SUNSATIONAL

University of Missouri

Park Avenue Apartments

Mixed-Use Multifamily
Design Competition 2019

U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

“Piece of Mind for a Lifetime”

Financial, Aging, and Health Security

Academic Institution

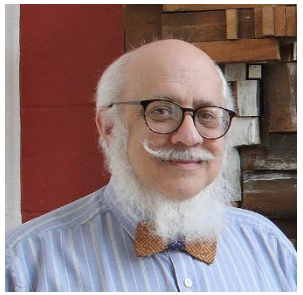
Department of Architectural Studies & College of Engineering

4-year undergraduate program in architecture and interior design (CIDA)

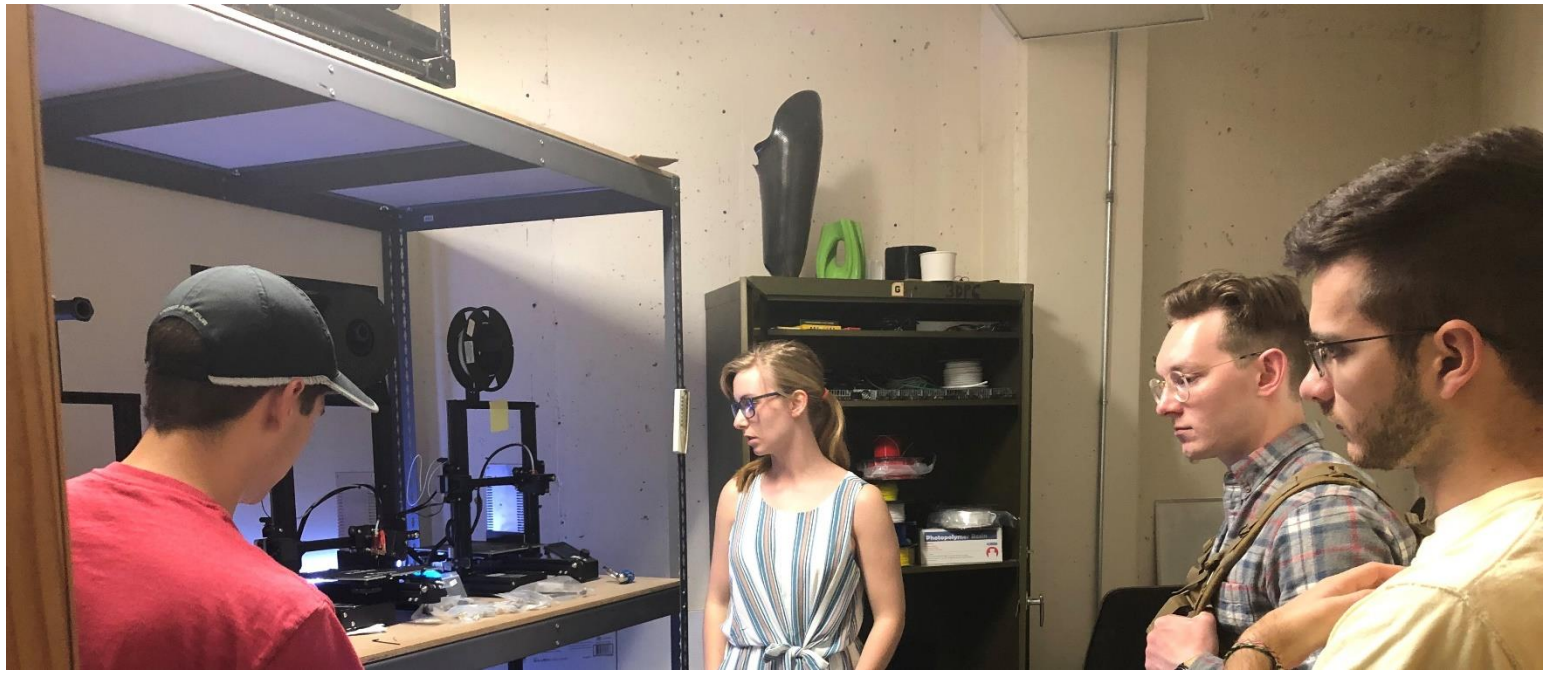
University of Missouri

Faculty Advisor

Michael Goldschmidt, AIA LEED AP BD+C



Associate Teaching Professor in the Department of Architectural Studies at the University of Missouri and a State Housing and Environmental Design Specialist with University of Missouri Extension.



Project Team

Megan Wahlquist
Team Leader
Junior

Jessica Blankinship
Architecture
Senior

Janee Thompson
Financial Analysis
Senior

Margaret Jordan
Interior Design
Senior

Brandon Smeets
Engineering
Senior

- 10 engineering capstone students (Fall 2018)
- 14 architecture and interior design students (ArchSt 4323, Sustainable Technologies)
- Faculty Lead Advisor Michael Goldschmidt
- Engineering Faculty Advisor Dr. John Bowders
- Two Additional Faculty Advisors (energy modeling & sustainable design)

Industry Partners

Columbia Housing Authority (CHA)

University of Missouri –Extension, Housing and Environmental Design
Midwest Energy Efficiency Research Consortium (MEERC)

The National Healthy Homes Partnership

City of Columbia Missouri- Office of Sustainability
and Office of Water and Light

Malicoat & Winslow Engineering

CM Engineering

Net Zero Structural Insulated Panels

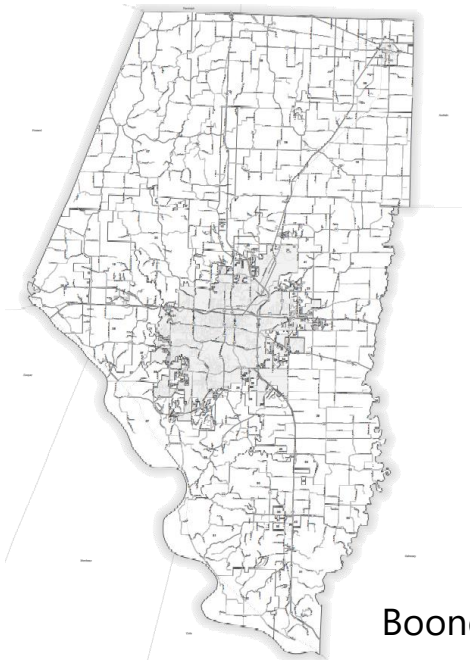
Quaker Windows

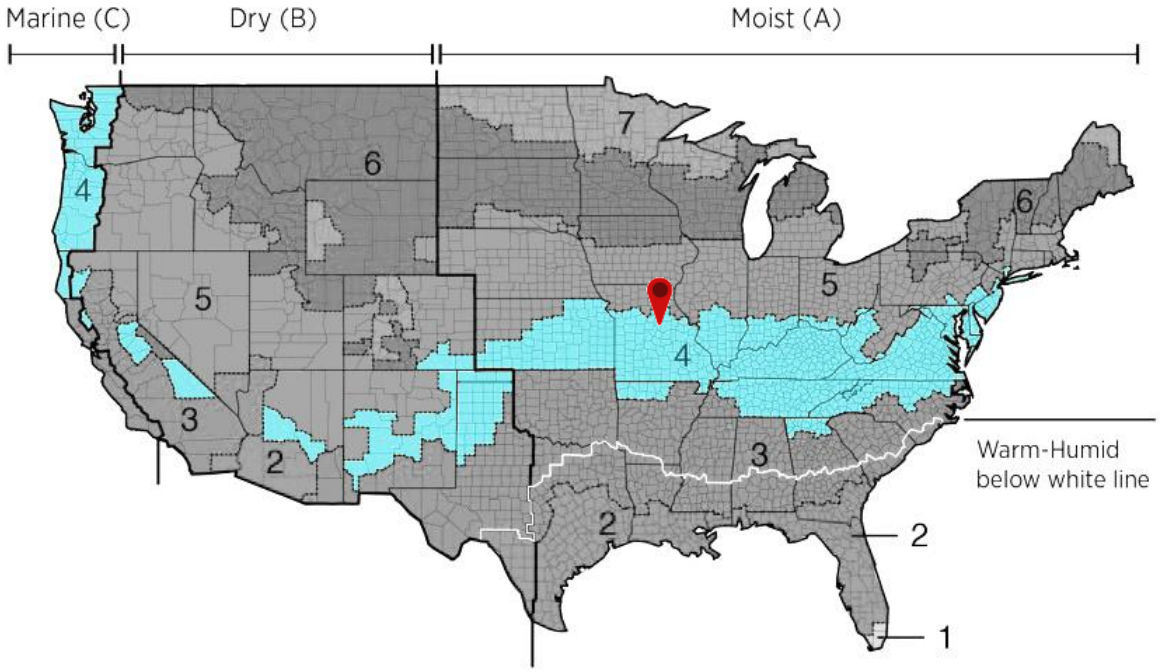
Missouri Solar Apps

Design Constraints

Climate Summary

Climate Zone: 4A Mixed-humid
Cool to cold winters
- 4800 heating degree days
Long, hot, and humid summers
- 1550 cooling degree days





Boone County Missouri

Project Summary

Location: 507 Park Avenue, Columbia, Missouri
Neighborhood: North-Central
Lot Size: 1.62 acres
Building Size: 56,650 square feet
[48 Apartments, common space, small retail space]
Building Cost: $5,525,082 ($115,106 per unit)

Design Constraints

Neighborhood Context (Park Avenue)

