STATION 1: BIG PICTURE

Thermal Energy Networks for Decarbonization

INTRODUCTION

CLEER is leading a one-year feasibility and design effort funded by the Department of Energy's Geothermal Technology Office. This describes the Big Picture context for WHY. DOE is interested in helping communities develop Thermal Energy Networks that promise to decarbonize our nations buildings. This is because burning fossil fuels like gas or oil to provide heating, cooling, and hot water in buildings is one of the largest sources of air pollution and greenhouse gas emissions in the US. Eliminating the carbon emissions from buildings through decarbonization efforts helps meet local, state, and federal emission reduction goals to mitigate climate change, clean our air, and reduce our dependence on imported fossil fuels.

CLEER: CLEAN ENERGY ECONOMY FOR THE REGION

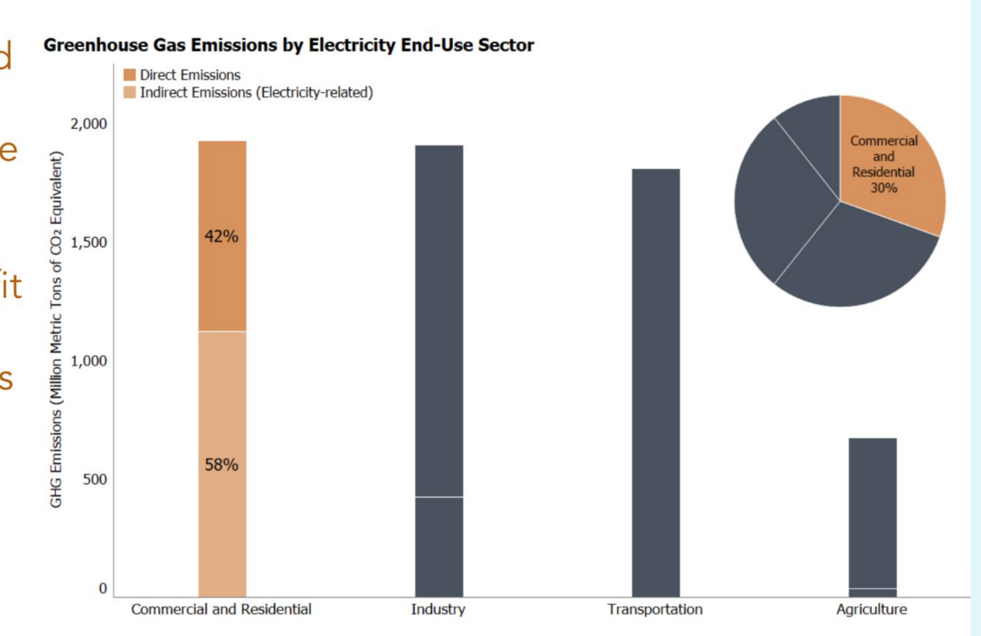
- **Applies** an integrated, systems approach to reducing greenhouse gas emissions focusing on built environment, renewables, clean mobility, economic diversification
- **Develops** and supports regional clean energy collaboratives to help households, businesses, & communities implement solutions (Garfield Clean Energy)
- **Drives** solutions and understanding of issues with energy data systems: Advanced Energy Management, GHG inventories, & economic analyses
- **Develops** coalitions, projects, & convenings to spur innovation

BUILDINGS ARE A MAJOR GHG CONTRIBUTOR

DIRECT EMISSIONS:
New buildings can be designed
- All electric for HVAC
- Net zero depending on site conditions

Existing buildings can be retrofit
- All electric for HVAC
- Multiple technical solutions with varying efficiencies

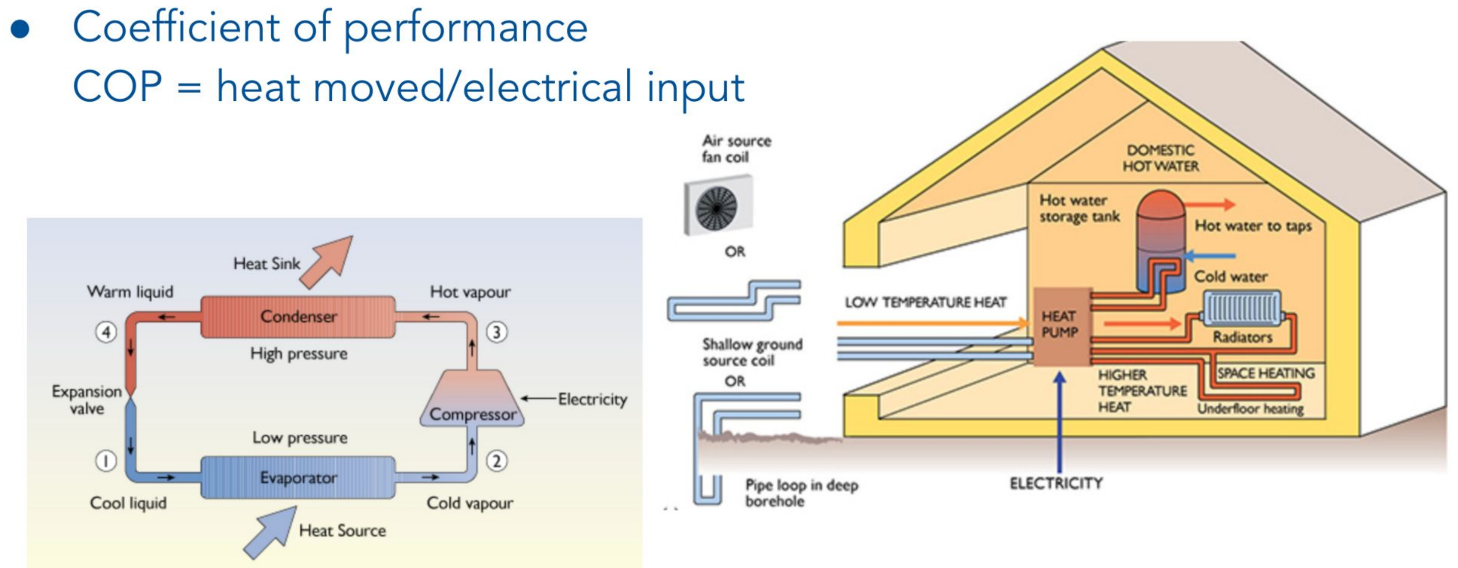
INDIRECT EMISSIONS:
Decarbonizing the grid
- Renewables
- Storage
- Demand management



Source: EPA https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

DECARBONIZING BUILDINGS W/HEAT PUMPS

- Use a compressor and a closed-loop liquid/gas cycle to transfer heat energy from the evaporator to the condenser.
- Coefficient of performance
  COP = heat moved/electrical input



