



# LINKoln Locale

TEAM LINKoln

U.S. DEPARTMENT OF ENERGY RACE TO ZERO STUDENT DESIGN COMPETITION

# TEAM INTRODUCTION

22 students

8 majors

1 university



2007



2009



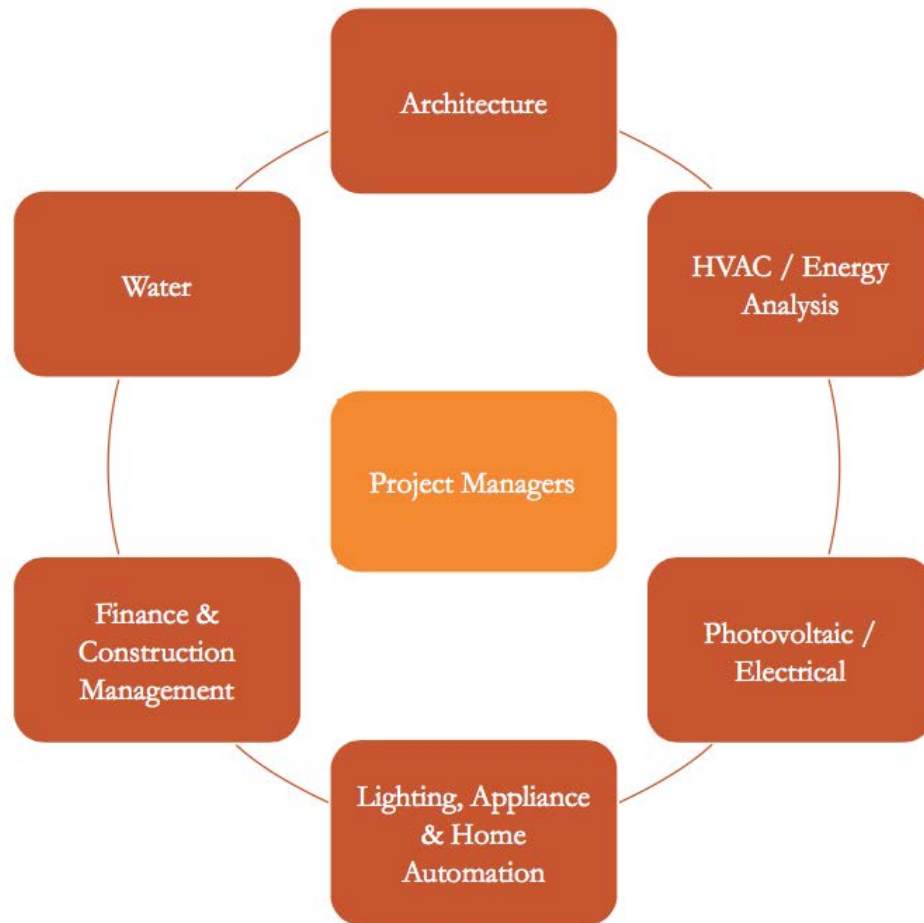
2011



2013



## TEAM STRUCTURE



## OBJECTIVES





# PROJECT SUMMARY

## OVERVIEW

Deep energy retrofit

Existing Student Housing

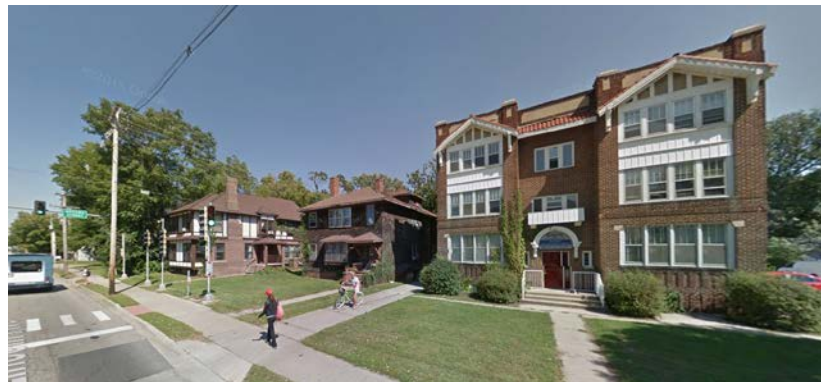
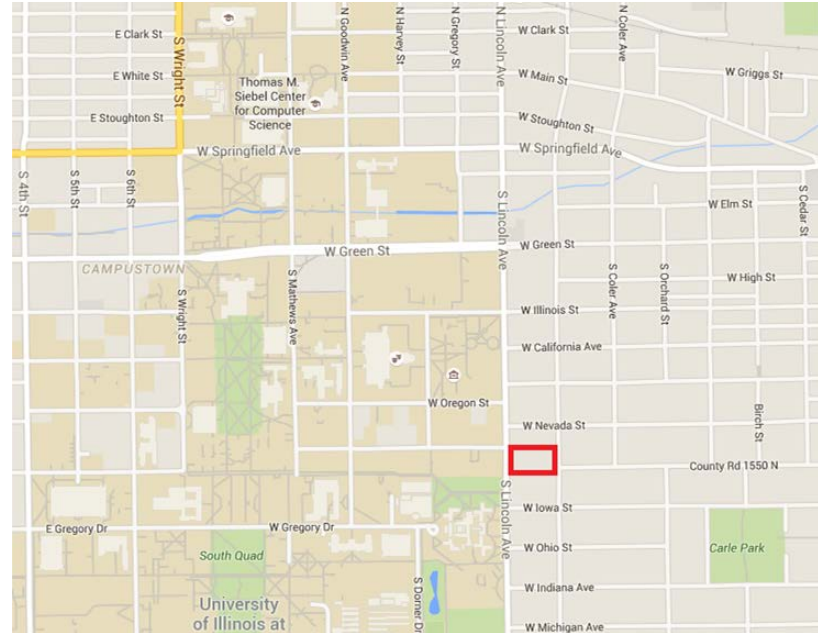
Multi-family



# PROJECT LOCATION

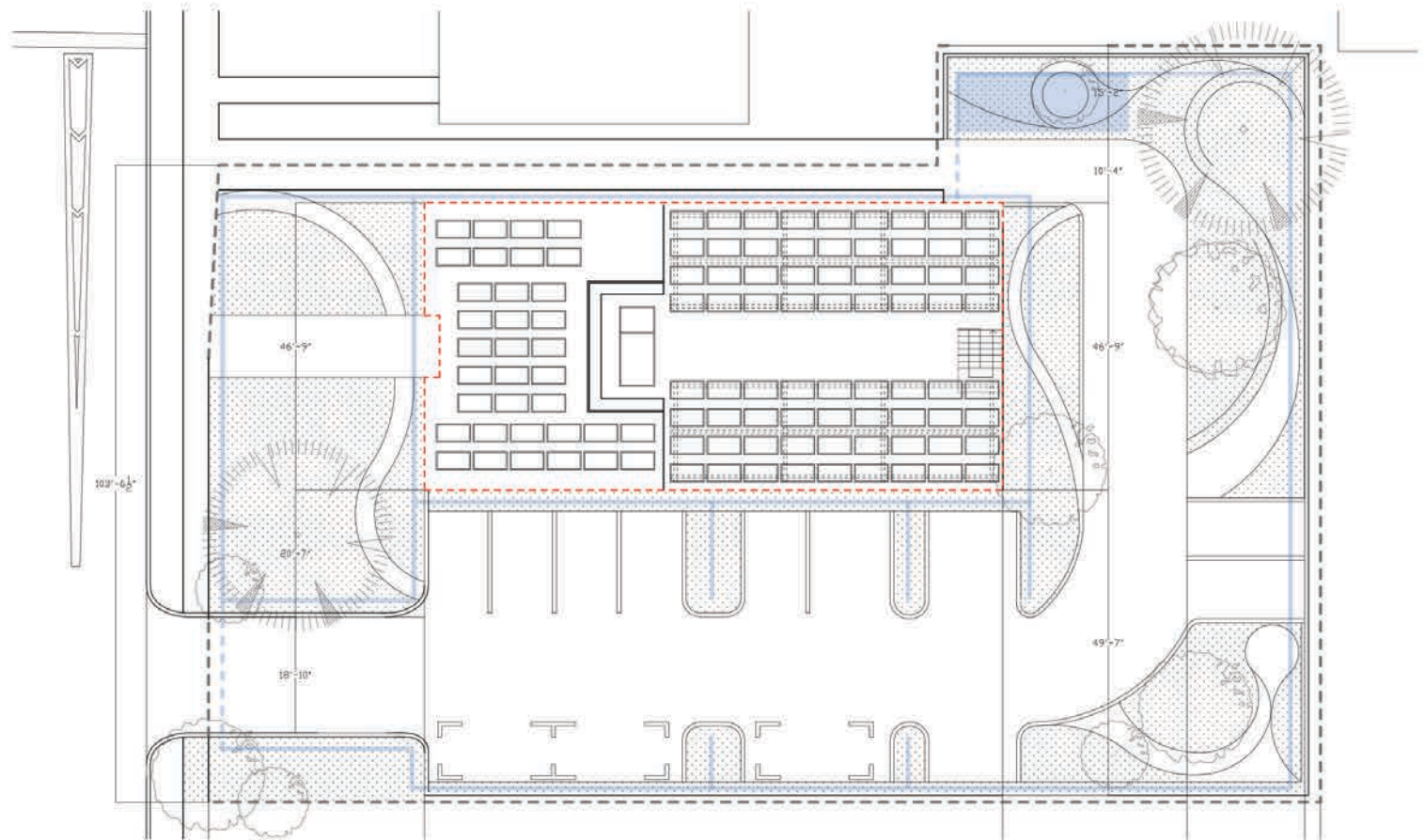
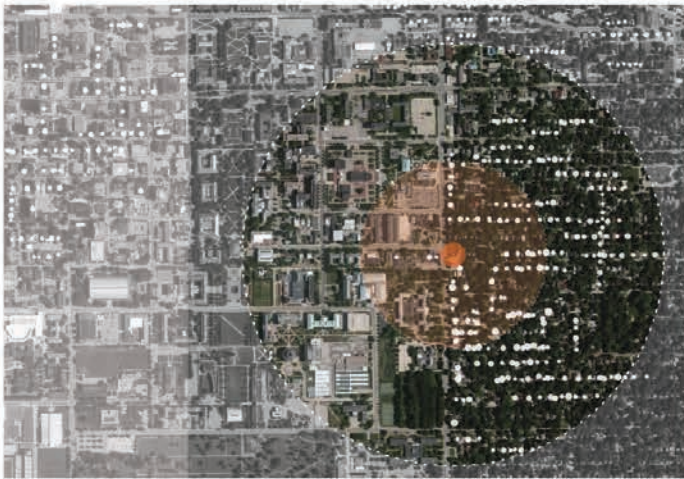
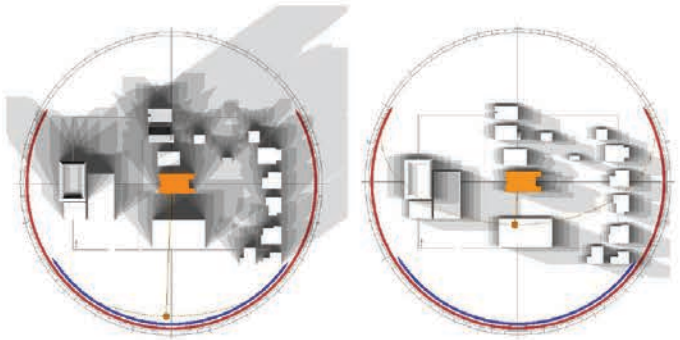
Urbana, IL