Current Public Housing on Park Avenue

Downtown Student Housing

Design Constraints

Columbia Housing Authority (CHA) Properties

McBaine Townhomes

Bear Creek Townhomes

Providence Family Townhomes

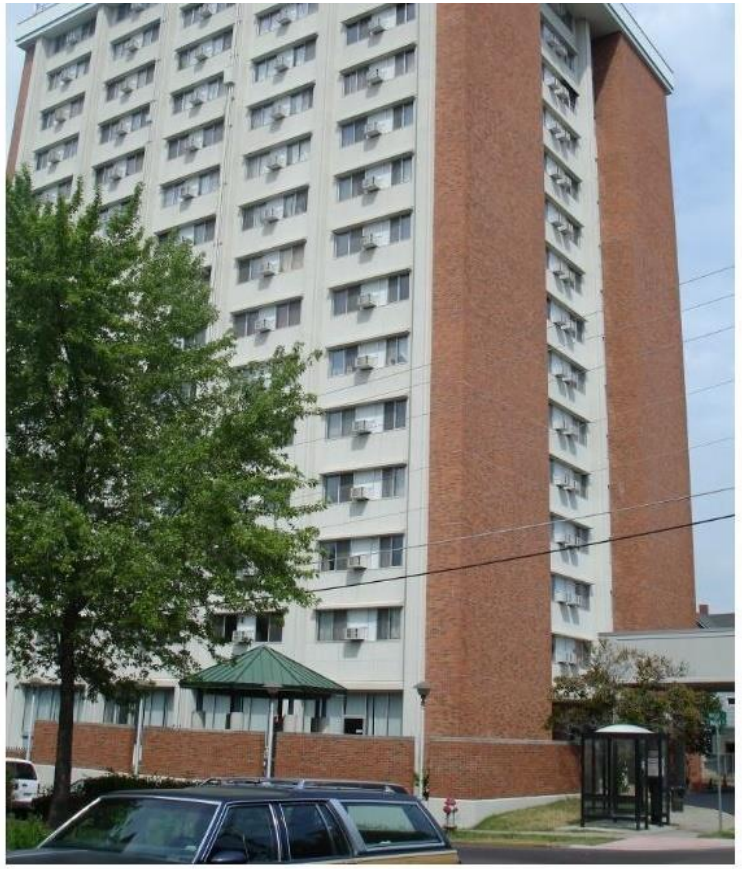
Stuart Parker Townhomes

McBaine Kitchen

Park Avenue

Paquin Tower



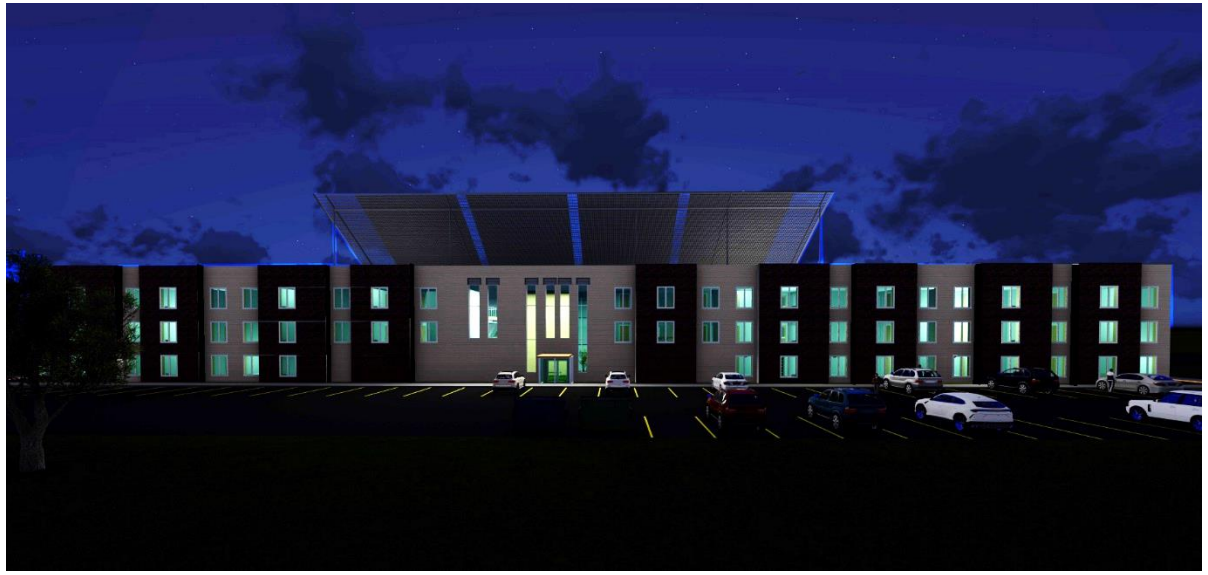




Design Constraints

Design Standards

Columbia Housing Authority regulations
ADAAG 2010 Uniform Federal Accessibility Standards (UFAS)

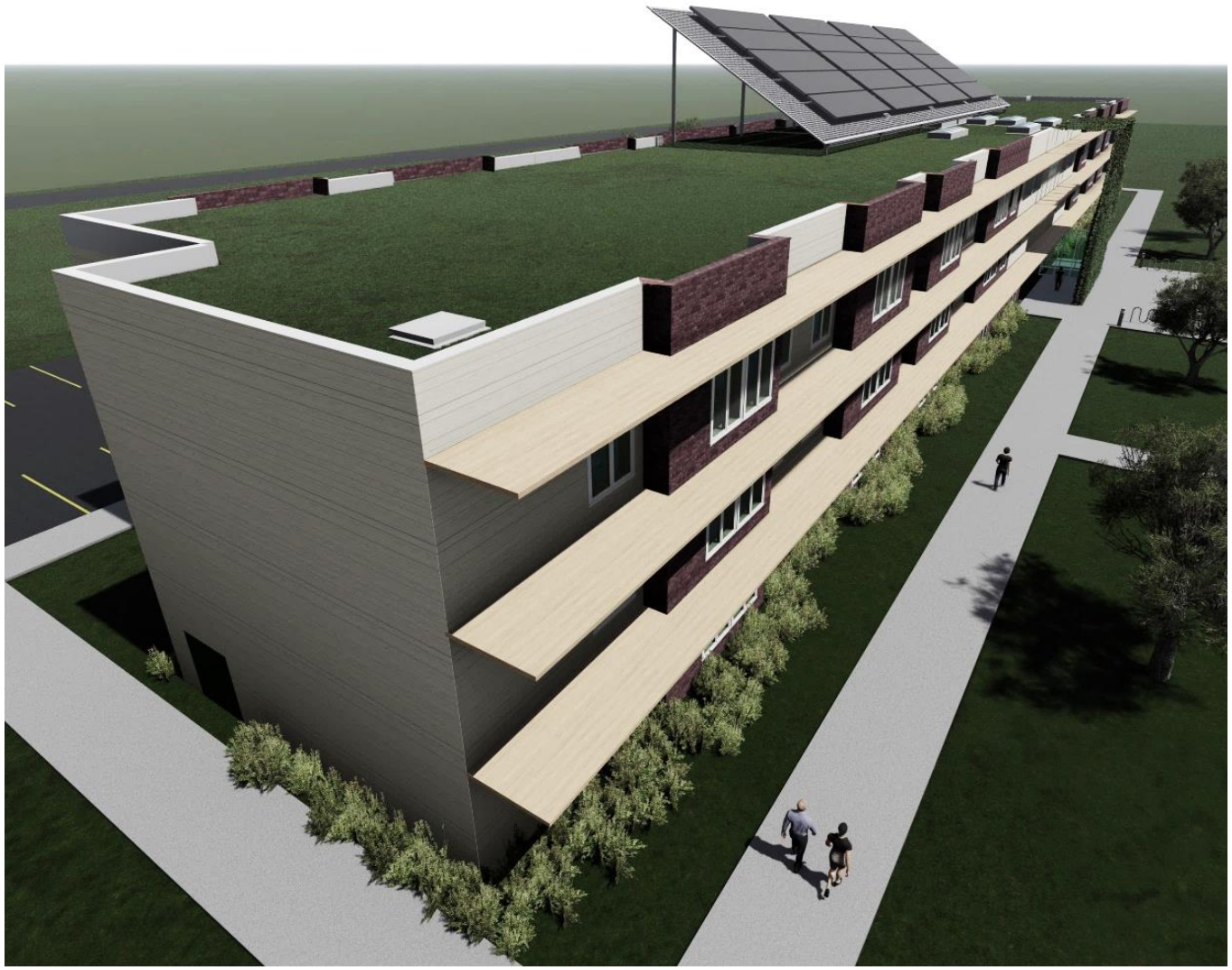
Design Goals



Design Mission

To create an affordable, energy-efficient, resilient, and environmentally friendly apartment design within the urban context of the North-Central Neighborhood in Columbia, Missouri to accommodate low-income families.

Design Goals



1. Design apartment plans that can be used by CHA as a **model** for efficient, resilient, affordable, and flexible housing.

2. Create a **resource efficient and net-zero energy** design, **reduce construction costs** and follow **appraised value precedent** of nearby neighborhood and public housing .

3. Create a design with a friendly relationship with the street and reconcile **public and private relationships** between the **apartments and neighbors**.

4. Create a flexible interior that utilizes **universal design** principles.

5. Utilize building materials that consider **embodied energy**, **rapidly renewable** and/or **recycled content**, **distance to the project site**, and **reduction of construction waste**.

6. Create a design that allows options to use **manual systems** for ventilation, lighting, heating, and cooling, versus automatic systems.

7. Use appropriate, affordable, and researched-based **industry standard strategies**.

8. Design the apartments to provide **ultra-affordable** home rental and ownership to low income Columbia residents.

Proposal

3-story building

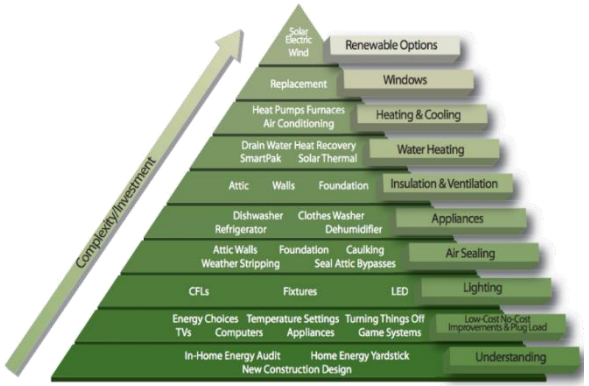
- Approximately 19,000 square feet per floor
- 27 one-bed one-bath apartments, 21 two-bed two-bath apartments
- 1,600 square feet retail store
- Commons area (meeting space for entire neighborhood and resilient core)
- Net zero with 160 kW photovoltaic array
- Construction cost approximately $115,000 per unit (with PV)

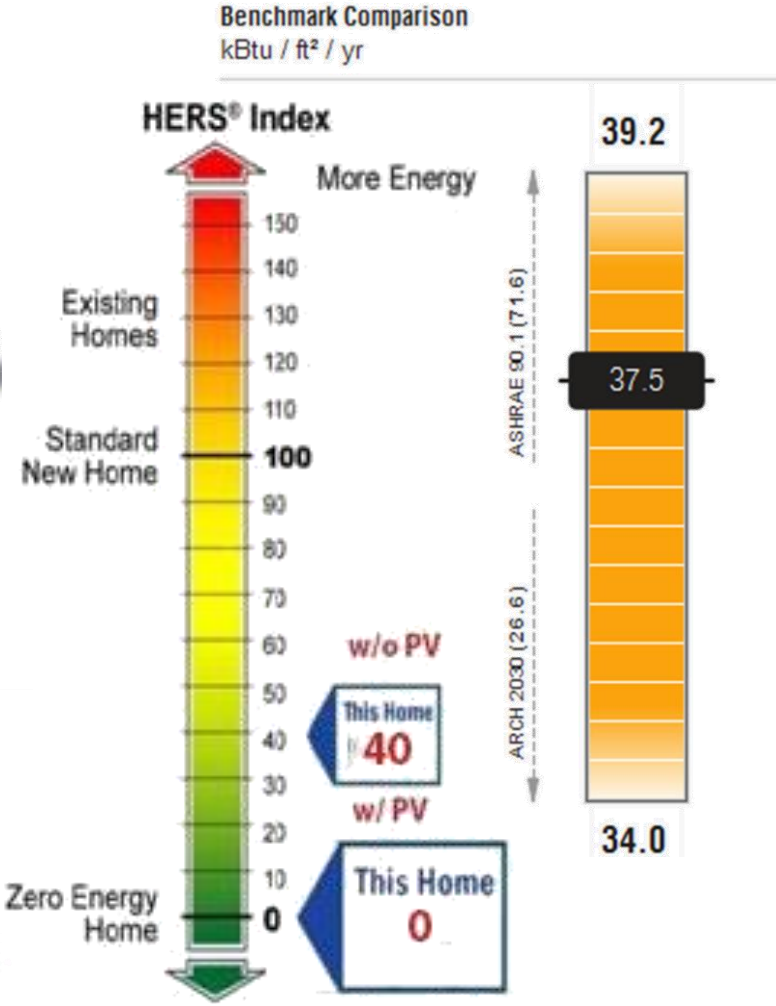
Construction

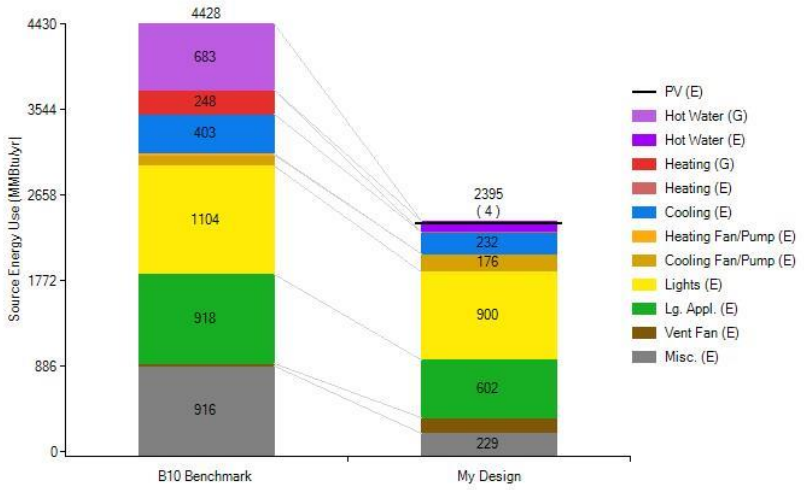
- Walls: R-40 SIPS with drainage plane between skin and SIPS
- High performance flashings and air/moisture/vapor control
- Roofs: R-50 SIPS with concrete topping and EPDM membrane; wood trusses
- Floors: Concrete floor topping on sub-floor over wood trusses
- Sound insulation (control) between apartment walls and ceilings