Source: https://www.open.edu/openlearn/nature-environment/energy-buildings/content-section-3.3.1

EFFICIENCY IN BUILDING ELECTRIFICATION

Scenarios of U.S. seasonal electricity demand with ALL buildings electrified:

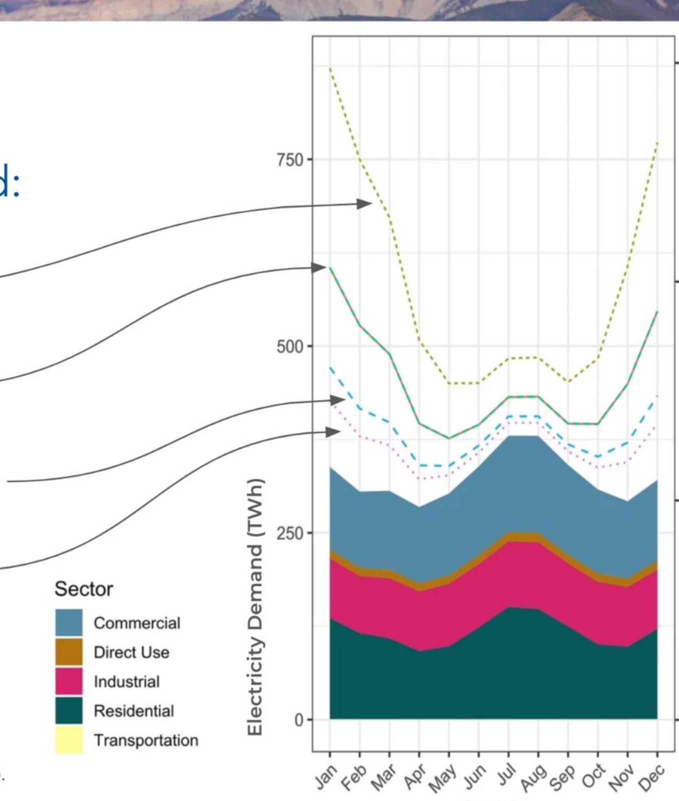
COP 1—Electric Baseboard

COP 2—Air Source Heat Pumps

COP 4—Ground Source Heat Pumps

COP 6—Thermal Energy Networks

COP = Coefficient of Performance



Buonocore, J.J., Salimifard, P., Magavi, Z. *et al.* Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage. *Sci Rep* 12, 11931 (2022). https://doi.org/10.1038/s41598-022-15628-2

SUMMARY

Thermal energy networks (TENs) are geothermal systems which use water-filled pipes in closed loops under the ground to both heat and cool buildings in a neighborhood, campus, or town center. Network pipes are installed at the same depth as gas or water pipes and are connected to geothermal bore-field loops and ground source heat pumps in buildings.

Thermal energy can be drawn out of the earth, returned to the ground for storage, and shared between buildings with different heating or cooling needs.

Thermal Energy Networks can also capture existing waste heat and put it to use to heat or cool buildings in the network. The more neighborhoods and multi-use buildings that are linked to the shared system, the more affordable and efficient it gets.

Benefits of Thermal Energy Networks Include:

- Safe & clean: With no oil or gas in the pipes, there's no risk of explosions or hazardous leaks, and no climate-damaging emissions.
- Affordable & reliable: Customer bills can be low and predictable year-round.
- Healthy: Nothing is burned inside, so indoor air is safer to breathe.
- Flexible: Systems are designed to fit many locations with minimal footprints.
- Resilient & secure: Durable, plastic pipes underground are protected from disruption.
- Equitable: As a community-scale solution, they can be available to everyone in a neighborhood, and fossil fuel workers can use skills they already have to install the networks.
- Local: We can build our own energy systems right in our communities.

STATION 2: CARBONDALE COMMUNITY GEOTHERMAL COALITION

Replicable Models for Decarbonizing Mixed-Use Rural Communities

INTRODUCTION

Representatives from CLEER and the Third Street Center formed the Carbondale Community Coalition as an offshoot of their work in 2017 to plan for a zero-energy district on a 16-acre parcel of land adjacent to the Third Street Center. The concept of a zero-energy district is that all of the energy needed to run the district is obtained from renewable sources either within the district or from off-site supplies. The initial members of the Coalition signed on to compete for a Department of Energy Grant from the Geothermal Technologies Office and CLEER developed a winning proposal. Phase 1 is a one-year design effort and Phase 2 is a multi-year Deployment effort, if selected for follow-on funding by DOE in the fall of 2024.

COALITION MEMBERS

CLEER: working since 2008 to cut carbon emissions, and to strengthen and diversify our regional economy.

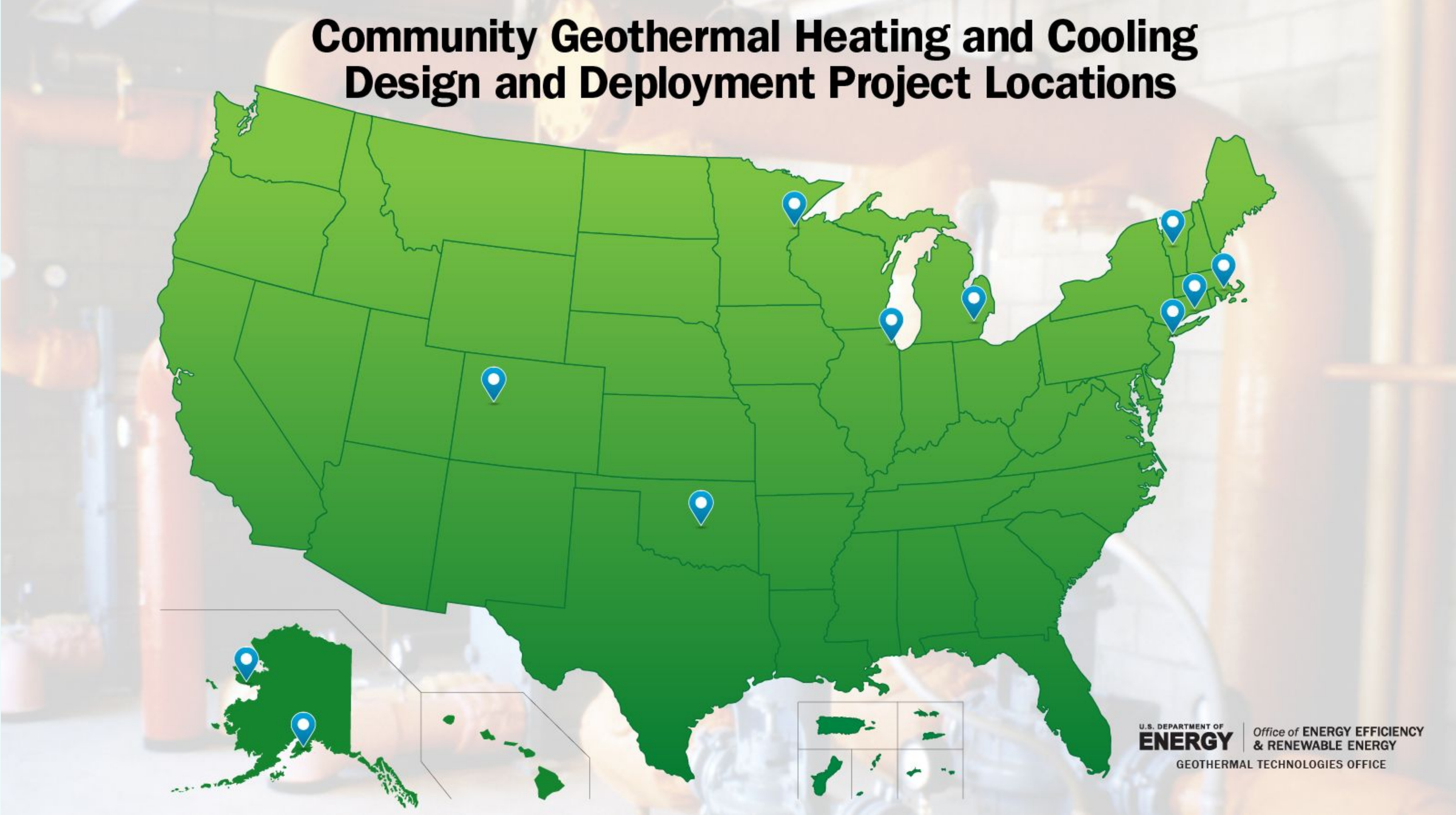
Town of Carbondale: A population of 6,434, has set climate goals around carbon emissions and energy efficiency.