Climate Zone: 5B

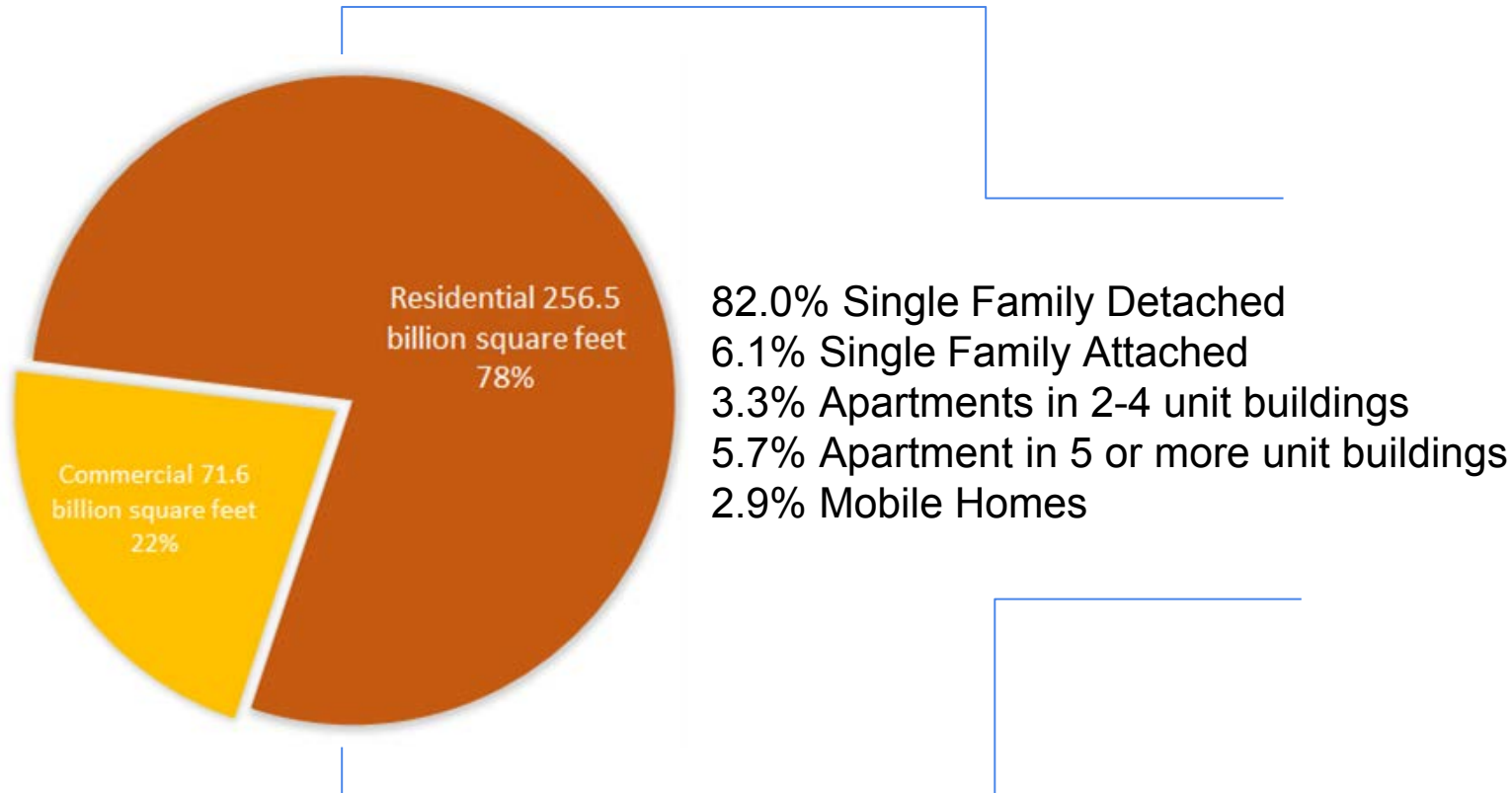




# PROJECT LOCATION



# WHY RETROFIT?



256.5 b sqf  
Residential building in the US

14.6 b sqf  
Multifamily homes in the US

Source: US Energy Information Administration

# WHY RETROFIT? (Retrofit vs. New Construction)

Basecase -9%  
Advanced Case -12%



Climate Change



Human Health

Basecase - 17%  
Advanced Case -20%



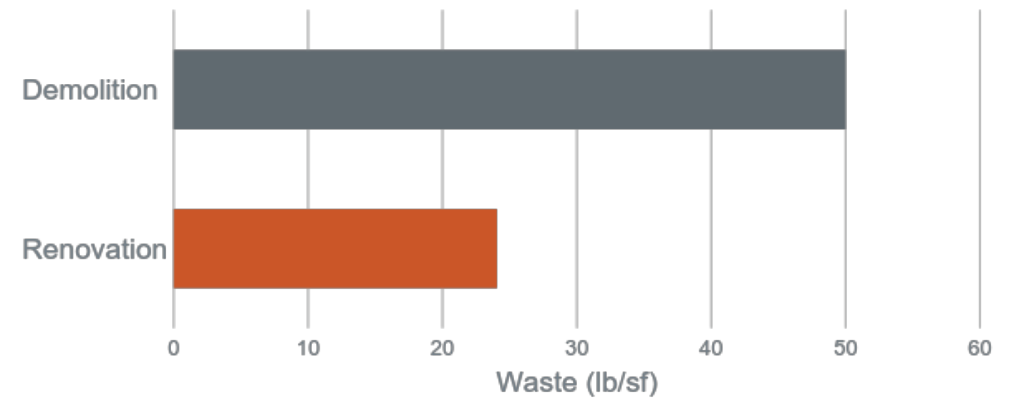
Resource Depletion

Ecosystem Quality

Basecase - 9%  
Advanced Case -12%