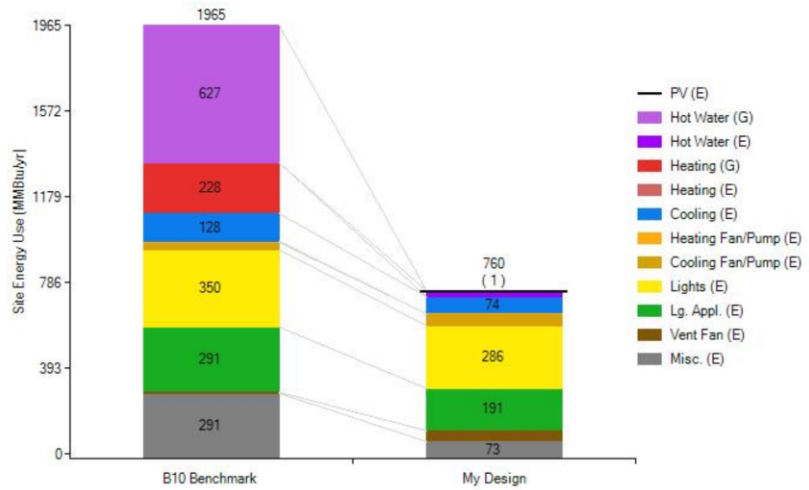
Energy Performance

- Followed Energy Pyramid
- **BeOpt** to optimize energy efficient strategies
  (3155 MMbtu/yr Source and Site)
- **REMRate** analysis to determine:
  - **HERS Rating**:
    - **40** without PV (one apartment)
    - **0** with PV (one apartment)
    - Compliance with IECC, ASHRAE 90.1, EnergyStar Homes
    - DOE Net-Zero Ready Home requirements
- **OpenStudio** analysis to determine:
  - **EUI Rating**: 49 kBtuh/ft^2/yr (37.5 kBtuh/ft^2/yr source)

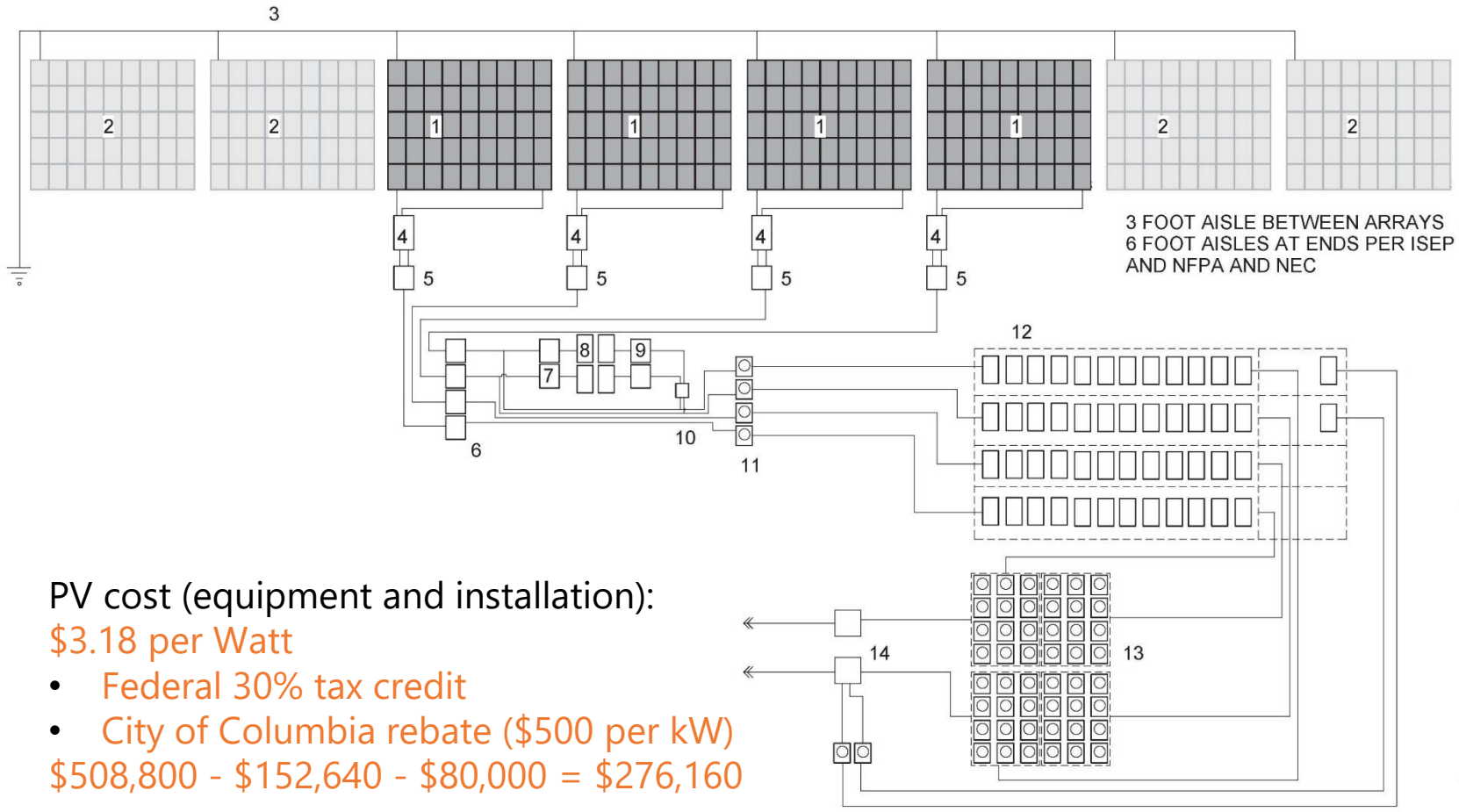








Energy Performance



PV cost (equipment and installation):
$3.18 per Watt

- Federal 30% tax credit
- City of Columbia rebate ($500 per kW)

$508,800 - $152,640 - $80,000 = $276,160

Photovoltaic array:

- Four arrays (180 panels total)
- Expandable to 8 arrays (360 panels total)
- 160kW array
- SunPower X21-470
  - Micro-inverters versus String or DC Optimizers
  - 470 W per panel
  - 17.2 SF per panel
- Per PVWatt:
  - 233,360 kWh per year
  - 31 degrees tilt (roof slope)
- **Micro-inverters** used for NEC/ISEP Compliance:
  - Rapid Shutdown
  - Anti-Islanding
  - Better performance under shading
  - Missouri PV Installers prefer micro-inverter systems

Energy Performance

Enphase iQ6+ Micro Inverter: IQ6PLUS-72-2-US

SunPower Photovoltaic Panel: model X21-470

RESULTS

Print Results

233,360 kWh/Year*

System output may range from 223,046 to 243,045 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.75	15,589	1,320
February	4.33	15,841	1,342
March	5.09	20,489	1,735
April	5.57	20,859	1,767
May	5.67	21,714	1,839
June	6.29	22,725	1,925
July	6.39	23,820	2,018
August	6.09	22,361	1,894
September	5.81	20,975	1,777
October	5.09	19,768	1,674
November	3.97	15,460	1,309
December	3.31	13,761	1,166
Annual	5.11	233,362	$ 19,766

Energy Performance

Lighting Controls:

Hubbell DLCPCI (indoor) DLCPCO (outdoor) DCLPCA/S (atrium/skylight)

Design Illumination Levels (FC):

Kitchen	50
Living Room	30
Bathroom	40
Bedroom	20
Hallways/Stairways	5
Commons/Atrium	30
Commercial	50

Lighting Load: maximum 125 Watts per unit

Plug & Appliance Loads:

Reducing Plug Loads: Legrand Plug Load Reducer
Appliances: Energy Star - lowest available energy use

Engineering

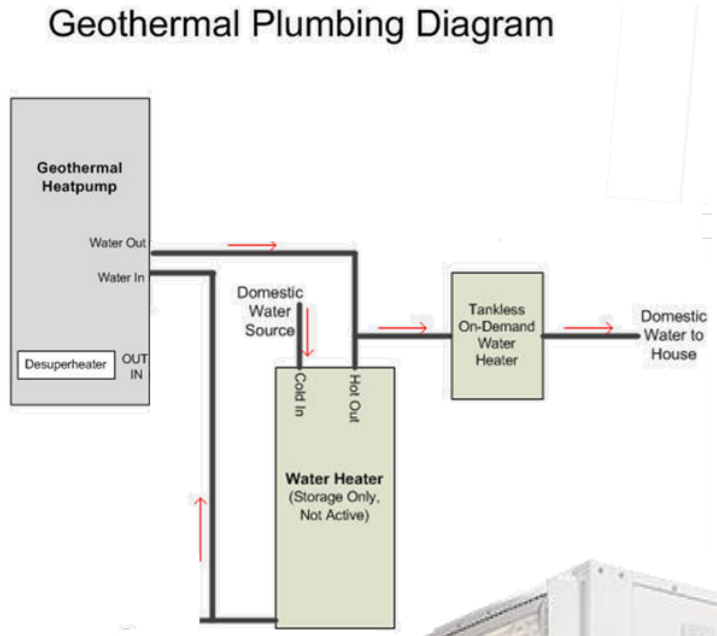
Overall Approach:

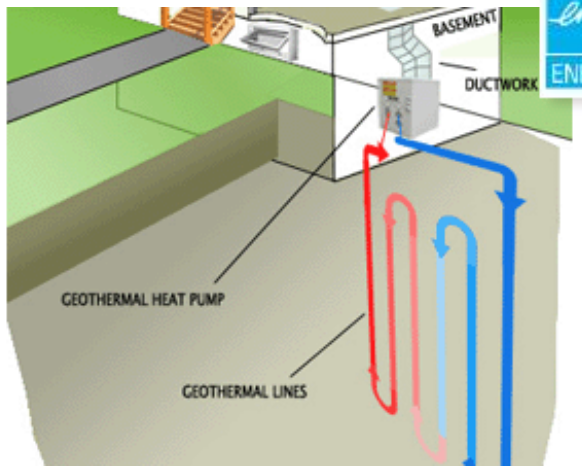
Fall Semester 2018, engineering students produced report evaluating preliminary site and building, structural, site utilities, control, mechanical and electrical systems (see supplemental report)

HVAC System

Process: HeatCAD evaluation → review by engineer (CM) → review by additional engineer (MW)