Third Street Center: A 1960's school renovated into a green facility with 45,100 ft^2 affordable space for 36 non-profits.

2nd St Townhomes: Built in the 70s and provides a mix of ownership and rental opportunities. Individually owned and managed.

Roaring Fork School District: Property owner with multiple uses occurring including teaching, continuing education, housing, and administration.

Garfield County Library District, Carbondale Branch: Property owner with on-site PV and desire to minimize energy consumption.



CARBONDALE'S 16-ACRE SITE

Facility	Capabilities/Resources	Square footage	Net Electric (MWh/yr)	Annual Gas (billion Btu/yr)	Total Energy Use (GWh/yr)	Percent of Total Energy
Third Street Center	Built in 1961 with later additions. Retrofit in 2010. A net-zero electric building heated w/natural gas.	45,100	-20.9	1.44	0.47	19.2%
Second Street Townhomes	Built in 1970s—20 townhome units, two stories. Range in size from 1,400 to 1,600 sf.	28,144	107.2	1.27	0.48	19.3%
RFSD Admin / Bridges High	Built in 1920's and 1980's with renovation in 2015.	43,390	240.0	1.90	0.84	33.9%
Carbondale Branch Library	Built in 2013 w/PV	13,000	84.0	0.70	0.32	12.9%
RFSD Staff Housing	Built in 2018—20 units in four buildings, with a mix of unit types: townhouses and flats.	33,000	121.8	0.83	0.36	14.7%
Total	**Mix of uses including education, public, non-profit commercial & residential**	**162,634**	**532**	**6.1**	**2.5**	**100%**

TECHNICAL PARTNERS

National Renewable Energy Lab:
transforming energy through research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.
Responsible for modeling of the buildings and Ambient Temperature Loop system

The GreyEdge Group:
Specializes in architecture, engineering, and design of complex thermal energy systems. Successful systems are operating around the world from single-family homes to large district geothermal systems including a 123-story skyscraper. Has received national recognition for their system at Colorado Mesa University.
Responsible for test well & Ambient Temperature Loop system design

BigHorn Engineering:
Bighorn Consulting Engineers is a mechanical and electrical engineering firm dedicated to providing the highest quality consulting engineering services for commercial, educational, institutional and residential building clients. Bighorn Consulting Engineers is actively engaged in the "green" and sustainability movement in the building industry.
Responsible for building retrofit design

COMMUNITY & EDUCATIONAL PARTNERS

Garfield Clean Energy— helps residents, businesses and governments throughout Garfield County, Colo., become more energy efficient and tap clean energy as a means to creating a stronger, more resilient economy. It is supported in partnership with 6 municipalities, Garfield County and the 6 municipalities within the County.

Oklahoma State University—Garen Ewbank, also of The GreyEdge Group, supports efforts on workforce development for college and certificate solutions along with credentialing through the International Ground Source Heat Pump Association.

Colorado Mountain College—our region's community college with wide footprint in rural CO and multiple pathways for workforce development. CLEER and CMC are co-evolving a workforce development plan to support clean energy career pathways.

New Energy Technologies—has developed an education plus internship program focused on helping high school students develop their energy literacy skills and practical hands-on skills around building energy management.

STATION 3: BUILDING MODELING

Modeling buildings in the district to inform system design

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Abstract

Building energy modeling in this project allows the project team to better understand the heating, cooling, and domestic hot water needs of existing and future buildings of the Three-Two Zero Energy District. We leveraged NREL's URBANopt™ platform to generate the building models. A detailed monthly energy model calibration was performed for existing buildings using monthly utility bills. The building annual thermal load profiles generated by the building energy models were then used to inform the district loop design.

Introduction

Building energy modeling plays a crucial role in sustainable building design and operation by providing insights into energy consumption patterns, identifying energy-saving opportunities, and optimizing building performance.

- In this project, the building energy models allow the project team to better understand the heating, cooling, and domestic hot water (DHW) needs of existing and future buildings.
- This is achieved through careful model calibration to align with historical utility bills and then simulate the calibrated models annually to forecast future building performance.
- The hourly load profiles for heating, cooling, and DHW generated from these simulations serve as important inputs for the district loop design.

Relationship

1. The building annual thermal load profiles generated by the energy models are used to inform the district loop design.
2. The loop design parameters are then used in the district loop modeling to predict the actual loop operating performance.
3. The predicted loop performance can then guide building retrofit decision-making.