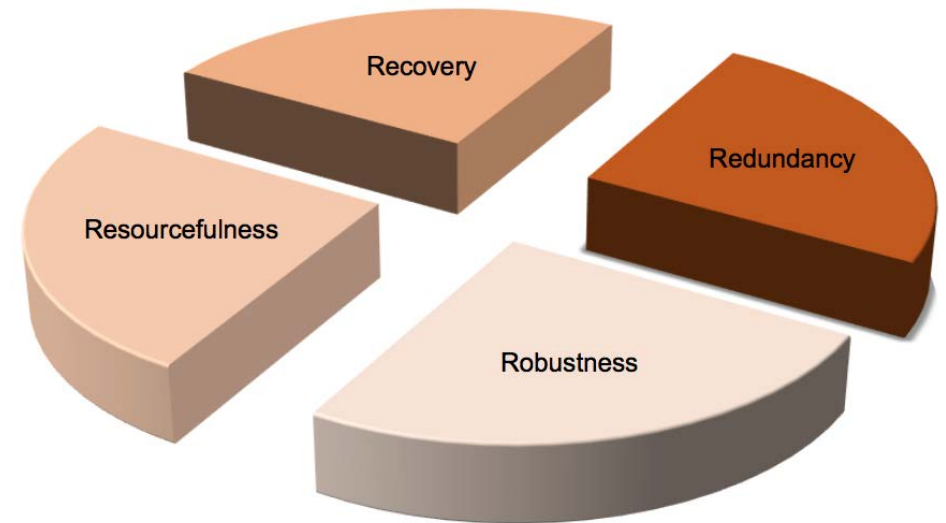
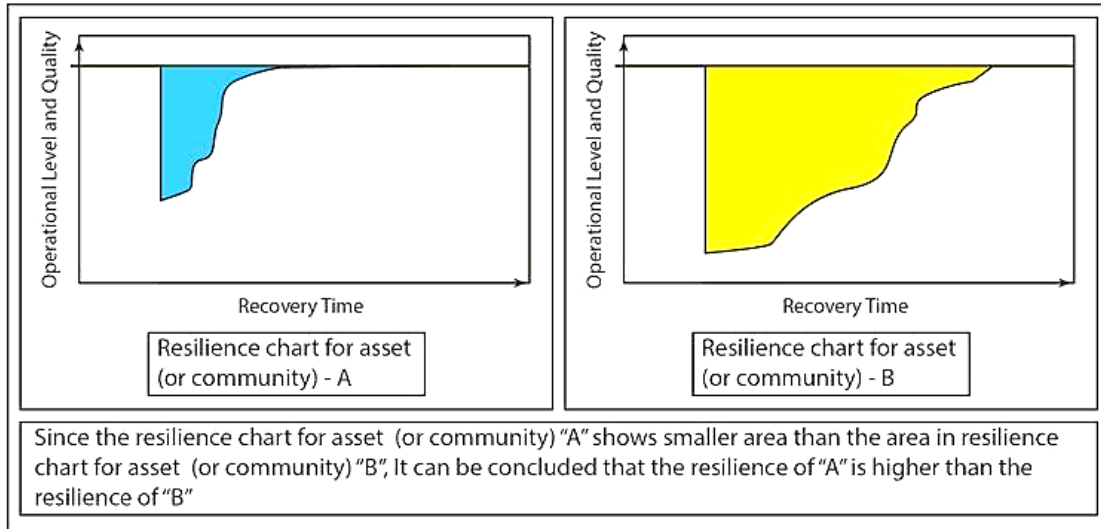


Basecase - 24%  
Advanced Case -28%

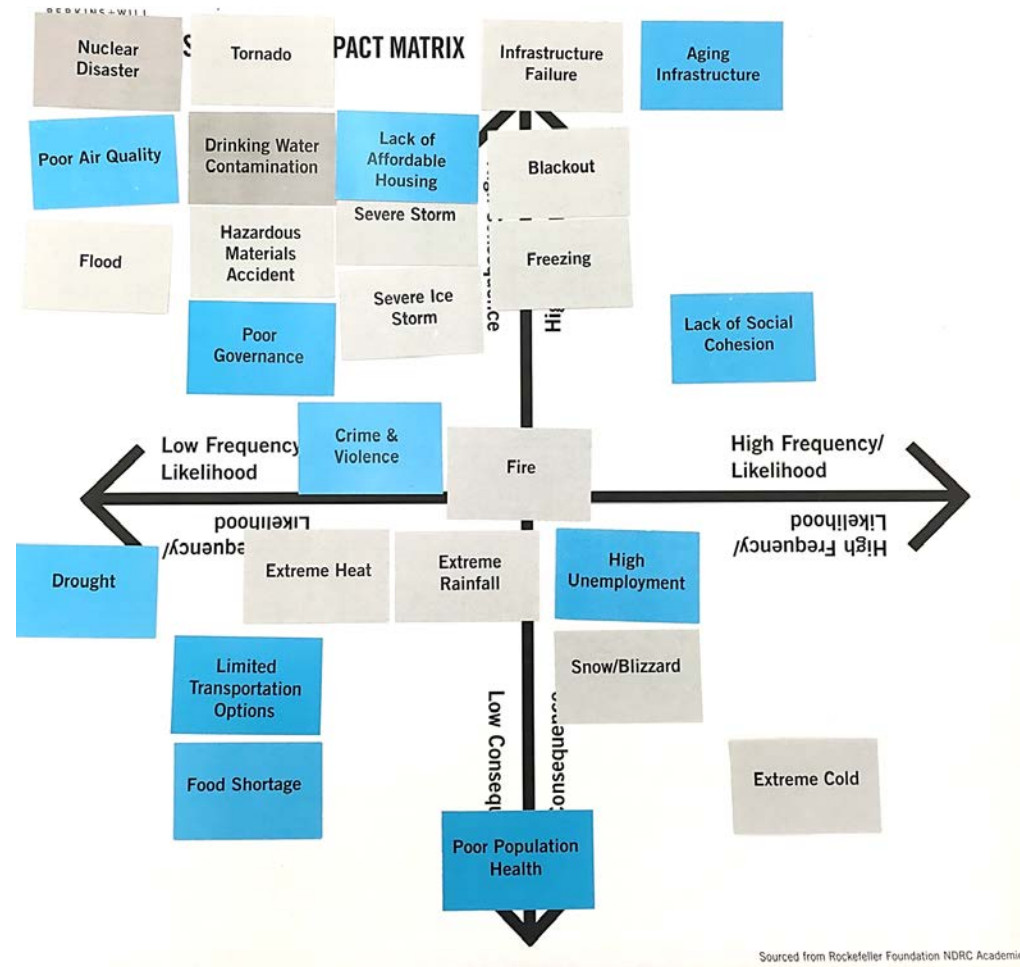




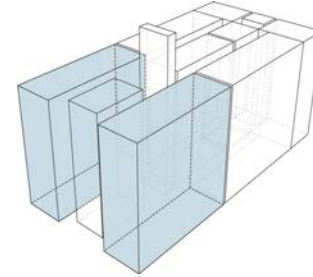
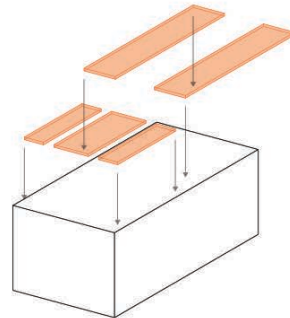
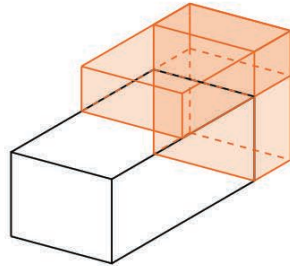
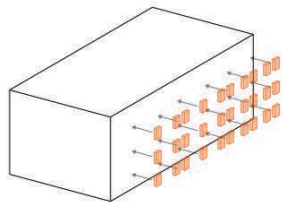
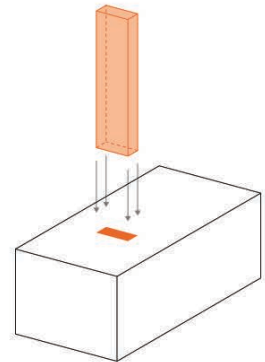
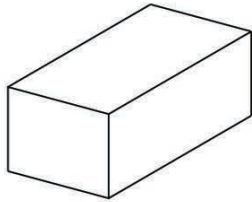
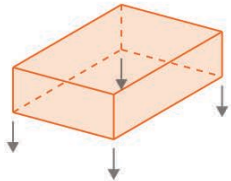
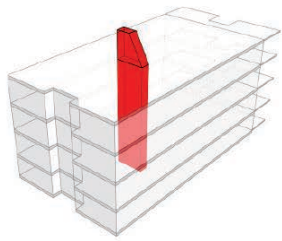
# RESILIENCY - THE FOUR R's