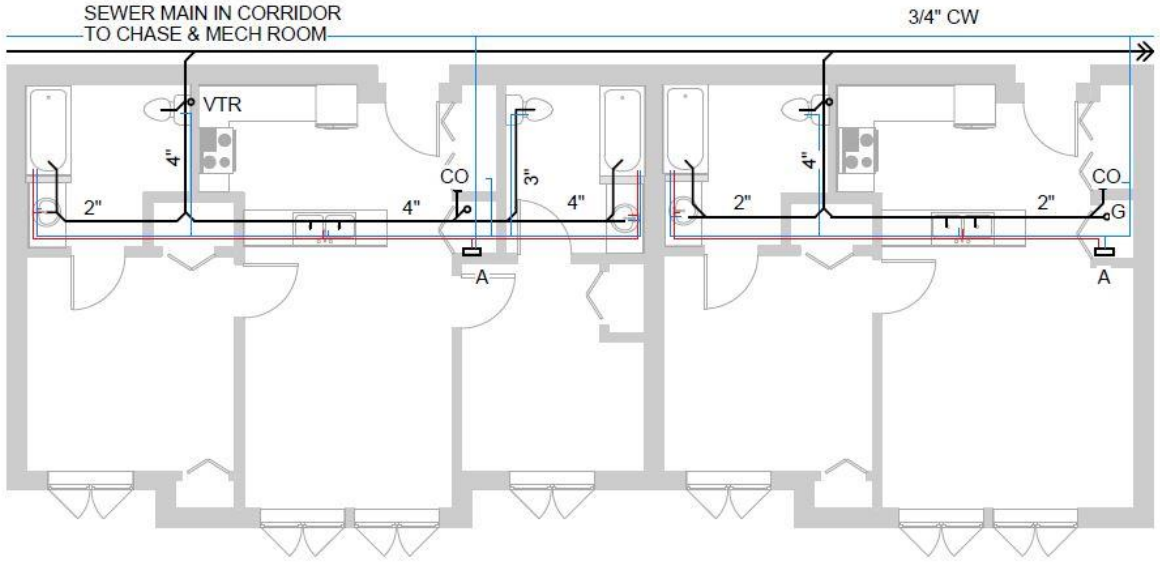
- 1.5 ton geothermal heat pump system (each apartment)
  - Bosch Greensource CDi SM-024 Split-System with attached Bosch DX025-1VTX Compact Air Handler and Fan Coil
  - Interfaces with passive solar heating and cooling strategies
  - Provides primary water heating
  - 300 foot vertical loop wells
- 4 and 6 ton units for commons area and retail
- MERV 13 air filters
- Thermostat: Honeywell Lyric T5



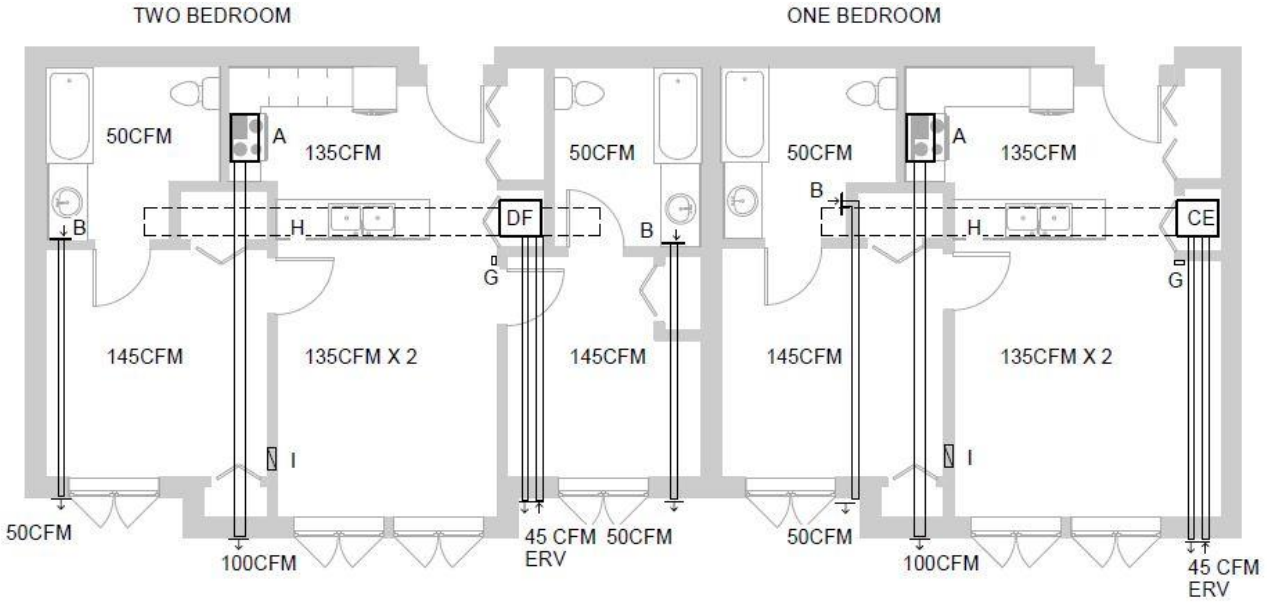


Engineering

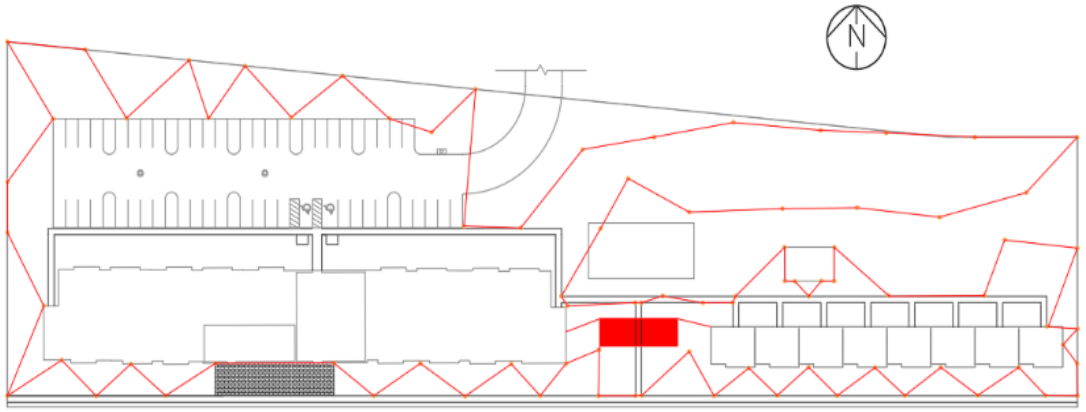
Plumbing System Layout



HVAC System Layout



Rainwater collection for irrigation (22,886 Gal/Week)



Product Label	Fixture	Demand	Unit Cost
Cosmo KF776SS	Kitchen Faucet	1.5 gal/min	$133
LG WM3575C	Clothes Washer	4,239 gal/yr	$900
Pfister LG143-5000	Bathroom Faucet	1.5 gal/min	$23
American Standard Flowise	Shower Head	1.5 gal/min	$35
Niagra 77001 WHC01 Stealth	Toilet	0.8 gal/flush	$230

	Hot/Cold	Linear Feet	Unit Cost per 10 ft
Main Line	3/4"	70	$14.80
Branch	1/2"	50	$9.13

Financial Feasibility & Affordability

Cost Estimation:

- RSMeans Online (1Q 2019)
- Adjusted for known materials cost
- CHA pays no sales tax
- Full cost estimate in supplemental report
- $5,525,082 ($115,106 per unit)
    - Average unit cost for CHA properties: $145,000 per unit
    - Average unit cost for Columbia: $65,000 to $85,000 per unit

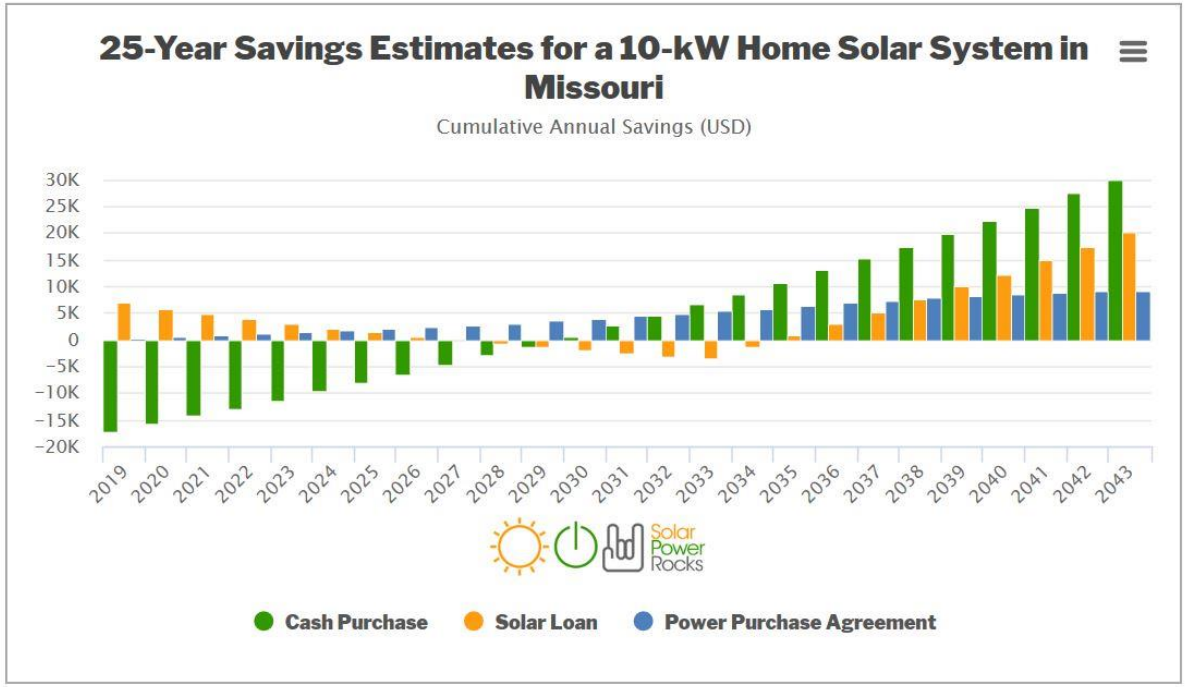
Rent-to-Own Possibility:

- Invest utility dollars savings for equity
- Floor plan configured for future condominiums

Repair & Maintenance:

- Rental Income: $765 per month/unit
- Rental Income: $535 per month/unit with housing assistance
- Total Rental Income: $440,640
- Per CHA maintenance = 9% rental income
    - $39,658 in maintenance

Optional Purchase Power Agreement

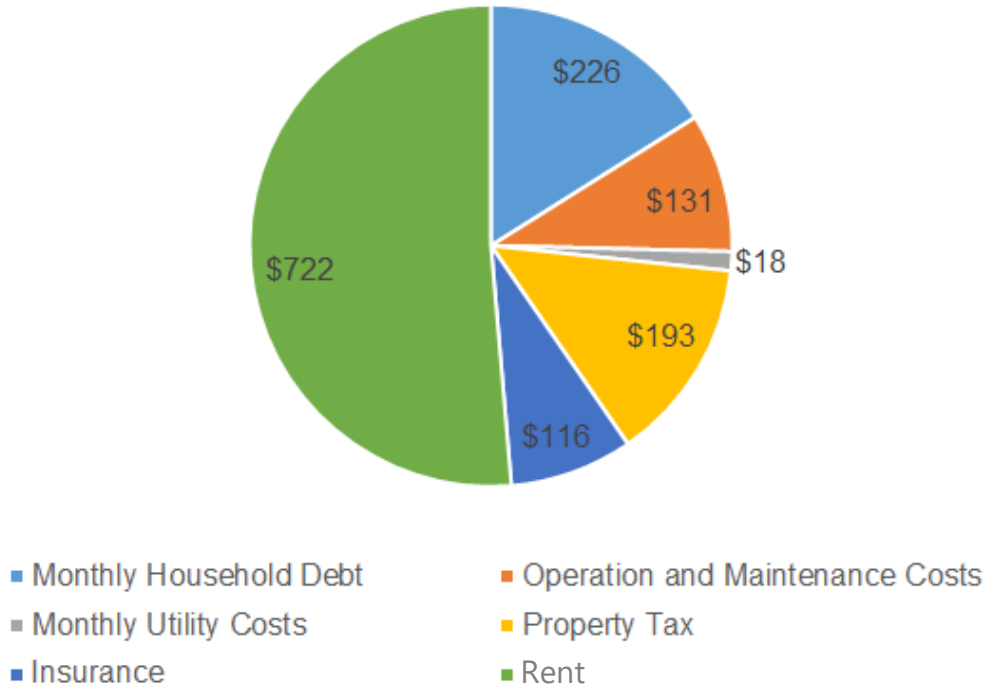


Financial Feasibility & Affordability

Rebates, Incentives, and More

- **CHA (client) is Non-for-Profit Organization**
  - Sales Tax 7% savings
  - No compensation or fees for marketing or sales commission
- **Job Point of Columbia** (Youth Build)
  - Lower contractor's overhead and profit (not-for-profit agency)
  - No sales tax on materials
- **Solar Property Tax Exemption** (Missouri)
- **Residential Renewable Energy Tax Credit** (30% Geothermal Heat Pumps)
- **Renewable Electricity Production Tax Credit** (PTC) ($0.023/kWh)
- **Columbia Water & Light - Home Performance with ENERGY STAR Rebates** (Multiple incentives)
- **Columbia Water & Light - Solar Rebates** ($500/kW)
- **Columbia Water & Light - HVAC and Lighting Efficiency Rebates**
  - HVAC: $570 - $3,770, Lighting: 50% of invoiced cost up to $22,500)