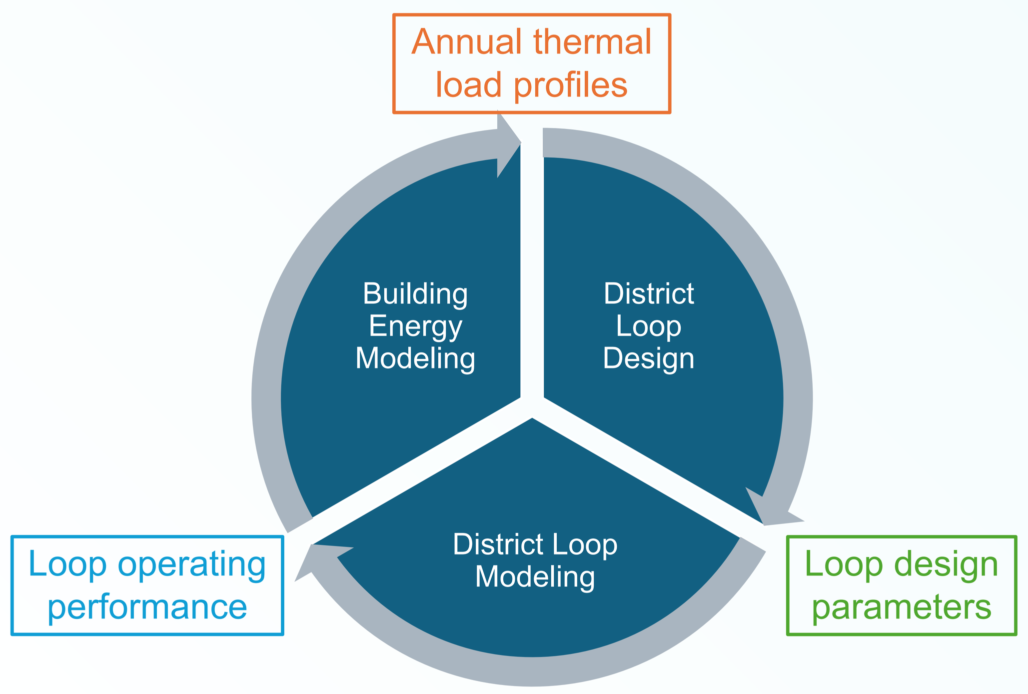


Figure 1: Relationship between building energy modeling, district loop design, and district loop modeling.

Methodology

1. URBANopt™ Platform

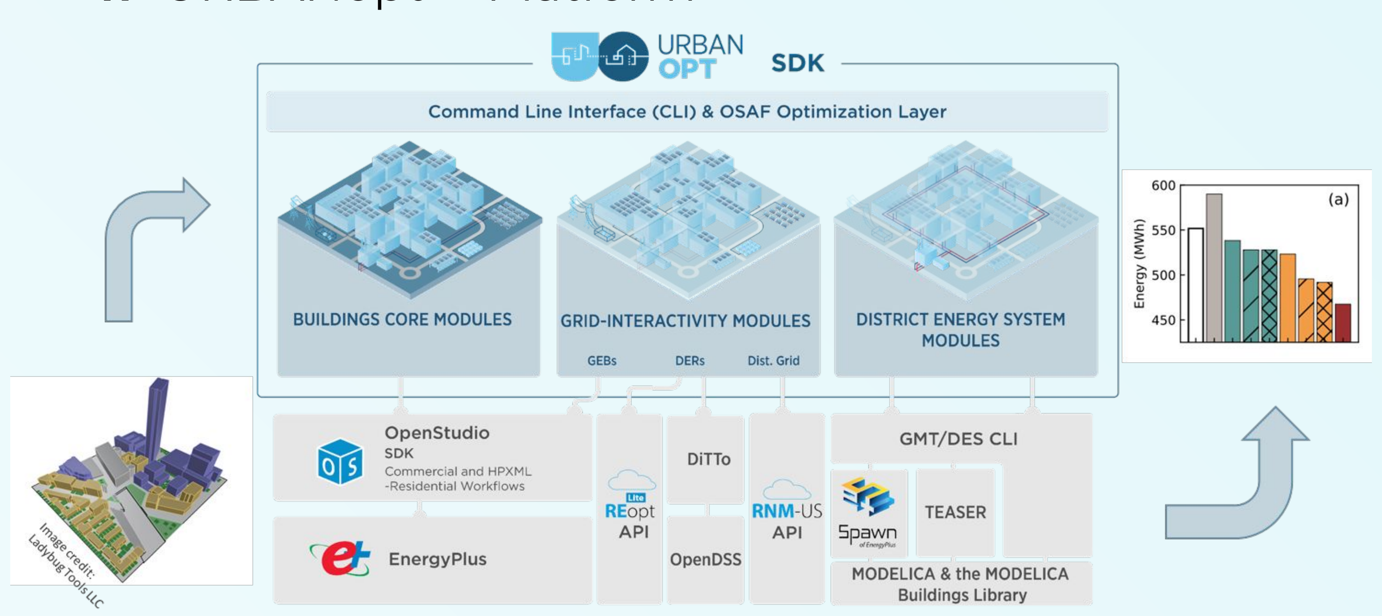


Figure 2: Modules of the URBANopt platform

URBANopt is an advanced analytics platform for high-performance buildings and energy systems within one geographically cohesive area within a city. It is an NREL-developed tool to investigate building and district energy strategies and technologies. URBANopt has three major modules:

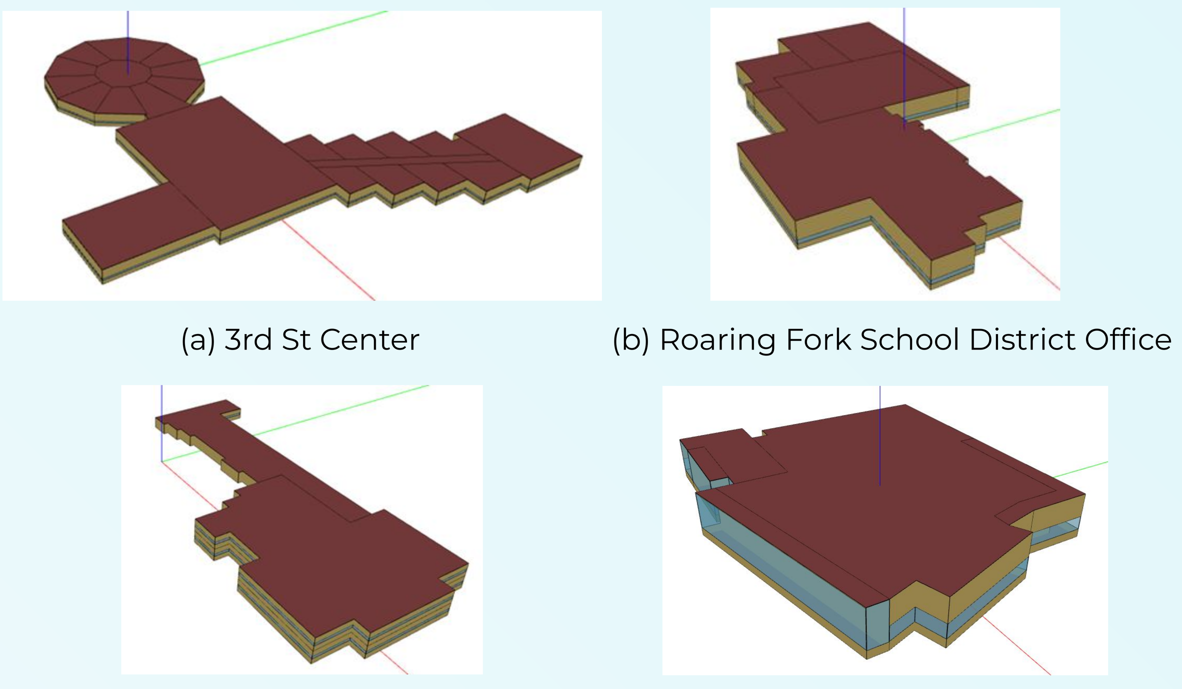
(1) building core module
(2) grid-interactivity module
(3) district energy system module.