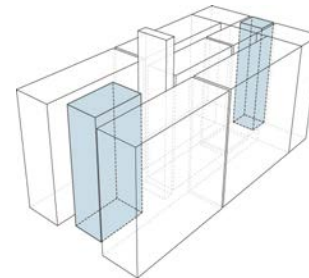
# LOCALIZING RESILIENCY IN URBANA, IL



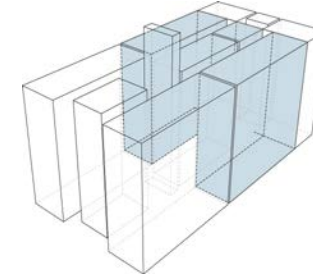
# PROGRAM



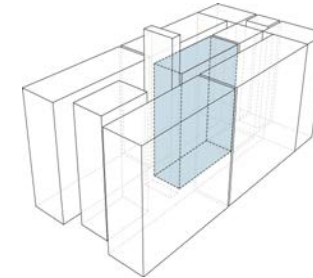
Living



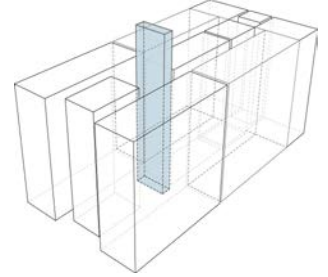
Circulation



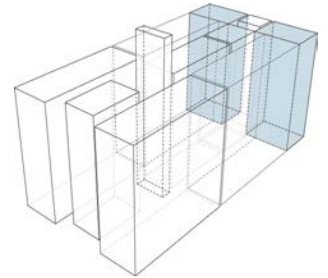
Bedroom



Mechanical and  
Plumbing Cores



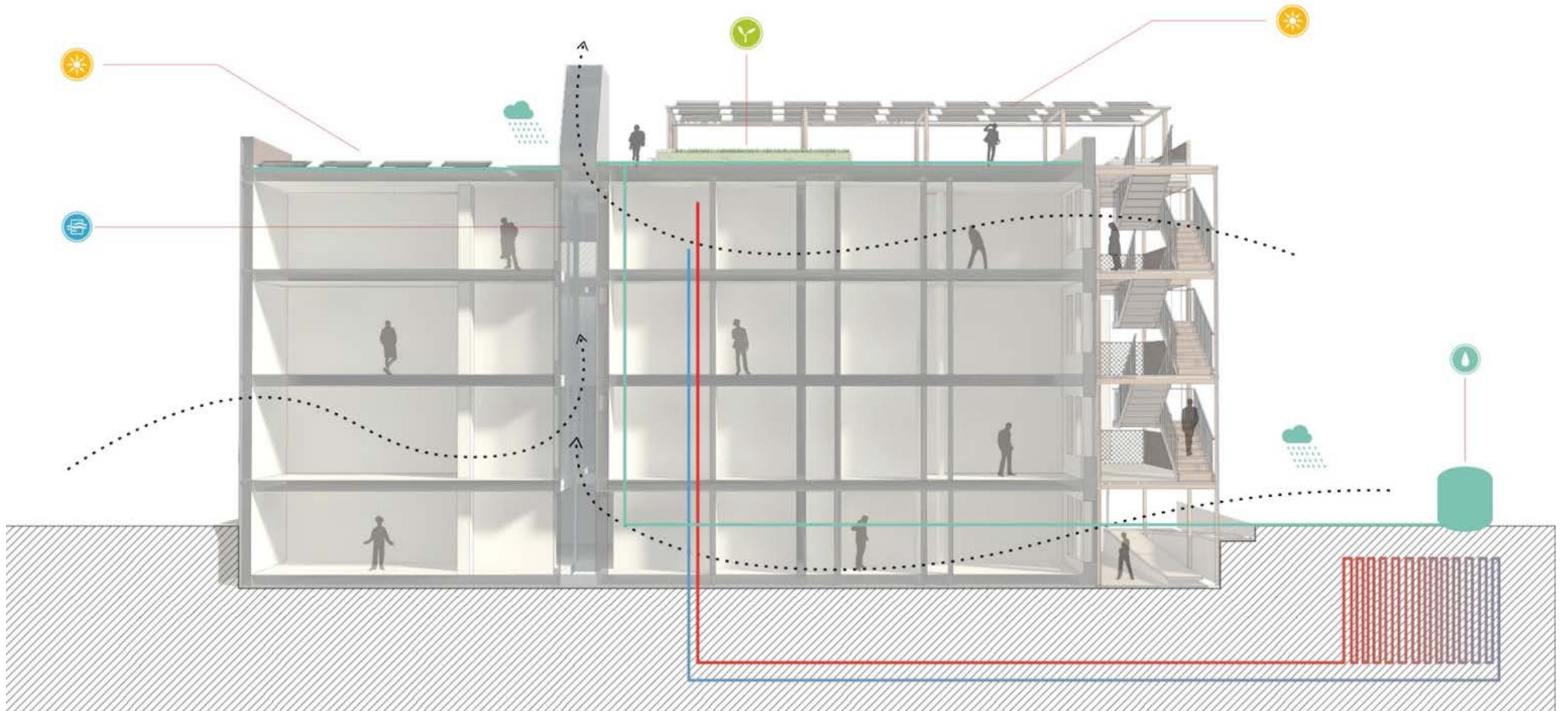
Solar Chimney



Patio



# SUSTAINABILITY DIAGRAM



# SITE PLAN





# EAST ELEVATION

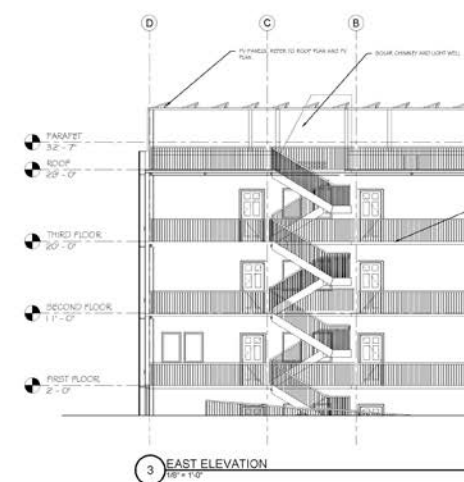
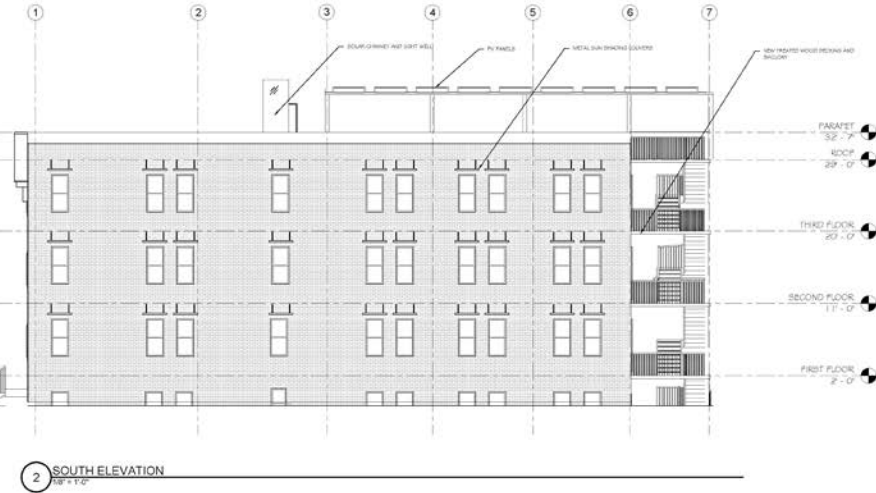
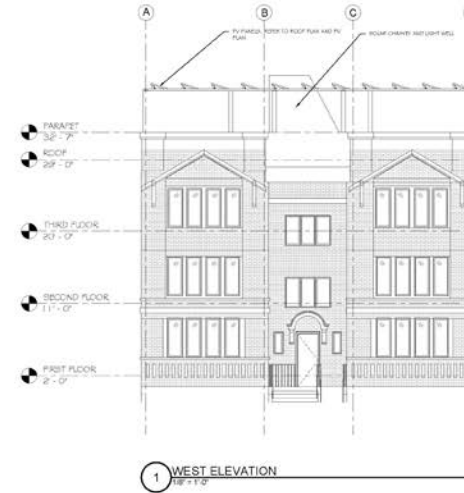
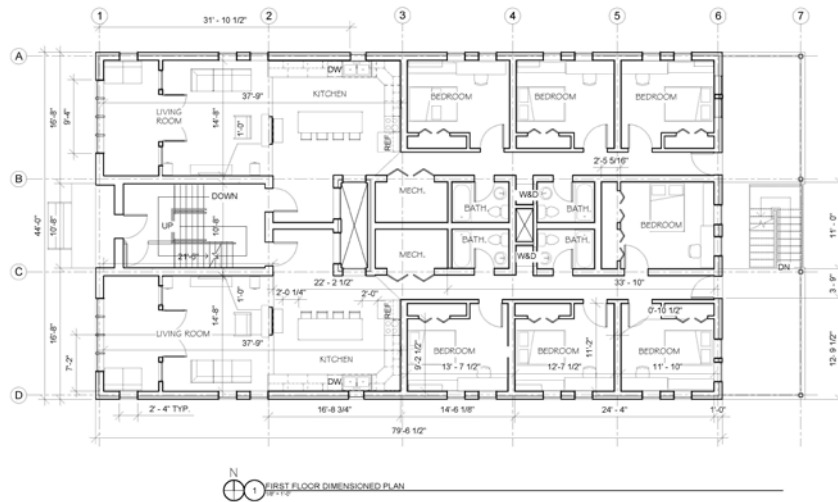
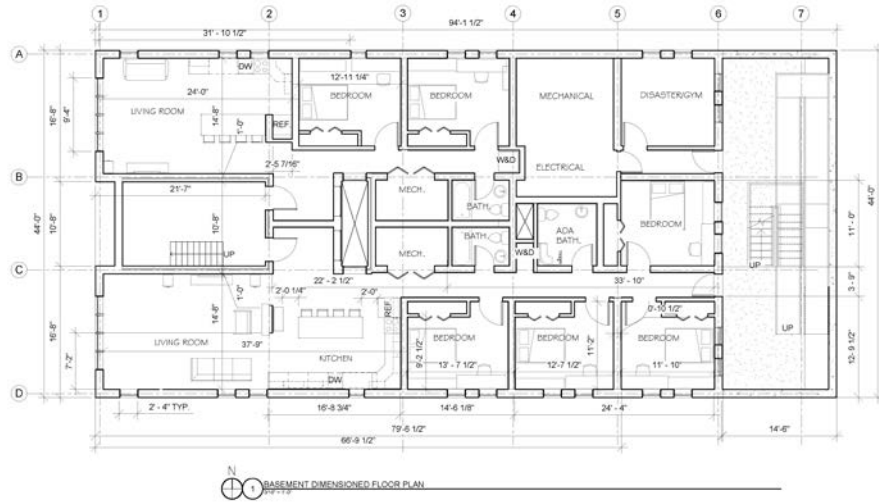