Summary & Cost of Living

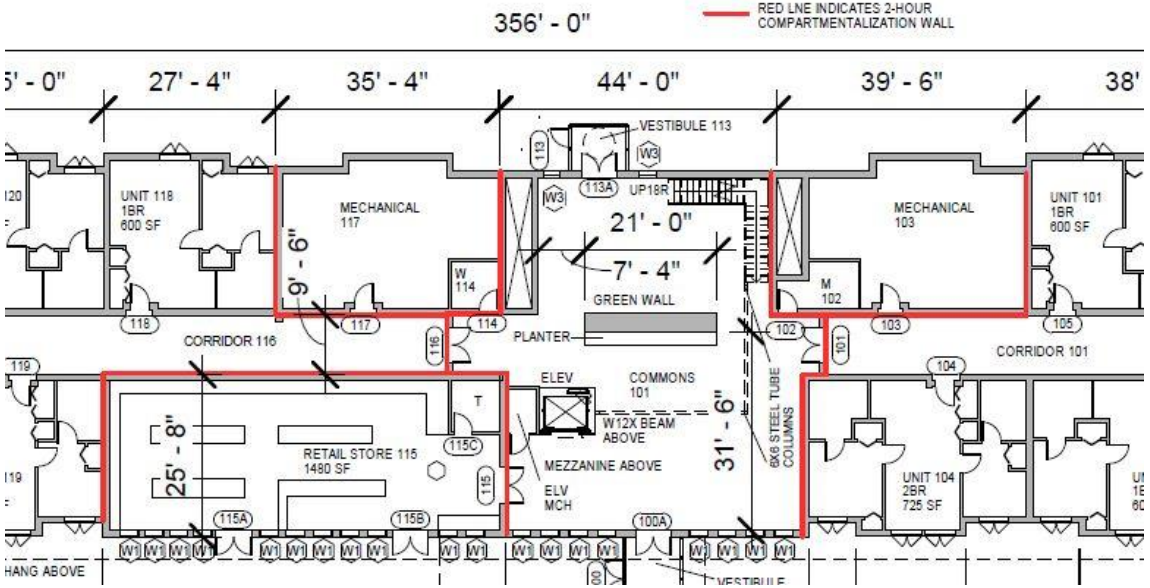


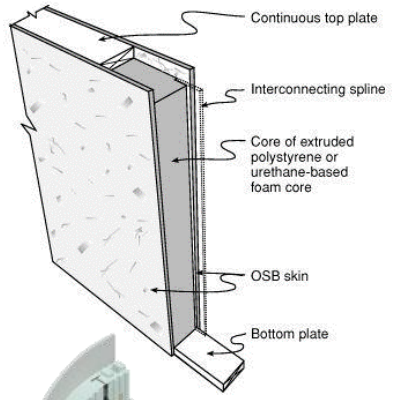
Resilience

Resilience

Compartmentalization

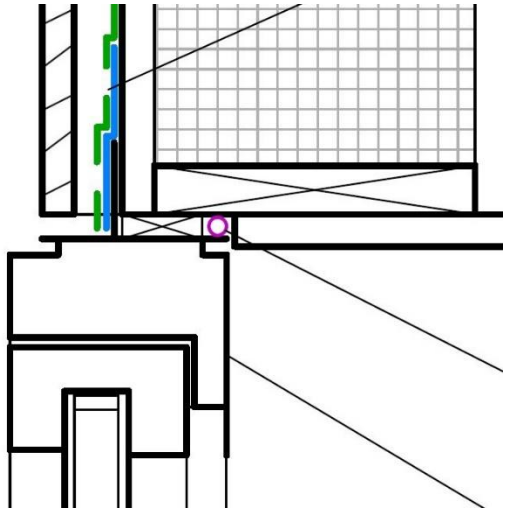
- Resilient Core & Apartments
  - SIPS walls and roofs; core surrounded by Insulated Concrete Forms (ICF construction)
  - Commons Area Mezzanine-Steel Construction; windows with rolling steel shutters
  - Concrete topping on roof SIPS reinforced with steel channels
  - Fire separation: two-hour from commons to residences; one-hour between hallways and residences; one-hour between residences
  - Backup Power (Tesla Batteries), water supply within core
  - Areas of refuge/shelter for apartments and entire neighborhood
  - Hurricane ties and straps on trusses and SIPS