2. Building Energy Models

The Three-Two Zero Energy District comprises:

- 3rd St Center
- 2nd St Townhomes
- 20 affordable housing units for teachers
- Bridges High School
- Roaring Fork School District's Carbondale Office
- Carbondale Branch Library.

Figure 3: Map view of the Three-Two Zero Energy District



(a) 3rd St Center (b) Roaring Fork School District Office (c) Bridges High School (d) Carbondale Branch Library

Figure 4: 3D views of the OpenStudio models of the 3rd St Center, Roaring Fork School District Office, Bridges High School, and Carbondale Branch Library as examples

Based on the building information collected, the NREL team completed energy modeling of all buildings in the district. URBANopt's building core module was used to generate the initial building models based on the DOE prototypical building models.

3. Loop Design Concept

- The district ambient temperature loop (ATL) will comprise a one-pipe central primary loop and two-pipe loops supplying and returning fluid to and from buildings and other thermal assets.
- The initial design only considers geothermal heat exchangers as heat sources/sinks for the loop. Additional thermal assets such as a wastewater heat recovery system and a solar thermal water heater can potentially be connected to the ATL to provide further heating if needed.
- The initial phase includes the 3rd St Center and the 2nd St Townhomes, and the remaining buildings will be included in the future development.

Model Calibration Results

A detailed monthly energy model calibration was performed for existing buildings using monthly utility bills. For existing buildings without historical utility data, we adjusted the building models based on engineering judgement to match annual gas energy usage intensity (EUI) values.

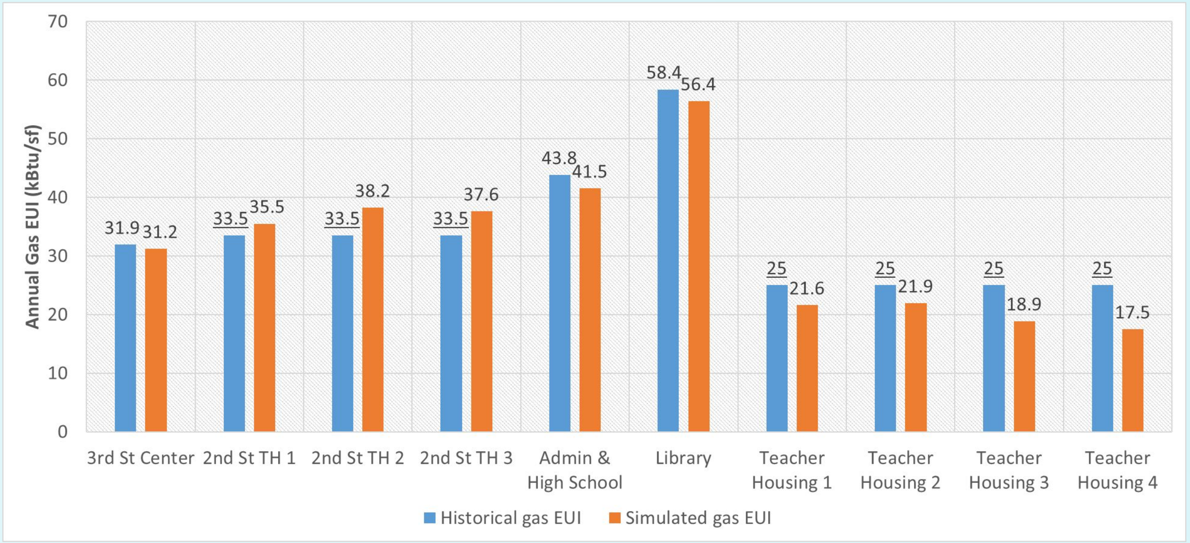


Figure 5: Comparison of historical gas EUI and simulated gas EUI for the building models

Results:

(1) For most of the buildings, the calibration results align with ASHRAE Guideline 14.
(2) The simulated gas EUI for the townhomes and staff housing are slightly deviated because the baselines for comparison are estimated values (underlined).

Next Steps

As next steps, we will utilize the building and district models generated from this project to investigate the following research topics:

- Different district energy system control logics to provide grid interactivity by utilizing system inertia.
- District system performance under resilience scenarios and the corresponding control strategies.
- Interplay between building energy efficiency measures and the thermal performance of the district loop.