# INTERIOR DESIGN

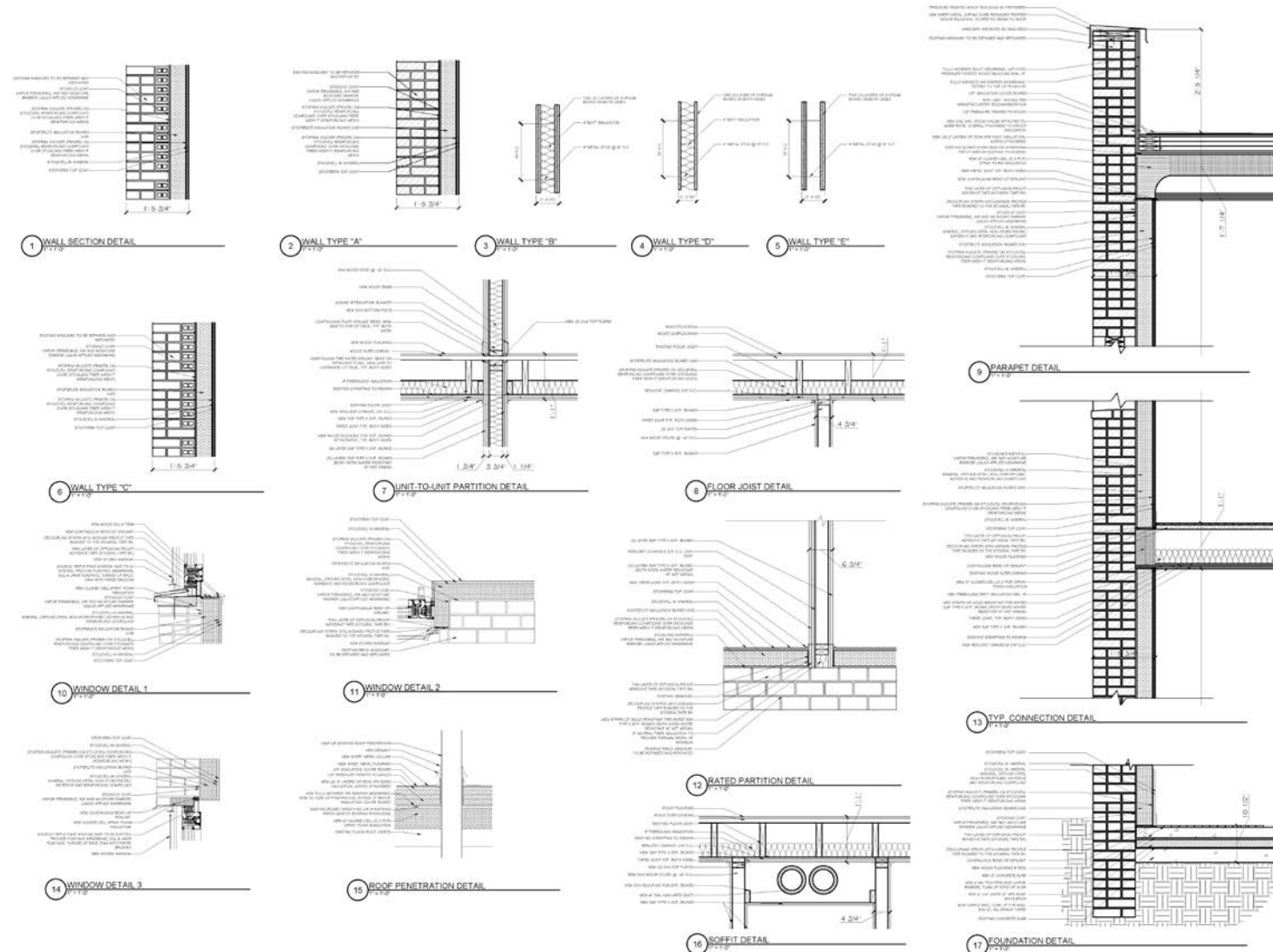


# CONSTRUCTABILITY



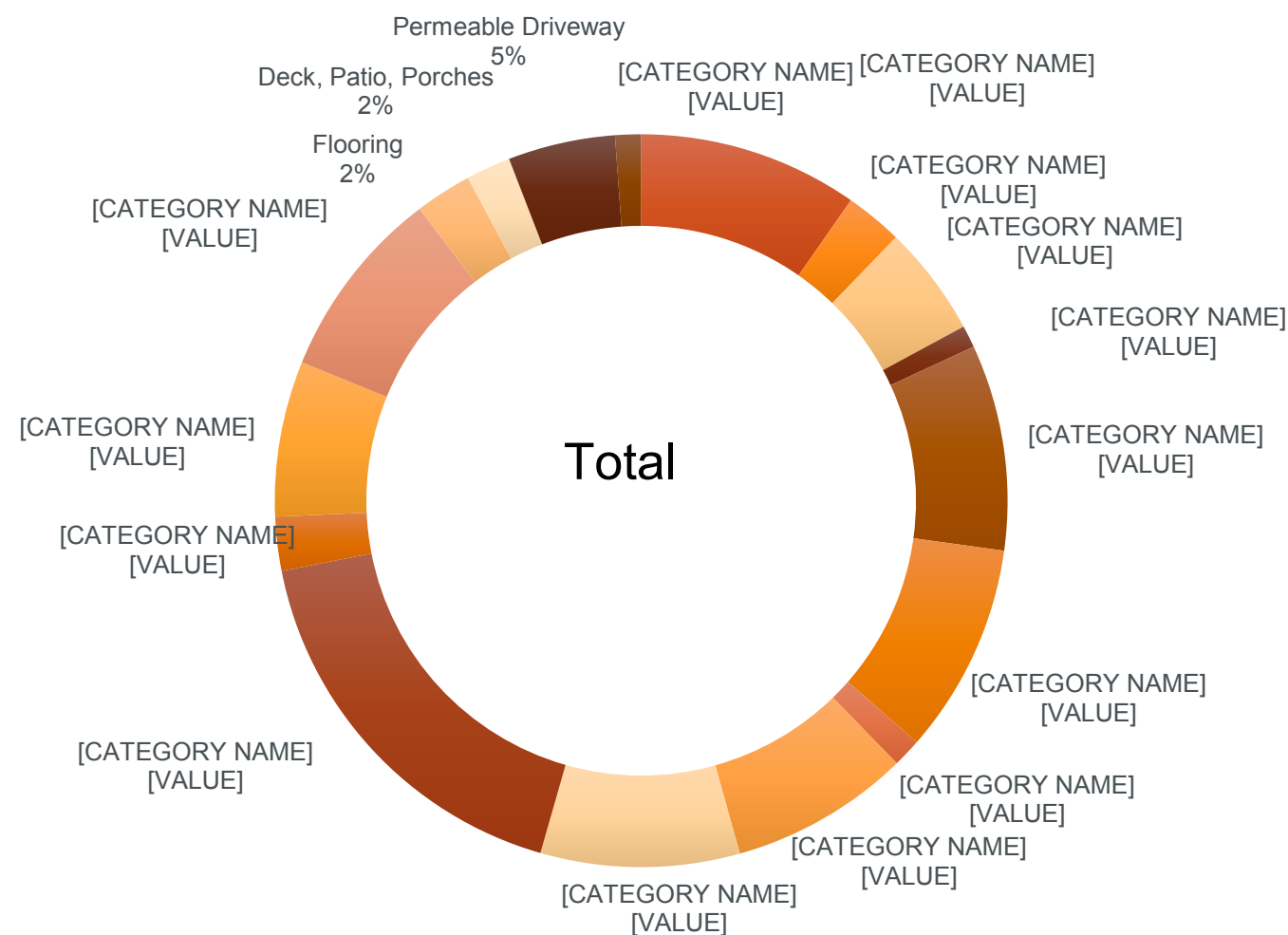


# CONSTRUCTABILITY





# FINANCIAL AND CONSTRUCTION ANALYSIS

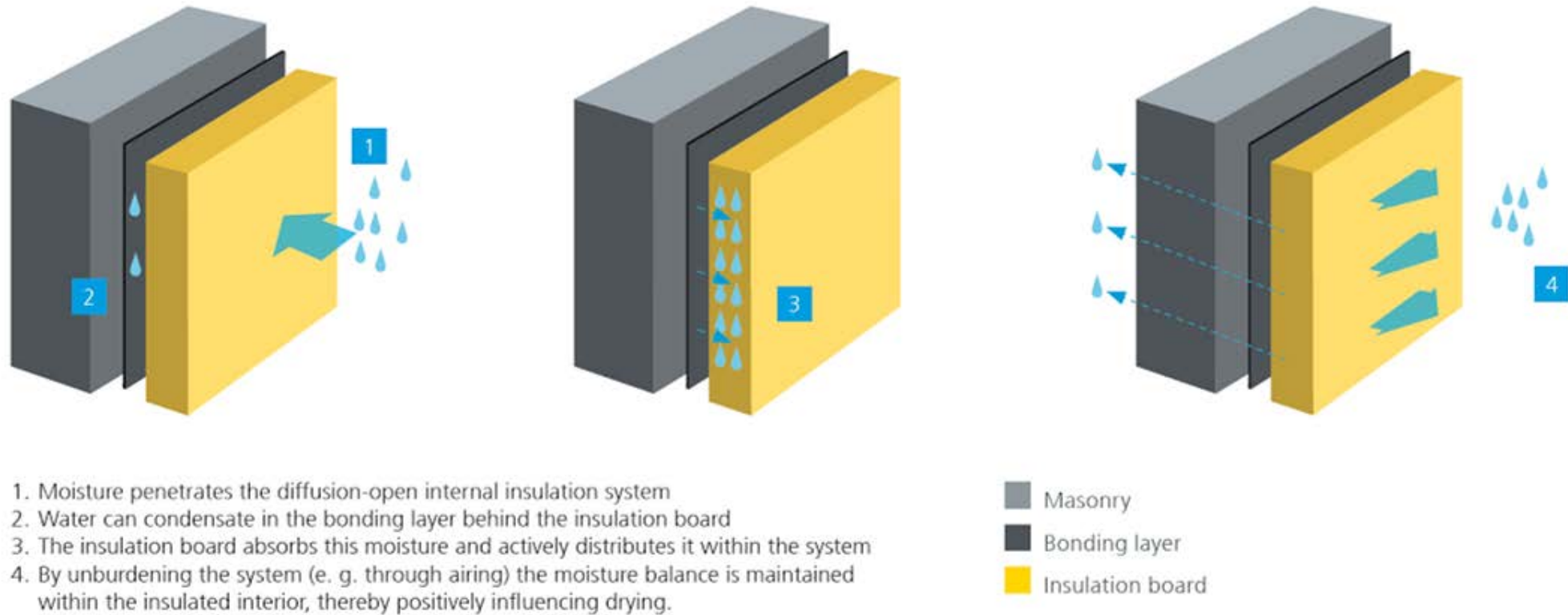


Debt to Income Ratio Calculation	
Annual Median Family Income (MFI)	\$ 54,916
Monthly Household Debt (0.5% MFI)	\$ 34
Operations and Maintenance Costs	\$ 24
Monthly Utility Costs	\$ 10
Property Tax	\$ 369
Insurance	\$ 10
Mortgage Payment	\$ 718
Home Ownership Affordability Target	38%
Calculated Debt to Income Ratio	25%

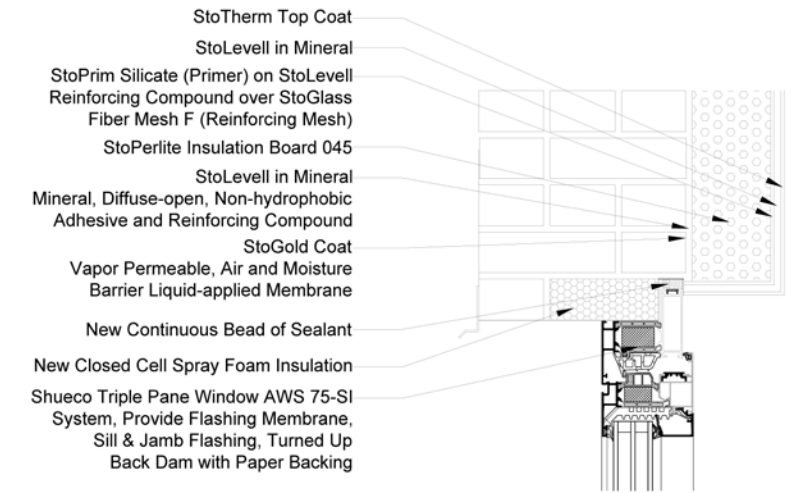