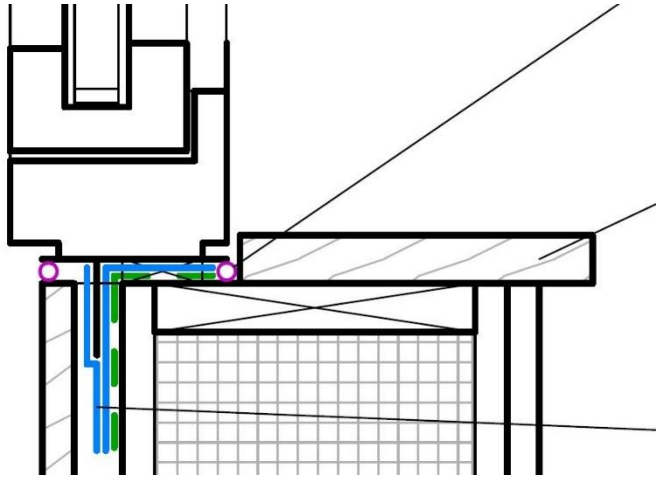


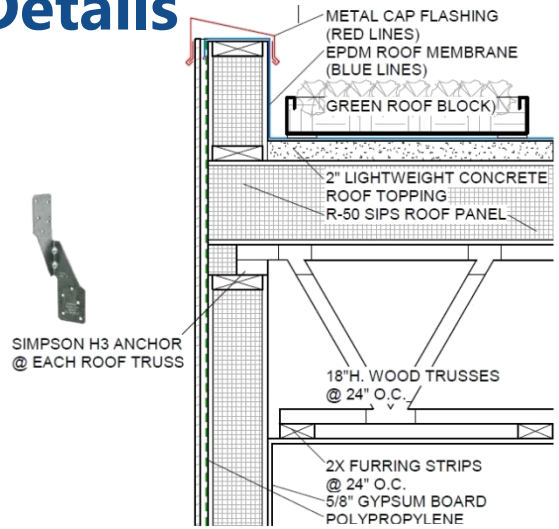


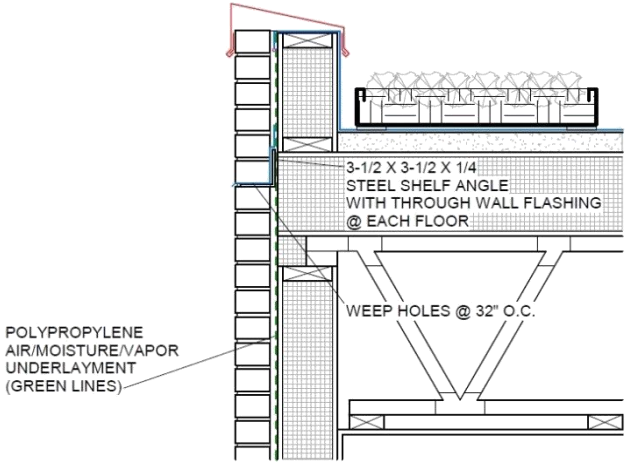
Resilience

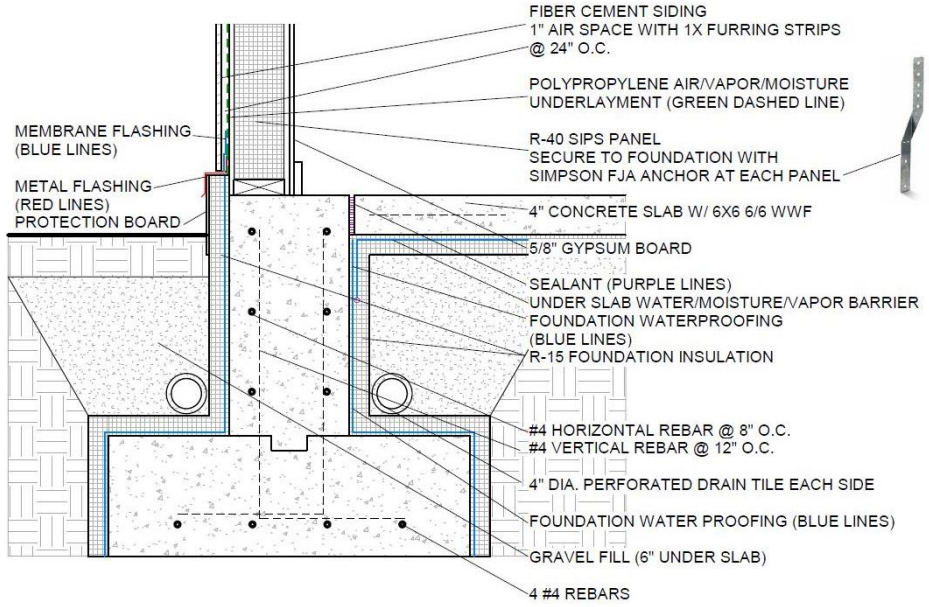
Building Enclosure Design Details

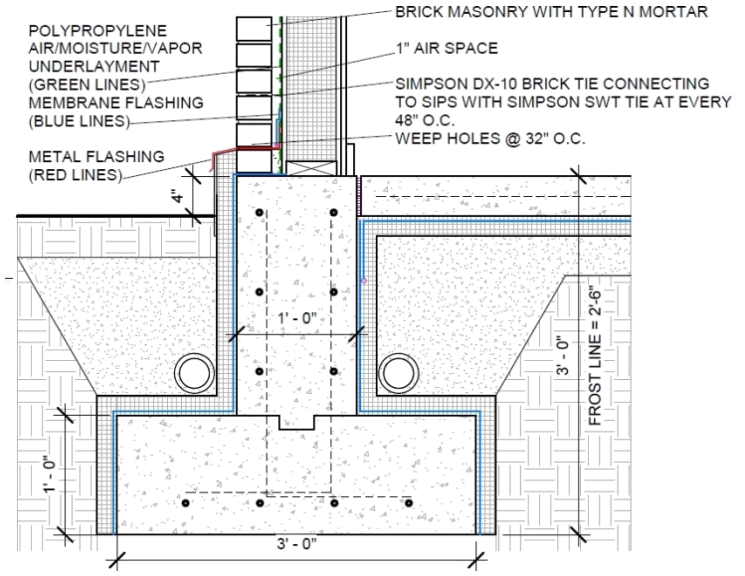








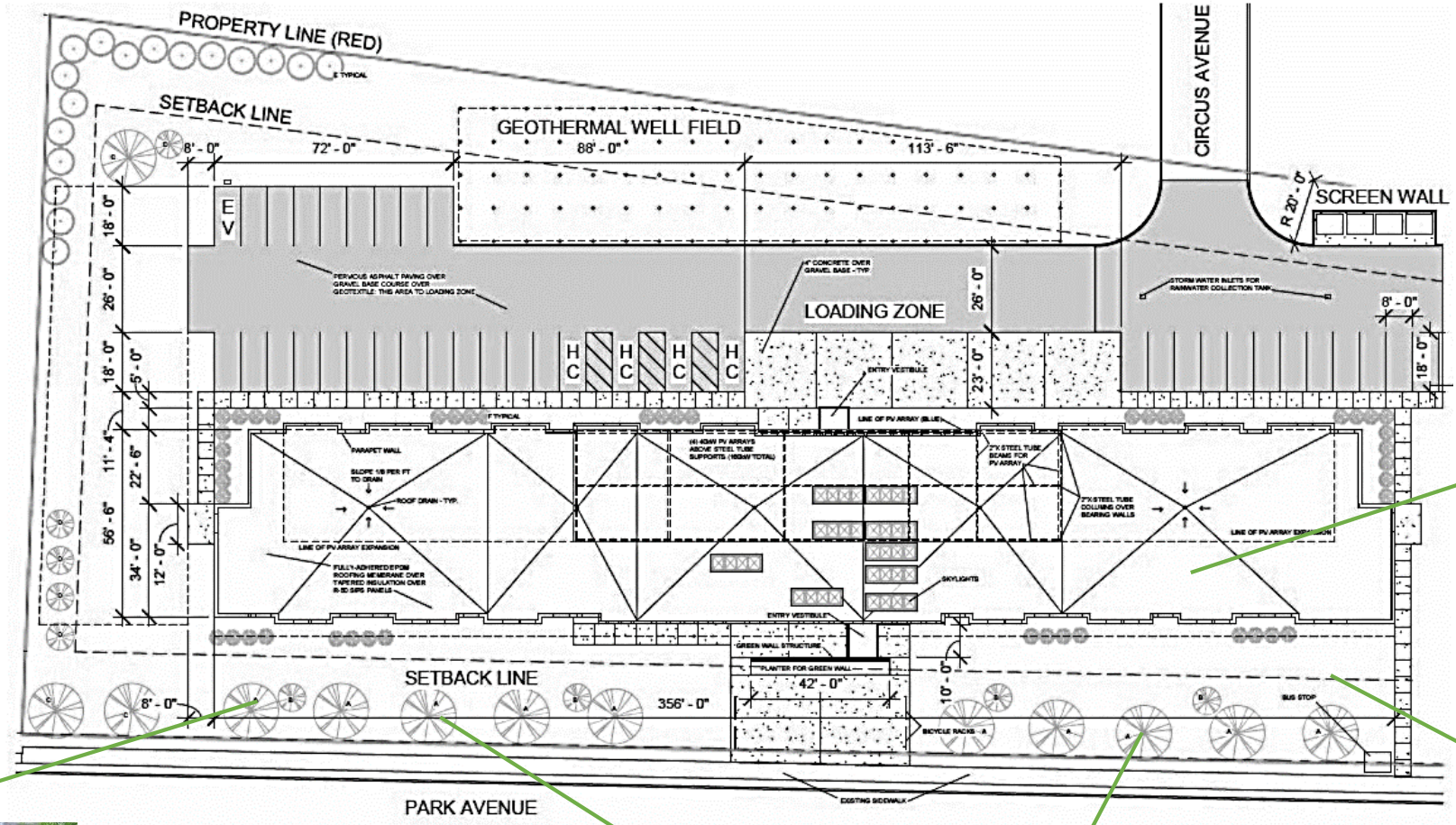




Architecture

Site & Roof Plan

- Xeriscaping (native plants) limits the need for additional irrigation and fertilizers
- Modular green roof blocks (optional)
- Rainwater collection from roof and parking lot
- Permeable paving in some areas



Green Roof

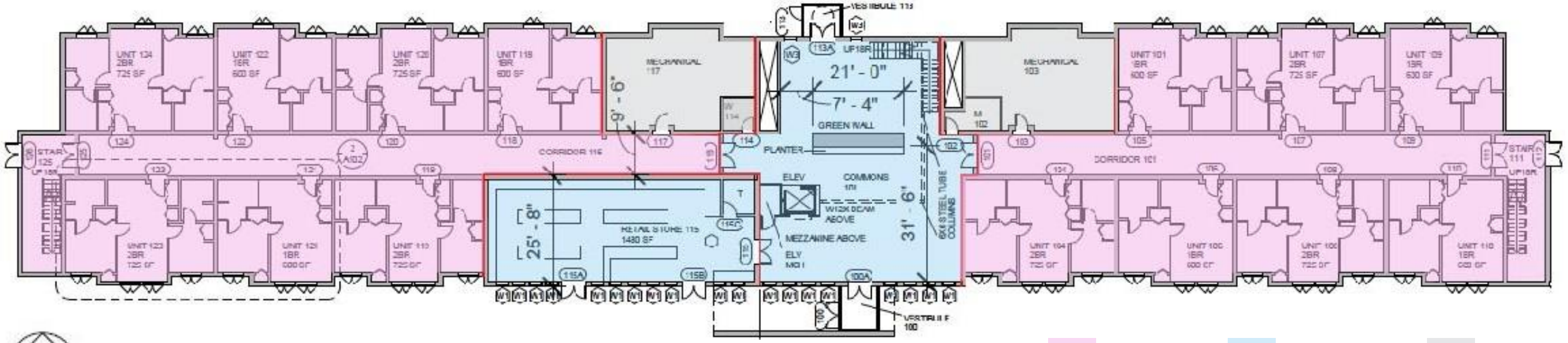
Buffalo Grass

Coneflower

Yellow Wild Indigo

Bluestem

Architecture



1st Floorplan

PRIVATE PUBLIC SERVICE

Long central axis maximizes solar (**passive** and **active**) exposure

Separation of **public/private/services** spaces

Resilient core (red lines): ICF walls and two-hour fire separation

Exterior material and **form** of building inspired by surrounding street and neighborhood

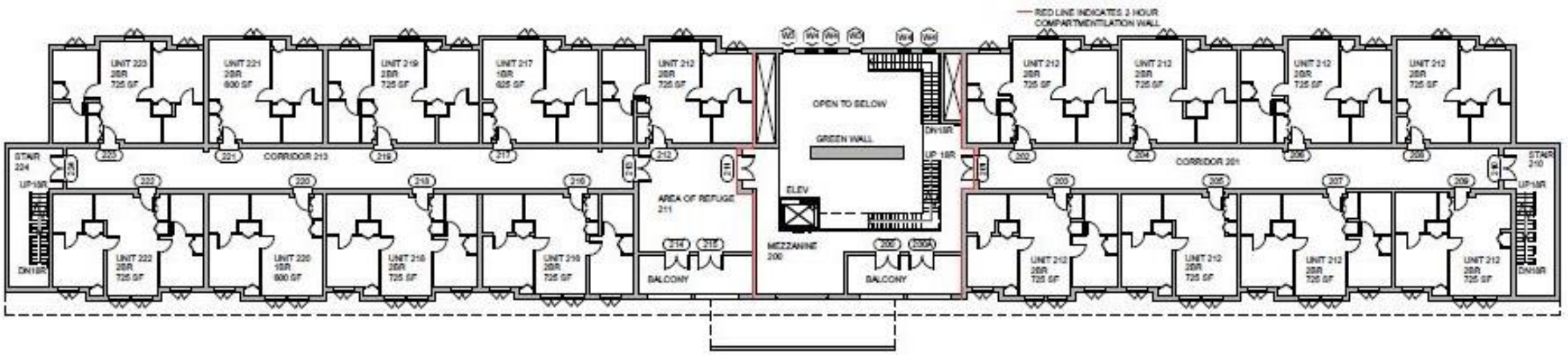
- Brick and fiber cement siding
- High-performance vinyl windows and doors

Air lock vestibules at entries

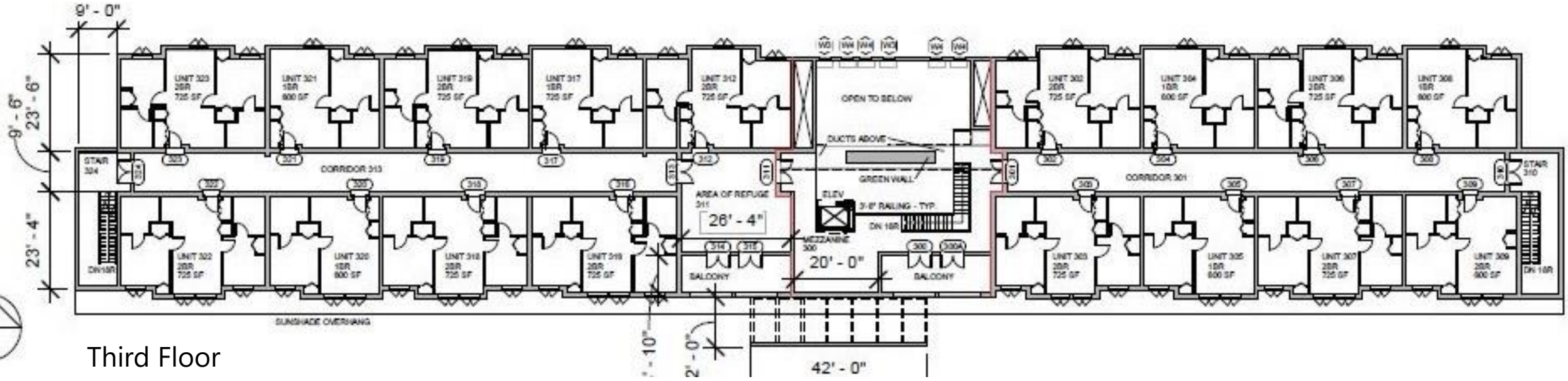
27 one-bed, one-bath; **21 two-bed**, two bath apartments