STATION 4: DEPLOYMENT PLANNING

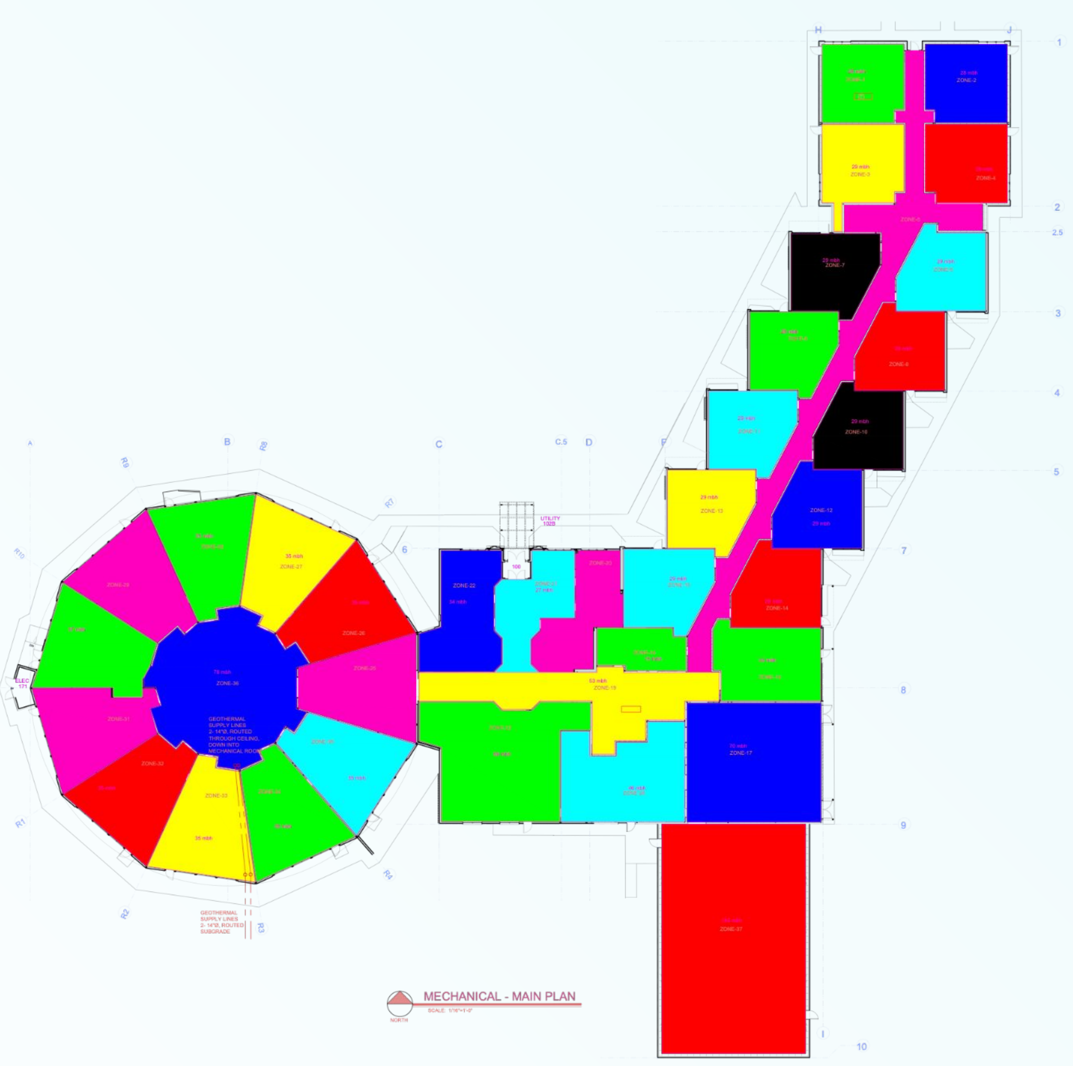
Design & Implementation Considerations

INTRODUCTION

The design team has broken up the deployment of the thermal energy network into multiple phases. The first phase is designed to serve both the Third Street Center and Second Street Townhomes. All of the land for this deployment is on Town of Carbondale property surrounding the Third Street Center. Subsequent phases of deployment are envisioned for the network to expand North to serve the Roaring Fork School District and Carbondale Branch Library parcels. It is also designed to expand to points South, East, and West. Note: the Second Street Townhomes are individually owned and are under no obligation to join this proposed system.

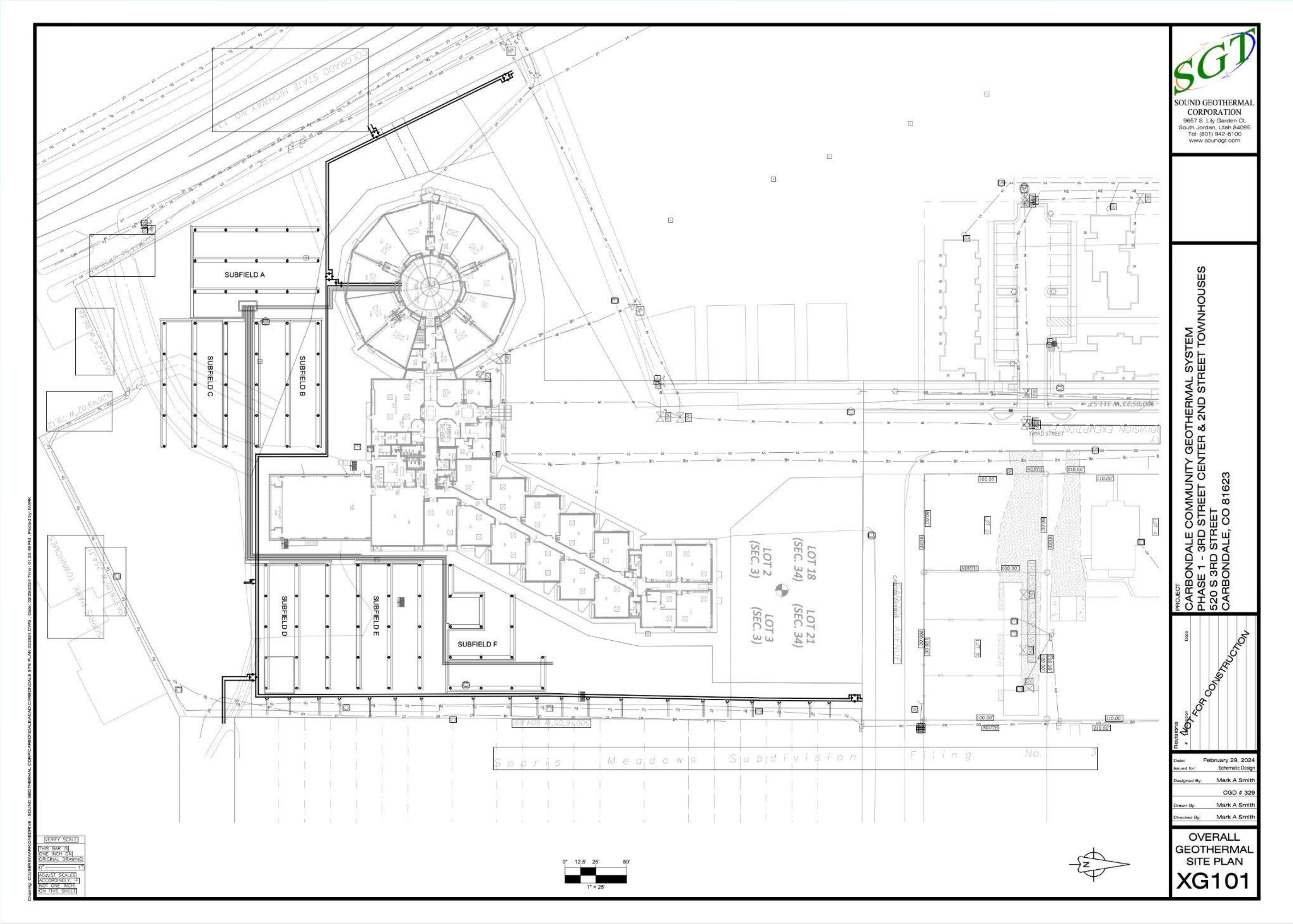
Building retrofits

Below is the preliminary heat pump zone design for the Third Street Center retrofit with internal water loop(s) for unitary water to air heat pumps. The design team is working on the retrofit design for the Second Street Townhomes.