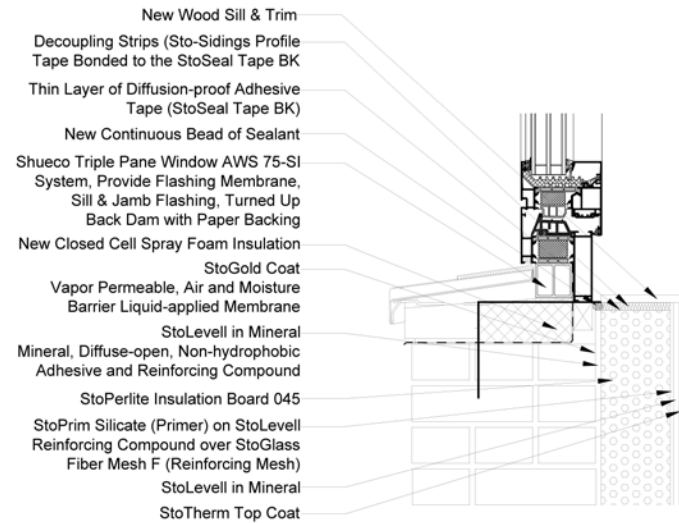
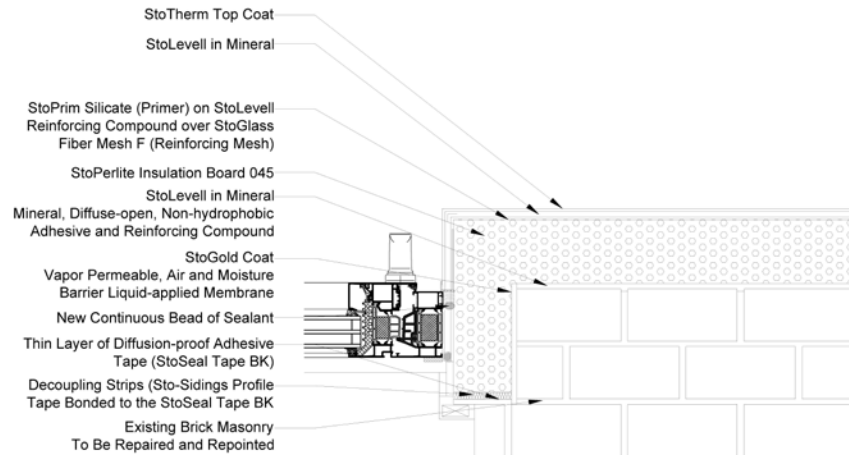
Financing Breakdown	
Annual Interest Rate	3.9%
Years	30 years
Payments per Year	12
Number of Payments	360
Down payment	\$ 305,644
Principle Amount	\$1,222,575
Monthly Payment	\$ (5,746)

Property Tax Calculation	
Property Tax Rate	2.32%
Annual Property Tax	\$ 35,455

# ENVELOPE RETROFIT

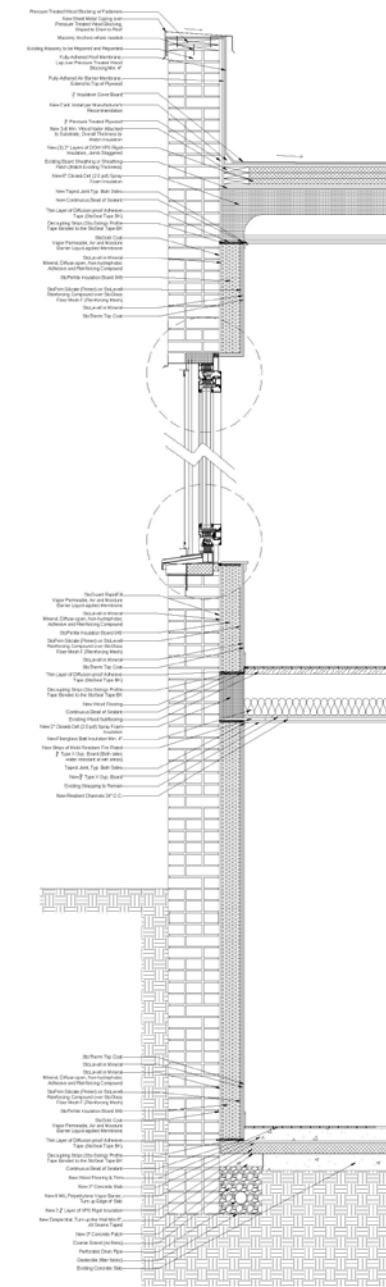
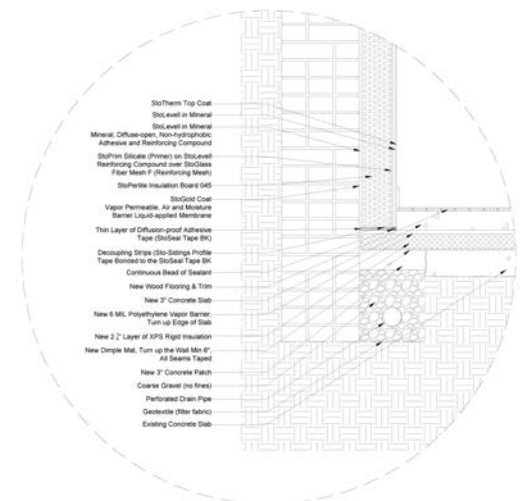
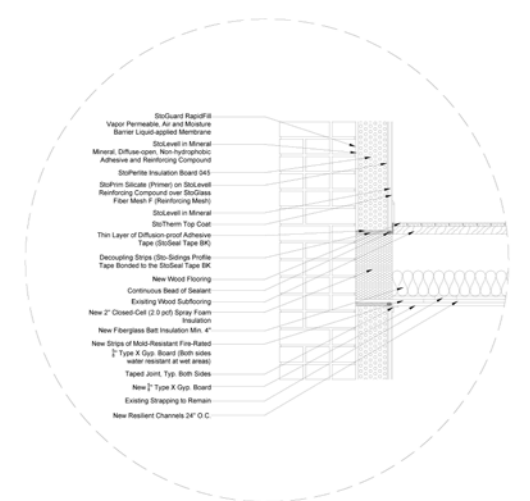
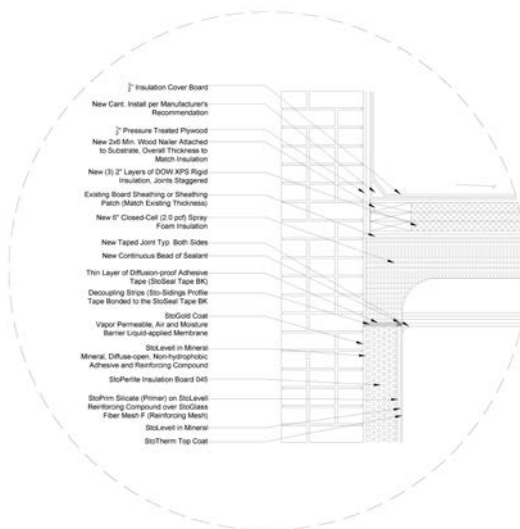
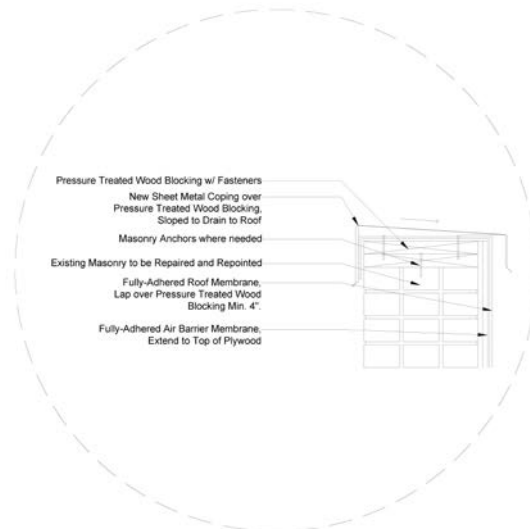