3-story, 32 feet tall building

Architecture

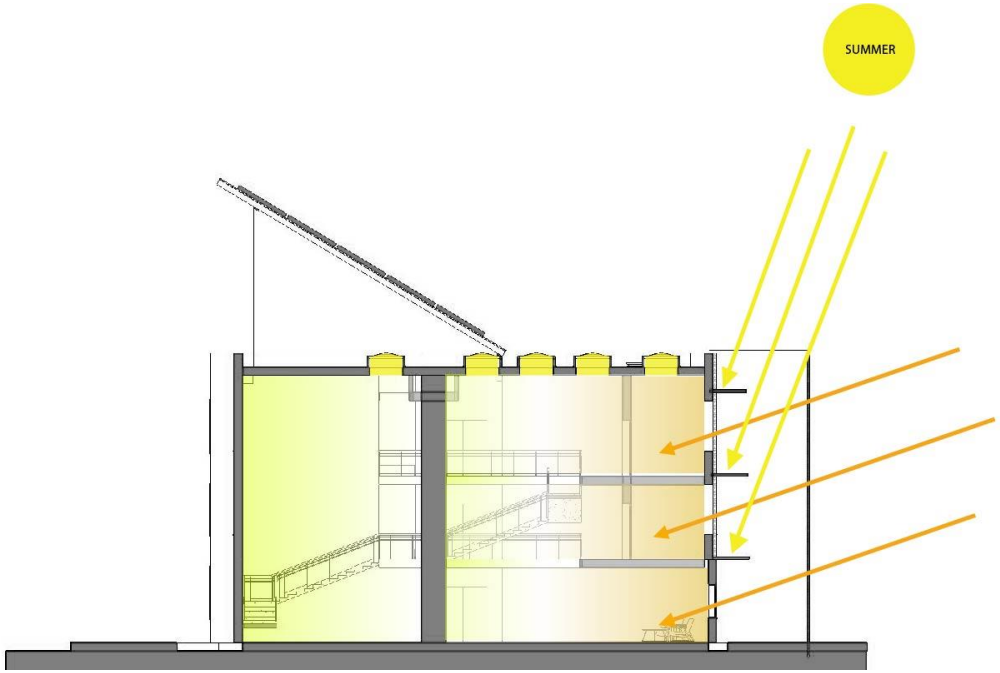


Second Floor

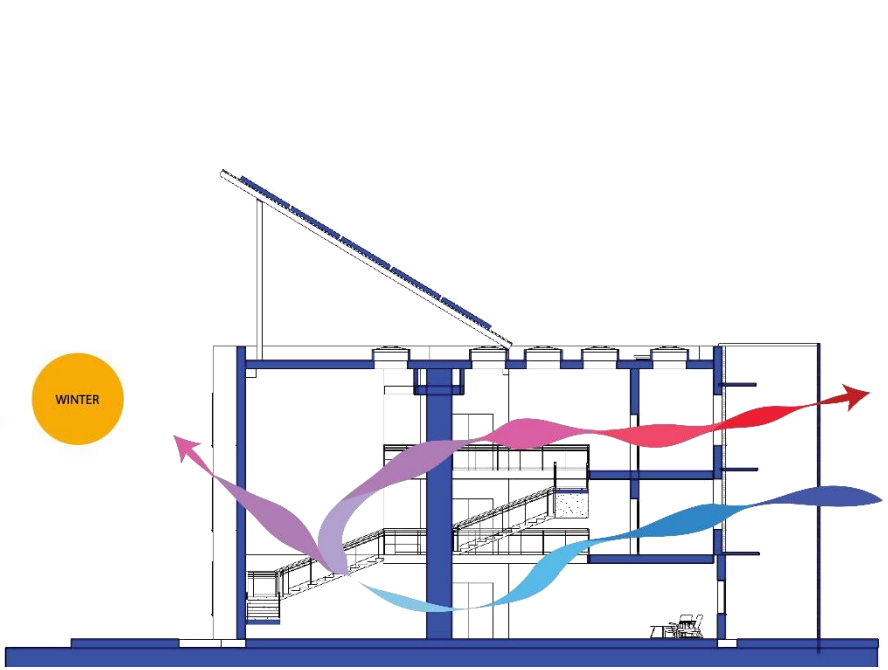


Third Floor

Architecture



Sun Diagram



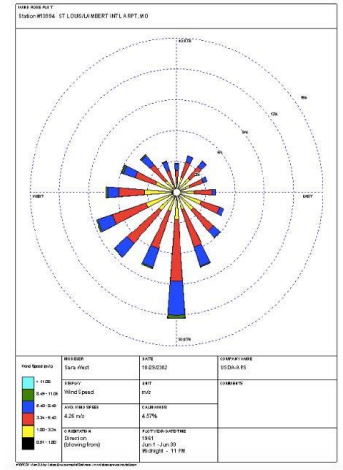
Breeze Diagram

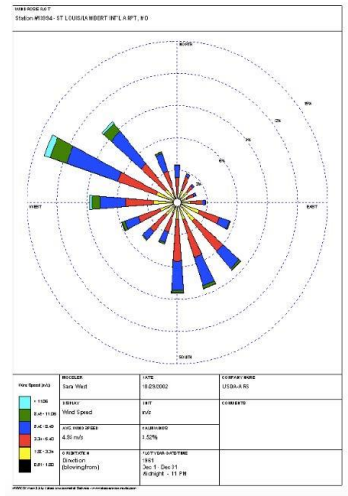
The commons area is designed for **passive solar heating**, **cooling** (natural ventilation), and **daylighting**.

- **Reduces loads** for mechanical and electrical systems
- Allow for heating, cooling and lighting during **disaster recovery** or **refuge**

Quaker Window Manchester Series

	U-Value	SHGC
Vinyl Casement	.23	.18
Vinyl Double Hung	.25	.21
Vinyl Picture Window	.22	.22





Wind Roses

Architecture

Indoor and Outdoor Vertical Green Wall

These walls include a variety of plants to give the building texture and life.

- The interior wall will be planted on a Florafelt Vertical Garden Planter.
- The exterior wall cools summer breezes entering the building and protects windows

Ecologically Sensitive Interior Materials

- Rapidly renewable, recycled content, and/or local materials
- No VOCs or Formaldehyde
- Concrete floor in public areas and South apartments for thermal mass
- Linoleum flooring in bathrooms: 98% bio-based; 78% recycled content; biodegradable
- Paperstone counter surfaces: 100% recyclable and durable
- Engineered bamboo hardwood: 50-year warranty
- 100% LED lighting, with photocell

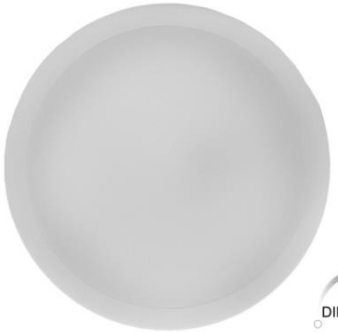
Operations

Frigidair Electric Stovetop and Oven

Energy Star Frididaire Refrigerator

Insignia Microwave

GE combination washer and dryer



Energy Star Recessed Green LED lighting

LED GE Morgan Ceiling Fan with remote

Bar pendants lightology freejack LED lights

Panasonic whisper recessed LED lights vent fan

Vanity DweLED Bathroom Lighting

Philips Vetro LED PW series wall sconce

Energy Star Bellacore LED table pendants

Market Potential

Target Occupant:

2-3 family members, low-income

Target Family Income: **$45,221 (2-3 family members)**

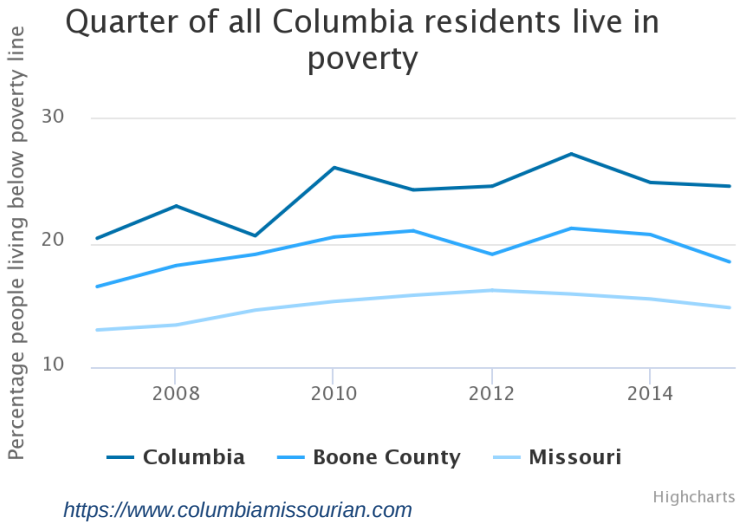
Cost of Living (Columbia, MO): **92.9%**

- Renters on public housing assistance (30% of adjusted monthly income)
- Most renters on LIHEAP and other government assistance
- Most families are food insecure

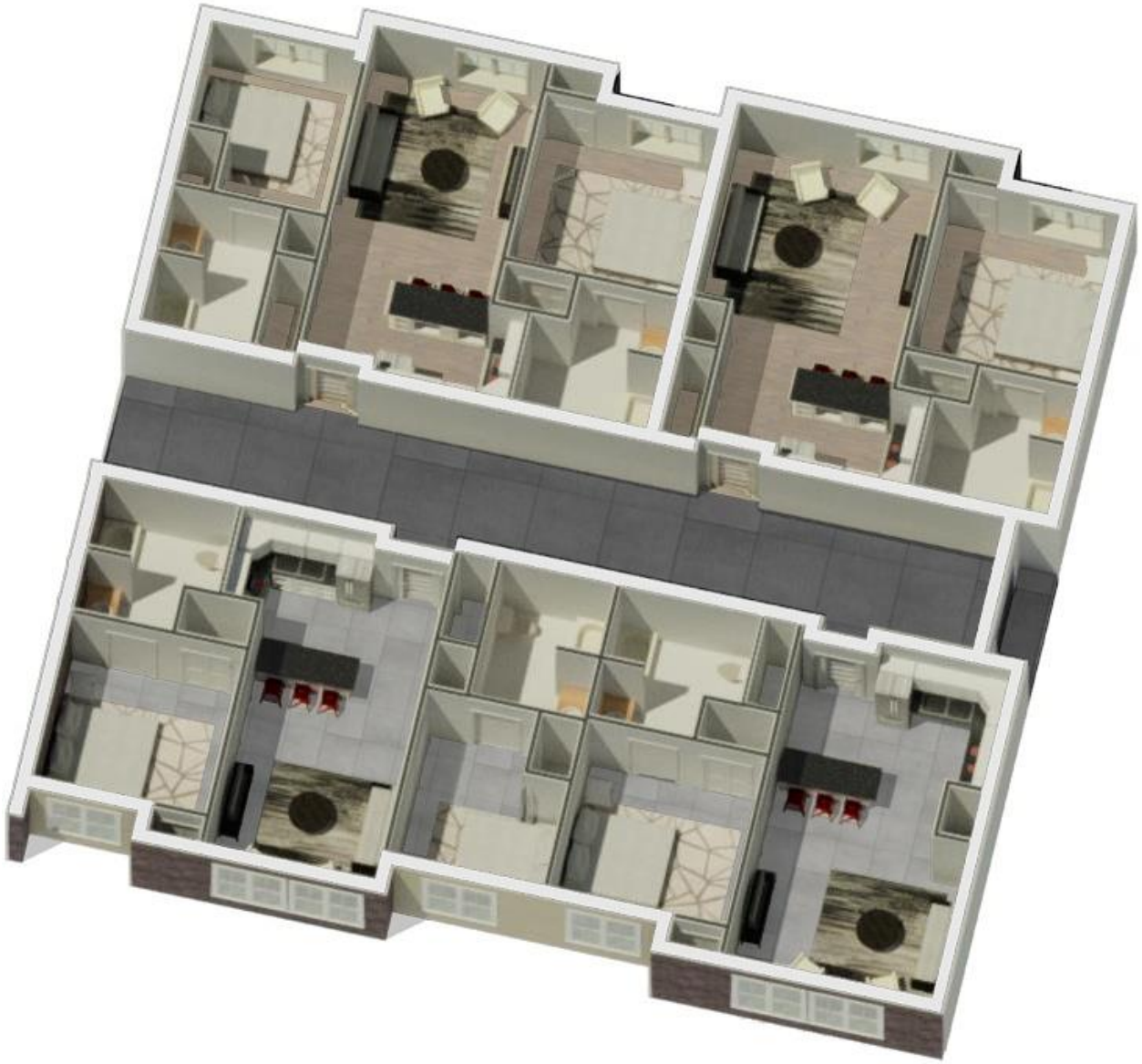
CHA Criteria:

- **1,200 applications** for housing assistance per year
- **1,900 units** currently in CHA ownership
  - 2 year wait list
- Income limits
  - $26,750 one-occupant
  - $30,600 two-occupants
  - $34,400 three-occupants
- Renters Assistance
- Livability and convenience
- Better benefits for less money

