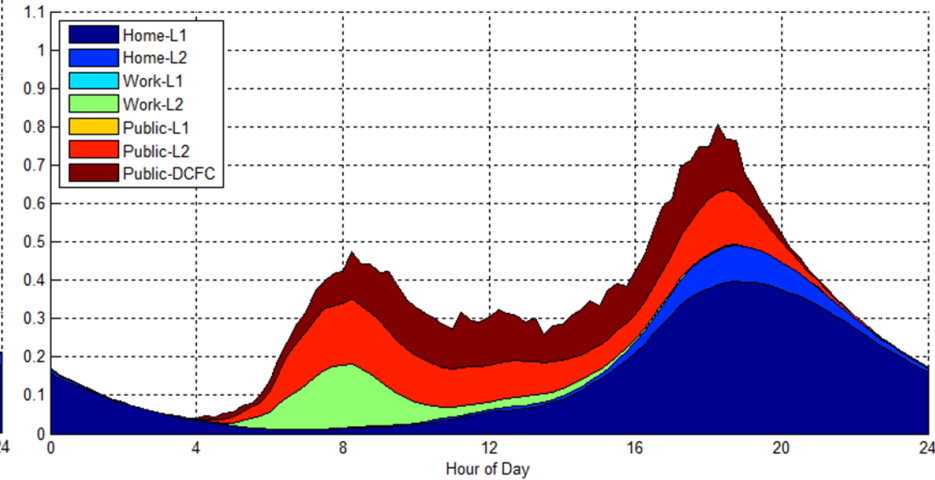
Output from EVI-Pro
Electric Vehicle
Infrastructure Planning
tool

<https://www.nrel.gov/docs/fy17osti/67436.pdf>

Work Dominant

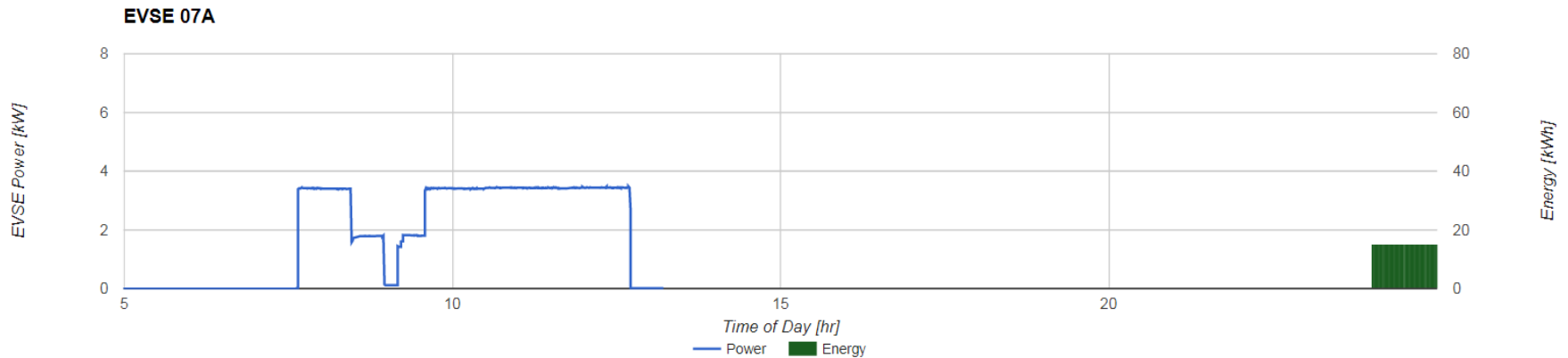


Public Dominant



NREL Parking Garage EVSE Status Display

9/11/2017, 1:18:36 PM



Departure Time: 5:00:00 PM

Miles Requested: 50 miles (about 14 kWh)