# WINDOW DETAILS





# PROPOSED WALL SECTION DETAILS



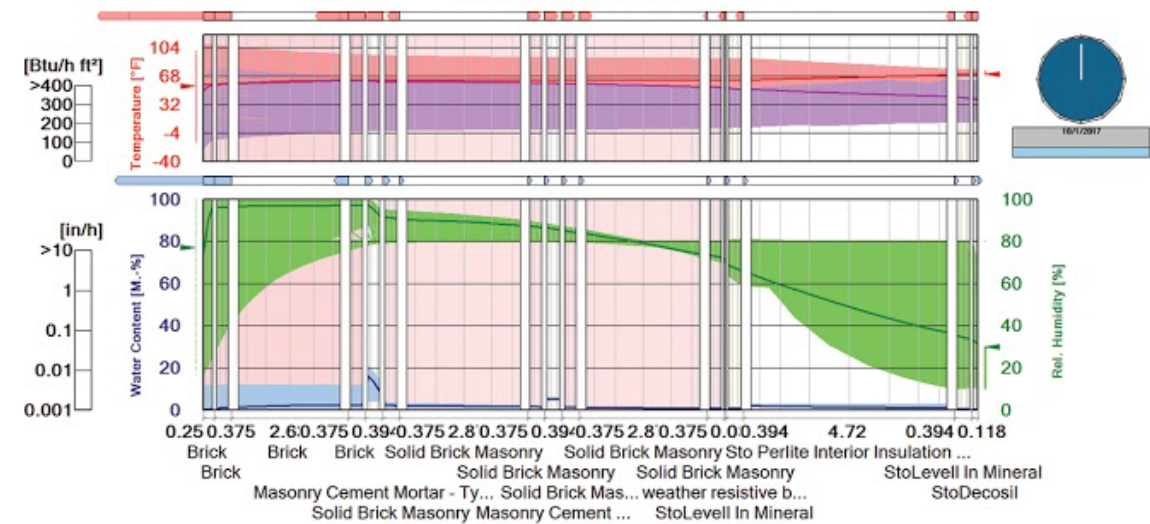
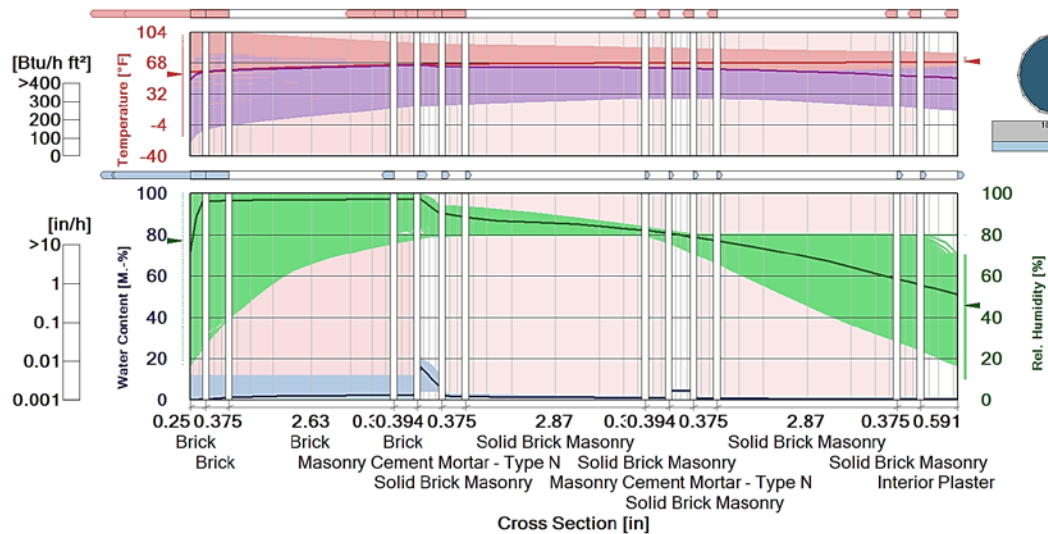
# HYGROTHERMAL ANALYSIS

Location: USA\_IL\_University.of.Illinois-Willard.AP.725315\_TMY3.epw;  
#Basecase

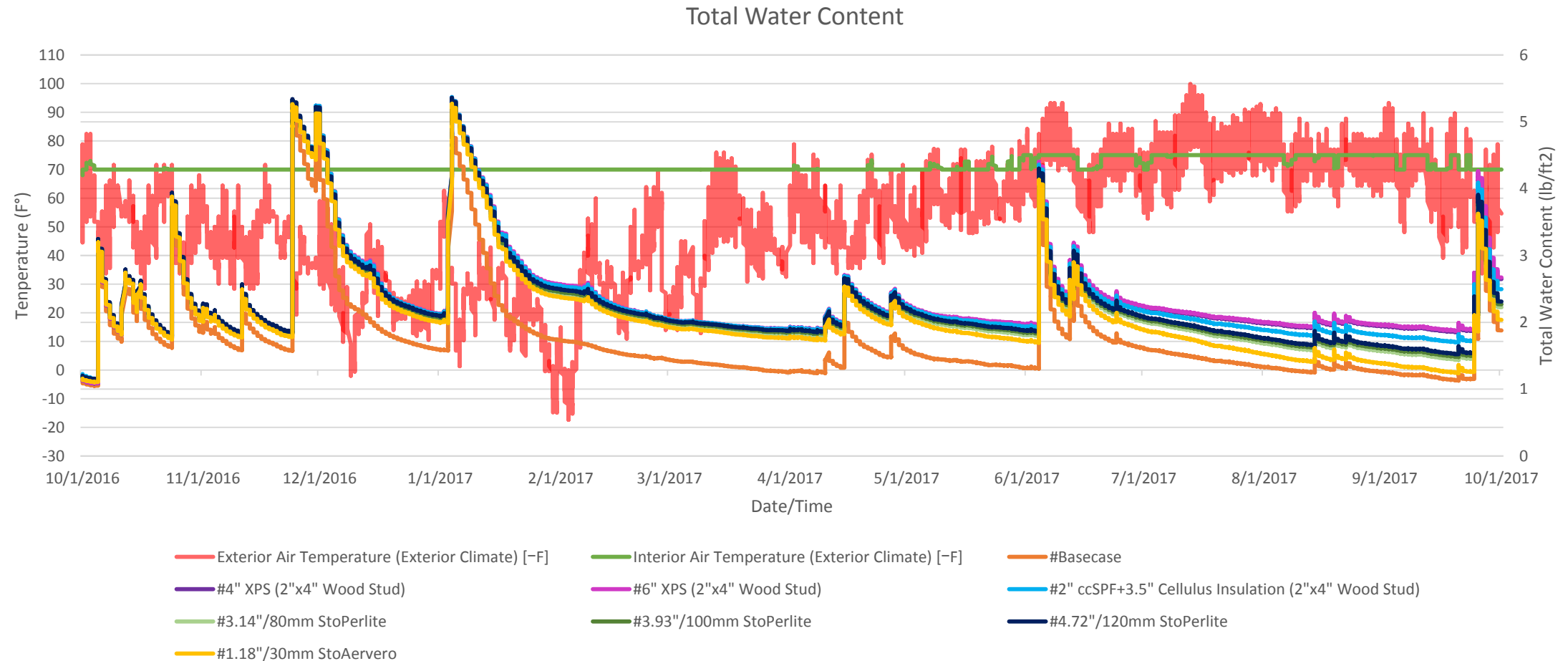
WUFI®

Location: USA\_IL\_University.of.Illinois-Willard.AP.725315\_TMY3.epw;  
#4.72"/120mm StoPerlite