LIHEAP
Low-Income Home Energy Assistance Program



Market Potential



Sun space South side apartments (bedrooms, living, dining, and kitchens) and atrium/mezzanines with thermal mass for solar heating

Universal design principles:

- 3 foot doors
- 5 foot turning diameter
- Clearances for approach
- One level
- Clear lines of sight

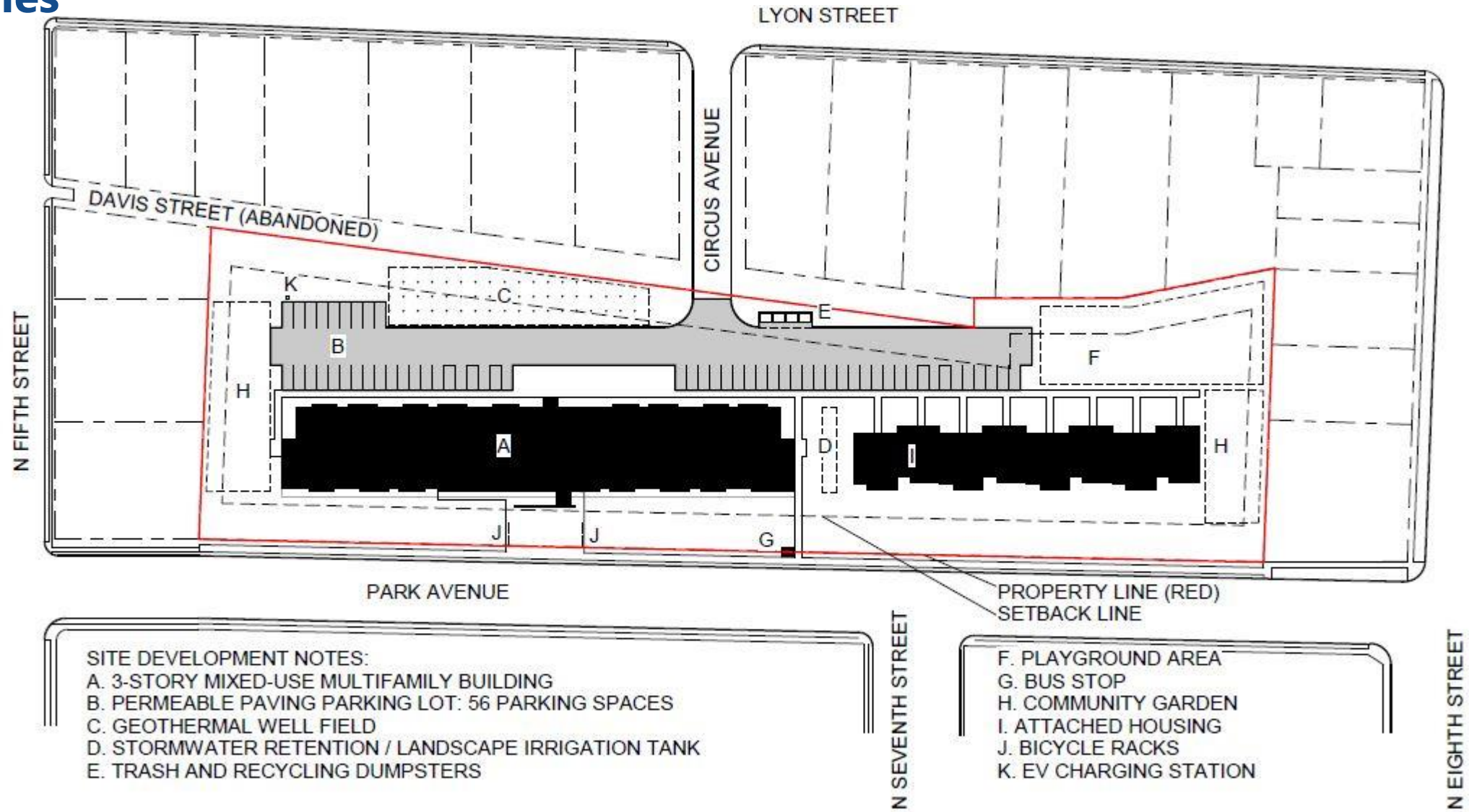
Heat spaces (kitchen, laundry, mechanical) located in central axis of building, near hallways

Open floor plan (flexibility)

- No hallways in apartments

Market Potential

Amenities

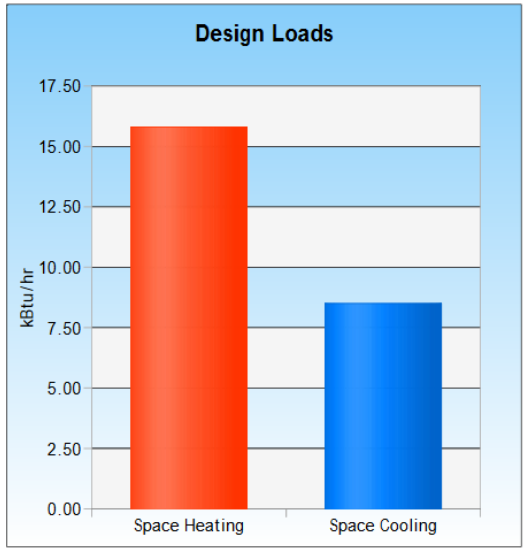


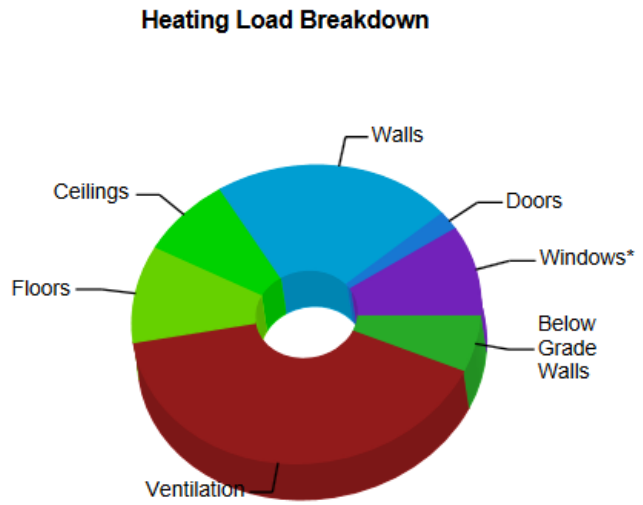
Comfort & Environmental Quality

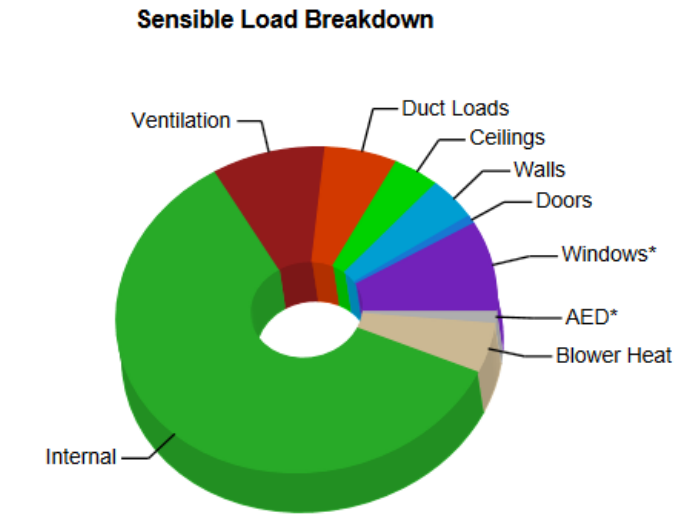
HVAC Design Criteria:

- Systems that fit into the limited area
- Maximizes human comfort
- Maximizes energy-efficiency
- Assists in reducing indoor humidity to below 50%
- Affordable for simple homes that are market ready
- Easy distribution of conditioned, filtered, and fresh air to all rooms for good indoor air quality
- Quiet system performance
- Reliable quality and low maintenance
- Simple and intuitive to use by homeowners
- Water heating through geothermal heat pump

Manual J Assumptions







REM Rate – Heating and Cooling loads

Comfort & Environmental Quality

Honeywell VNT5070 E 1000
Energy Recovery Ventilator

- **Radon Reduction**: Passive system in each residential wing
- **Whole House Ventilation**: Honeywell VNT5070 E 1000 Energy Recovery Ventilator (ERV)
  - 60 to 65 CFM
  - ASHRAE 62.2 compliance
- **Filtration**: MERV 10 (Winter and Summer), MERV 13 (Spring and Autumn)
- **Source Exhaust** (ducted to outside):
  - Bathrooms: 50 CFM
  - Kitchen: 100-135 CFM

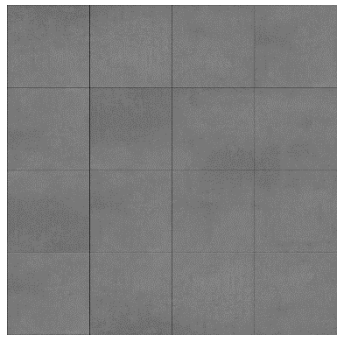
Comfort & Environmental Quality

Noise Control:

- Double-stud walls with insulation
  - Between units
  - Between hallways and units
- STC value:
  - 50 to 59 (loud sounds can barely be heard)

Contaminant Control:

- No VOCs or Formaldehyde
- MERV 10 to 13 filtration
- Indoor plant wall to naturally remove contaminants, and naturally control humidity
- Units are separated from each other thermally, acoustically, and for fresh air flow
- Independent exhaust for kitchens and bathrooms



Innovation

SUNSATIONAL University of Missouri

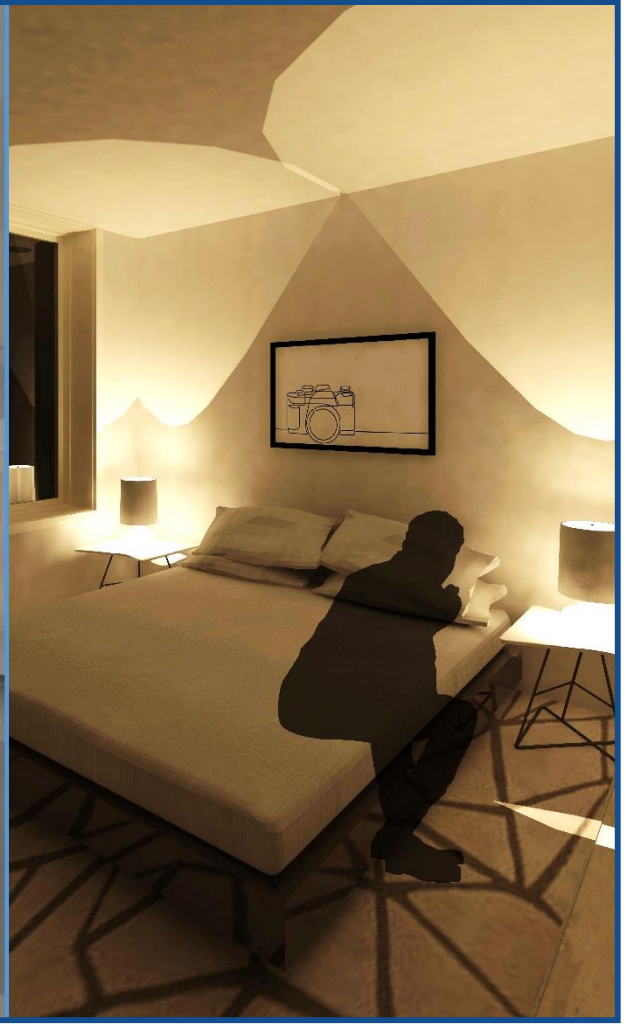
U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

Resilient Core

Green Walls

Affordability

Accessibility



“Piece of Mind for a Lifetime”

Financial, Aging, and Health Security