Energy Delivered: 15.136 kWh

Remaining Time: 0 minutes

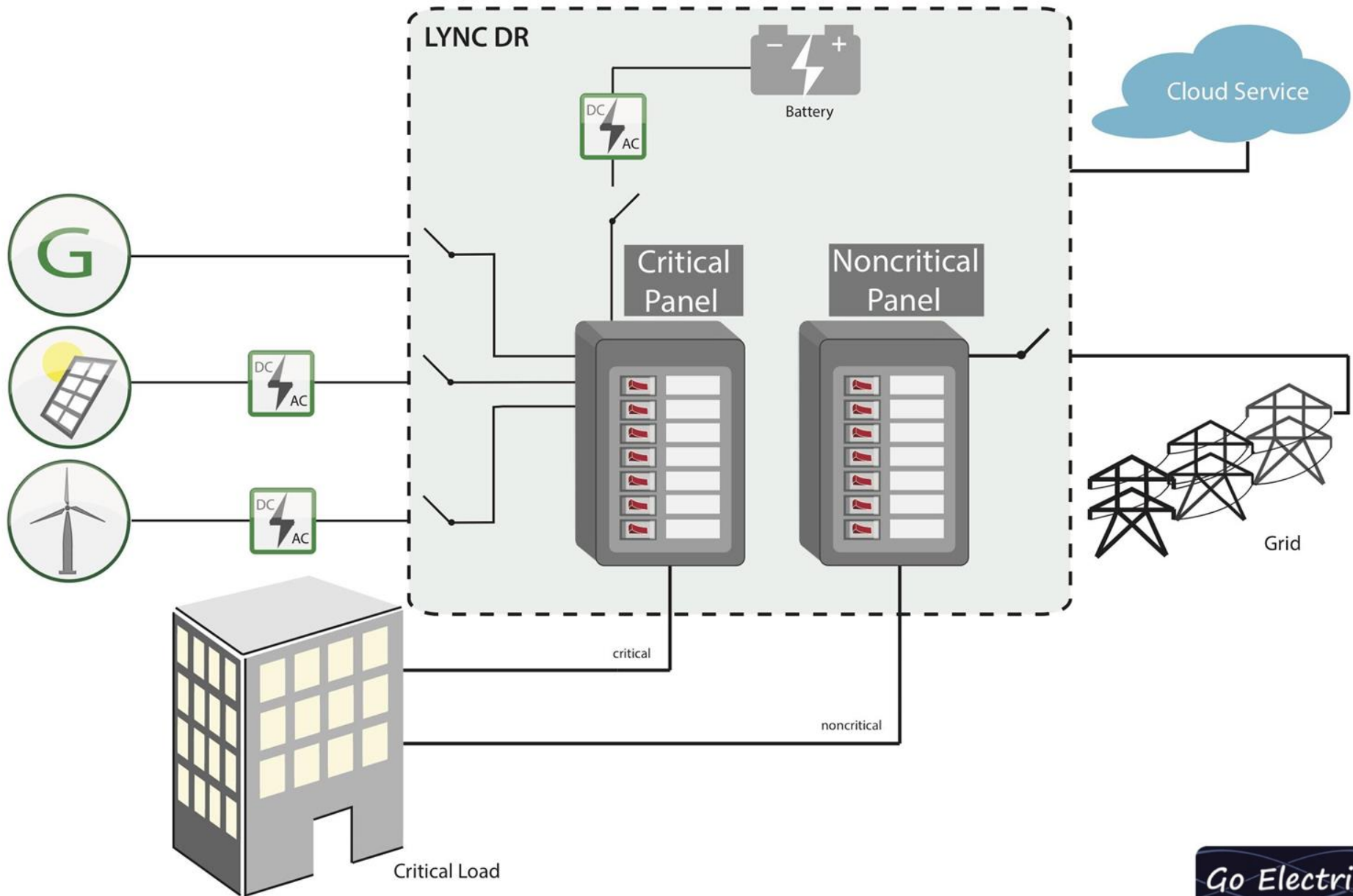
Charging Status: Charging Completed



Future Zero Energy Buildings Will Be...

- Grid Friendly
 - Reduce peak demand
 - Balance self generation and back-feed
- More resilient
 - Utilize efficiency and on-site renewables to enhance energy surety
 - Operational Islandable
 - Building scale microgrids
- And cost effective with viable business models

Battery Storage for Demand Management AND UPS



Is the answer just maximize your self consumption?

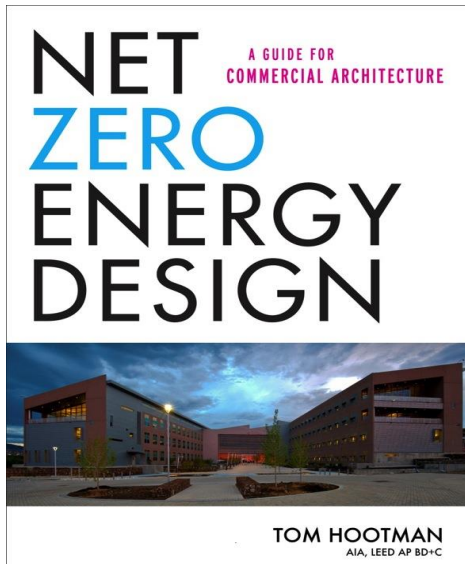
How to use as much of your on-site solar as possible?

- Design loads to match solar profile?
 - Electrification?
 - Electrification of hot water, EVs, and heating
 - Control load flexibility to match solar availability?
 - Make hot water during the day?
 - Charge your car at work or after midnight?
 - Integrate thermal energy storage?
 - Ice storage, hot water storage, building thermal mass?
 - Integrate electrical energy storage?
 - Power loads at night?
 - Fill up with excess during the day?
- Design PV system to match load profile?
 - Southwest tilt for summer afternoon peak production
 - South façade tilt for winter noon peak production
 - Southeast tilt for spring morning peak production
 - Flat roof tilt for Summer midday peak production
 - Dual axis or single axis tracker?

Thanks for your Time and Questions

Shanti Pless

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93% Eclipse Duck curve for ZNE in Colorado