Preliminary Ambient Temperature Loop

Below is the preliminary design of the bore field for the ground heat exchanger plus the below-ground infrastructure of the Ambient Temperature Loop. This initial design will be optimized as the team explores upgrading existing solar thermal and potentially waste heat recovery to reduce the number of bore holes and their associated costs and to increase efficiency of the system.



Construction, Ownership & Operation

The project team is exploring the following four options for the construction, ownership & operation of the thermal energy network being designed.

1. General Contractor built, owned by the Town of Carbondale, operated by a third party
2. Built, owned & operated by a Utility
3. Third-party built, owned & operated (with potential to transfer ownership to Town of Carbondale in the future)
4. General Contractor built, owned & operated by the Town of Carbondale

NEXT STEPS

- Finalize the retrofit and system designs
- Bring in general contractors to review designs and provide feedback before requesting bids
- Obtain bids for various aspects of the construction and building retrofits
- Model costs of the system
- Select a preferred construction, ownership and operational model
- Ongoing outreach to community and Second Street Townhome residents and owners
- Develop & submit a follow-on proposal to DOE to fund up to 90% of the deployment cost

CLEER
CLEAN ENERGY ECONOMY FOR THE REGION

the GreyEdge group

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
GEOTHERMAL TECHNOLOGIES OFFICE

STATION 5: THERMAL ENERGY NETWORK EXAMPLES:

TOWN OF CARBONDALE ESTABLISHED 1887

THIRD STREET CENTER

GARFIELD COUNTY LIBRARIES

ROARING FORK SCHOOLS

THESE CASE STUDIES WERE COMPILED BY VERMONT COMMUNITY THERMAL NETWORKS AND ARE AVAILABLE ON THEIR WEBSITE AT WWW.VCTN.ORG

Colorado Mesa University

Ground source heat pump networks can create considerable financial savings over time.

Location: Grand Junction, CO
Size: 1.2 million sq. ft.
Operating Since: 2008

Energy Savings:

- Carbon footprint reduced by 17,742 metric tons of CO_2 per year
- Saves 14,862,864 electric kilowatt hours per year
- Saves 705,986 therms per year

Features:

- Colder Climate
- New Construction & Retrofit
- College Campus
- Phased Construction
- Future Expansion

The CMU network serves a rapidly growing campus community.

- **The student population has quadrupled in the last decade.**
- **The system has expanded from 6 to 17 buildings and serves 11,000 students.**

Ground source heat pumps provide:

- Building heating and cooling
- Domestic hot water

What the students say:

"We're talking about millions of dollars saved… and that's translating directly back into students' pockets… my tuition this past year was two percent cheaper because of the GeoExchange program!"

- Evan G. Piper, Student Trustee

Reliability

In its first 12 years of operation, this system:

- Never had to rely on its gas backup for heating/cooling
- Accrued no maintenance cost other than a heat pump bearing replacement

Long-Term Savings

- Saves the college $1.5 million in energy costs per year
- Has saved nearly $12 million since 2008
- Enables CMU to offer the second-lowest tuition rate in Colorado

Growth Opportunities

CMU is looking to expand their campus network into the local community. Prospects include City of Grand Junction buildings and Grand Junction High School.

Green Streetscapes

Revitalization projects can attract new business and residents to rural towns by creating access to clean heating and cooling infrastructure.

Location: West Union, IA
Size: 330,000 sq ft
Operating Since: 2012

Project Cost:
$10.2 M (for full project)
$2.3 M (for ground source network)

Features:

- Rural Community
- Retrofit
- Revitalization Project
- Future Expansion
- Neighborhood Scale

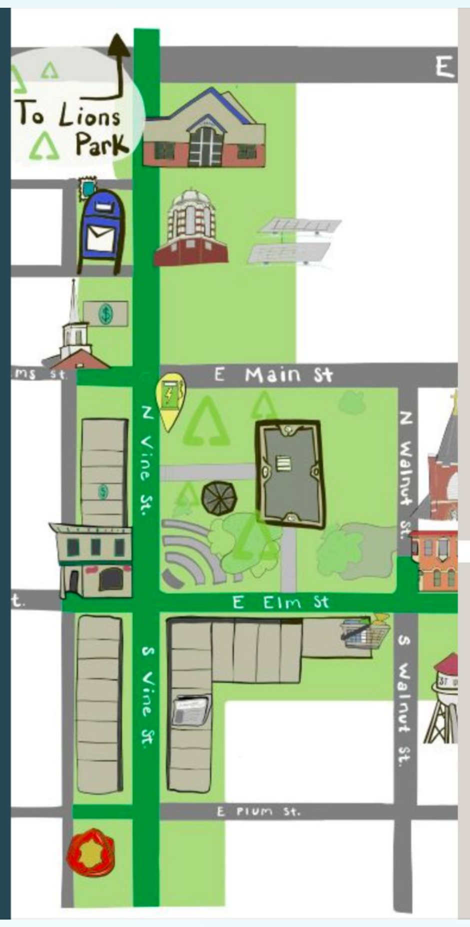
Green Streetscapes is a municipal revitalization project in downtown West Union, Iowa.

Project includes:

- **Ground source heat pump network:** 132 vertical wells under the courthouse lawn
- **Replacement of existing streets with porous paving**
- **Bioswales to handle flood water**
- **Civic plaza**
- **Sidewalks and street lighting**

The new ground source heat pump network can serve up to 60 buildings in the downtown area. As of 2023, it serves 12 customers who pay a monthly bill based on their energy use.

New participants must install their own indoor heat pumps in order to tap into the network. The town created financial incentives and tools to help new participants afford upfront costs.



Revitalization

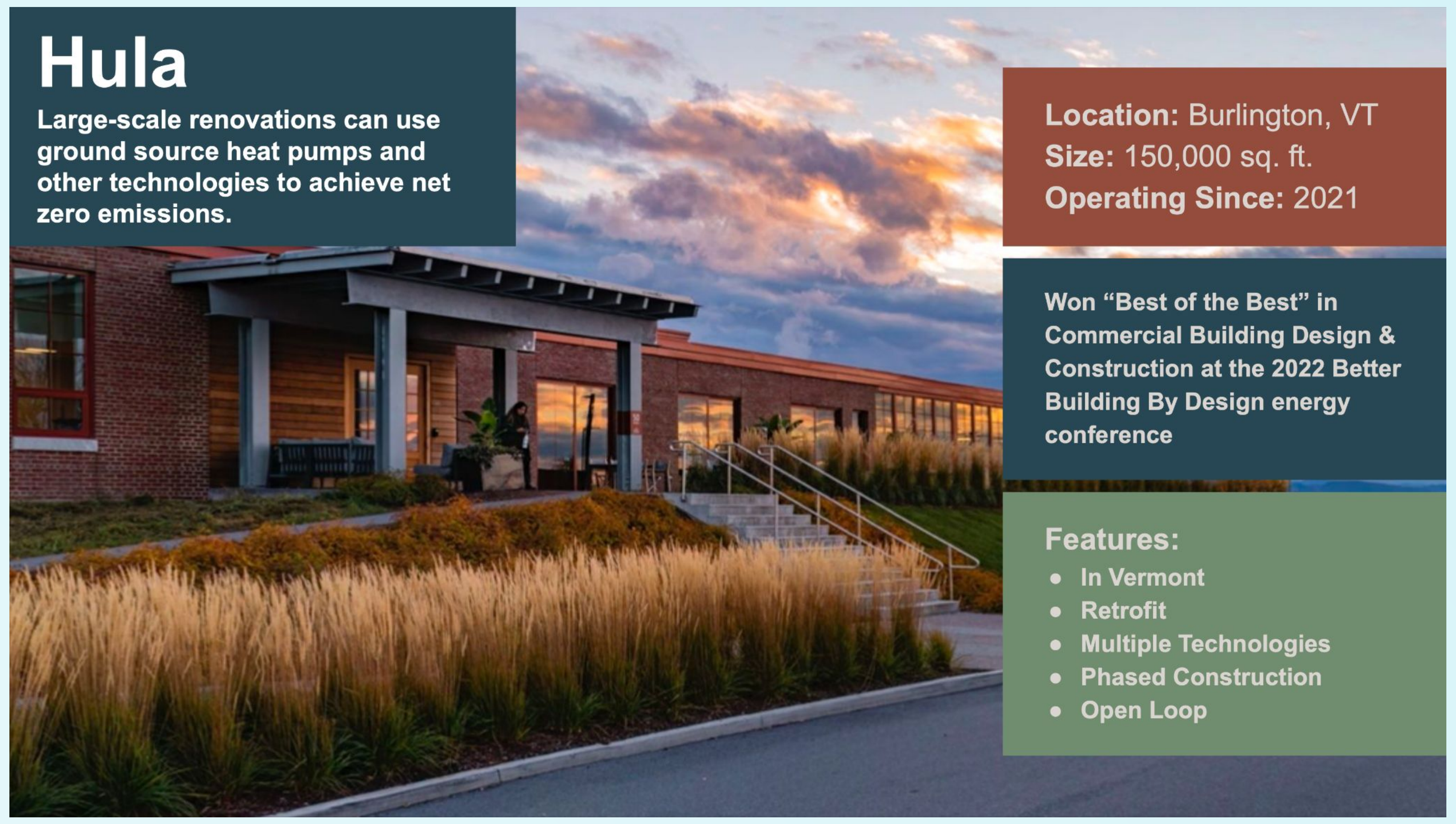
Like many rural communities, West Union suffers from decreased population growth.

This project hopes to attract businesses to the downtown with comfortable, clean, and affordable heating and cooling. The system will also create an increased demand for qualified solar and HVAC contractors.

The revitalization aims to attract new residents and businesses, stimulate the local economy, and build community.

Rural Community

West Union has a population of approximately 2,700 and is the county seat of rural Fayette County, making it comparable in size and structure to many Vermont towns.



Hula

Large-scale renovations can use ground source heat pumps and other technologies to achieve net zero emissions.

Location: Burlington, VT
Size: 150,000 sq. ft.
Operating Since: 2021

Won "Best of the Best" in Commercial Building Design & Construction at the 2022 Better Building By Design energy conference

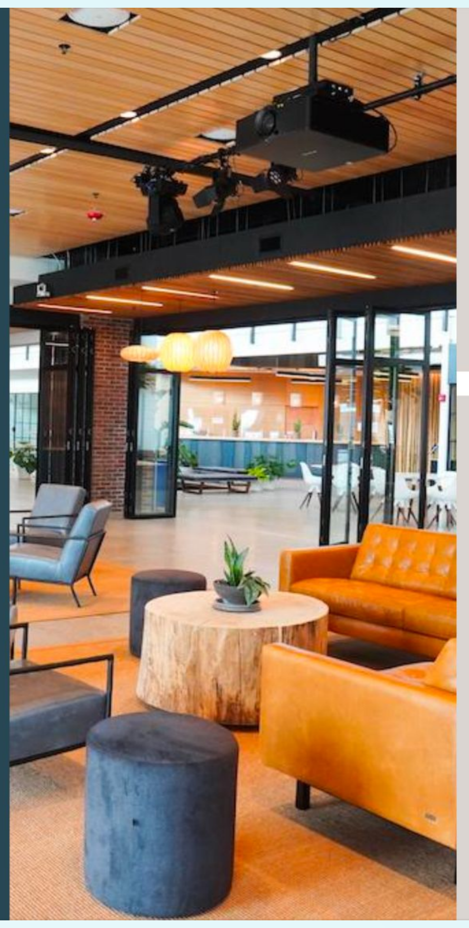
Features:

- In Vermont
- Retrofit
- Multiple Technologies
- Phased Construction
- Open Loop

Hula coworking space is housed in a refurbished oven factory on the shores of Lake Champlain.

Net zero emissions system features:

- Open loop ground source heat pump heating, cooling, and hot water
- Solar panels for electricity
- Highly efficient construction and building envelope
- Heat capture system for kitchen exhaust
- Heat pumps placed throughout buildings to distribute heating and cooling efficiently
- Includes 2 buildings and is expanding to serve more



Renovated Building Envelope

When renovating the oven factory, engineers paid special attention to the efficiency of the building's insulation. This is key when making retrofitted buildings viable for ground source heating and cooling.

Efficient Temperature Control

The buildings are equipped with many small scale indoor heat pumps which work together to transfer warm and cool air throughout the building. If, for example, one side of the building receives heat from direct sunlight, the system will distribute that solar heat to the shaded rooms of the building as needed before tapping into the ground source loop for warmth.

STATION 6:
OPEN HOUSE FEEDBACK & QUESTIONS

PLEASE LEAVE A STICKY NOTE WITH YOUR THOUGHTS BELOW

QUESTIONS	IDEAS TO CONSIDER	PUT ME ON CLEER's CONTACT LIST