WUFI®



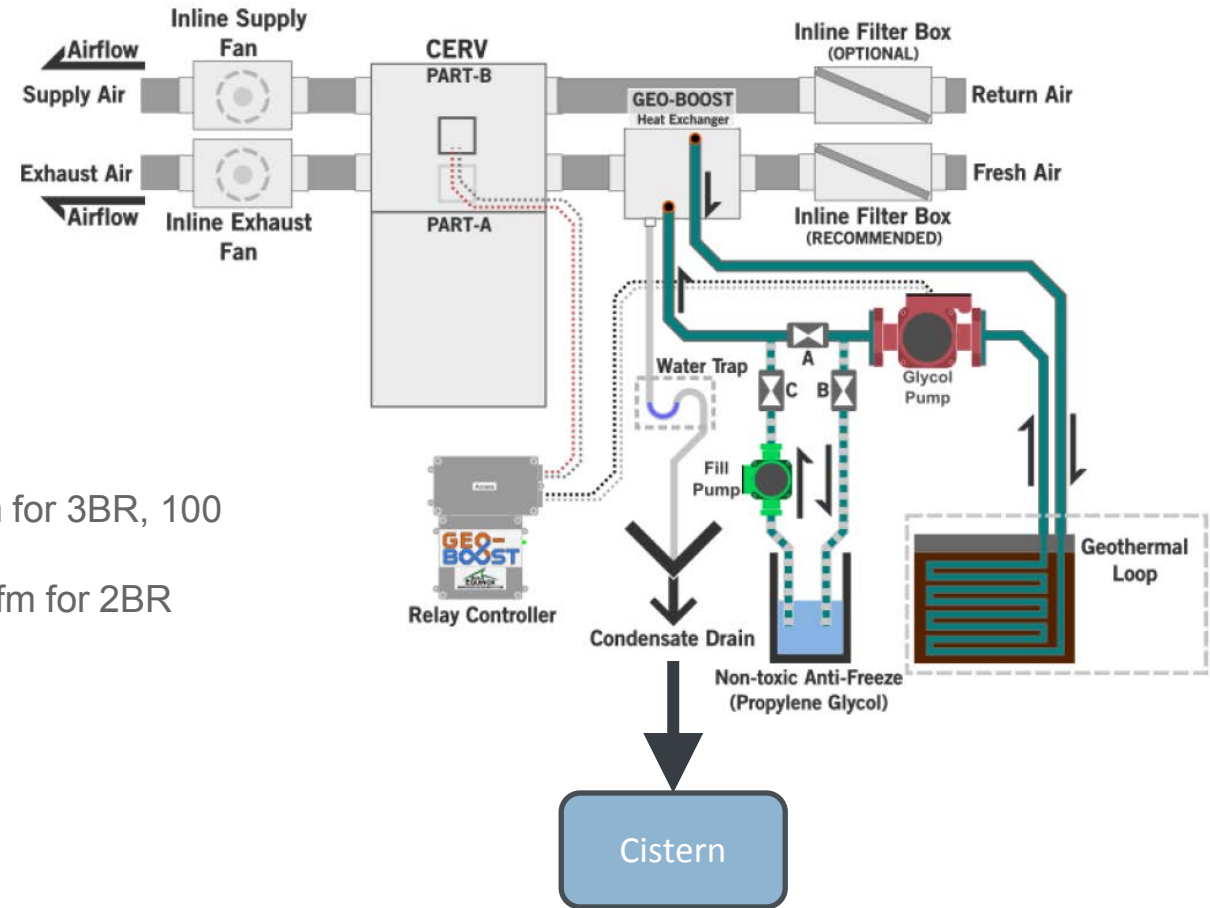
# HYGROTHERMAL ANALYSIS





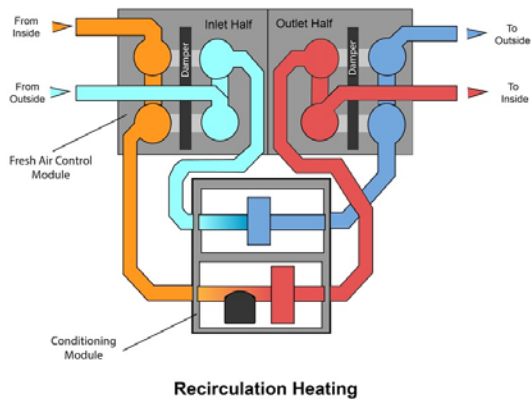
# HVAC DESIGN PRINCIPLES/SYSTEMS

- Eliminated ASHP from design
  - CERV to handle heat supply to all spaces
    - Individual bedrooms + open living space
  - Simplifies layout, downsizes system
- CERV with GeoBoost for heating
  - CERV placed in mechanical room in each unit
  - Geo-loop: HDPE piping for 300' main loop, circulating propylene glycol + water mixture
  - Taco 009 Cartridge Circulator Pump per CERV
  - Panasonic FV-30 WhisperLine air blowers
    - 100-175 cfm, MERV-13 filter
    - Total airflow supply: 160 cfm for 4BR, 130 cfm for 3BR, 100 cfm for 2BR
    - Total airflow exhaust: 110 cfm for 3/4BR, 80 cfm for 2BR

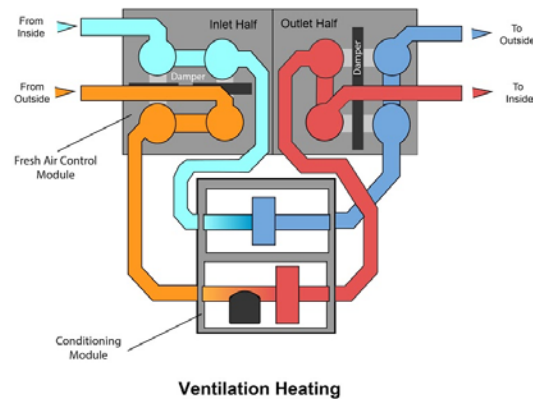


# HVAC SYSTEMS OVERVIEW

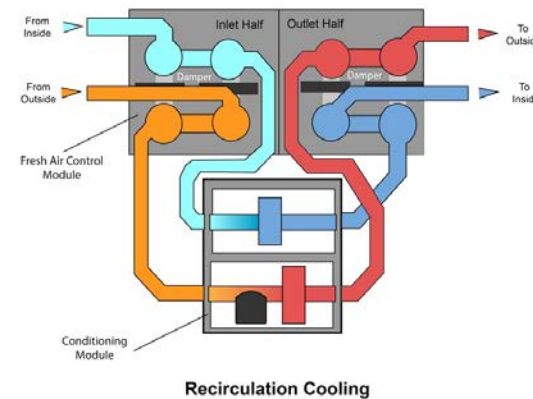
Coefficient of Performance (COP)  
 2.4 (without fan power) / 1.9 (with fan power)  
 Energy Efficiency Ratio (EER) = 8.6 Btu/W-hr  
 Total Cooling Capacity = 1079 W  
 Compressor Power = 450 W  
 Fan Power = 120 W  
 Lat. = 133 W Sens. = 947 W



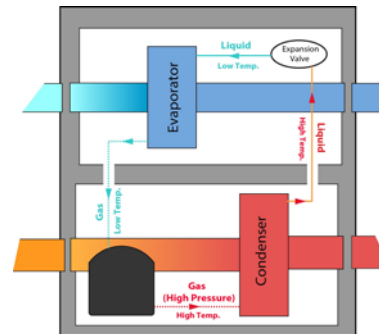
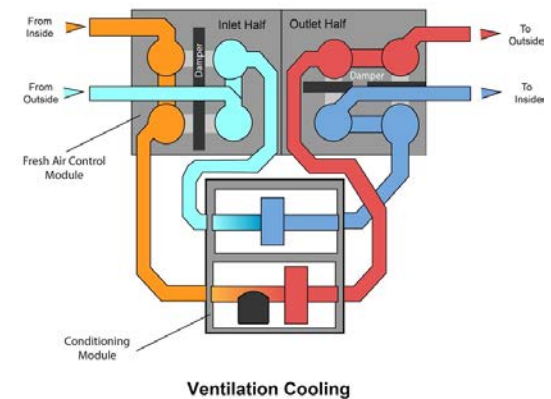
Coefficient of Performance (COP)  
 3.5 (without fan power) / 2.7 (with fan power)  
 Energy Efficiency Ratio (EER) = 12.7 Btu/W-hr  
 Total Cooling Capacity = 1342 W  
 Compressor Power = 381 W  
 Fan Power = 120 W  
 Lat. = 231 W Sens. = 1110 W



Coefficient of Performance (COP)  
 3.1 (without fan power) / 2.4 (with fan power)  
 Energy Efficiency Ratio (EER) = 11.1 Btu/W-hr  
 Total Cooling Capacity = 1165 W  
 Compressor Power = 377 W

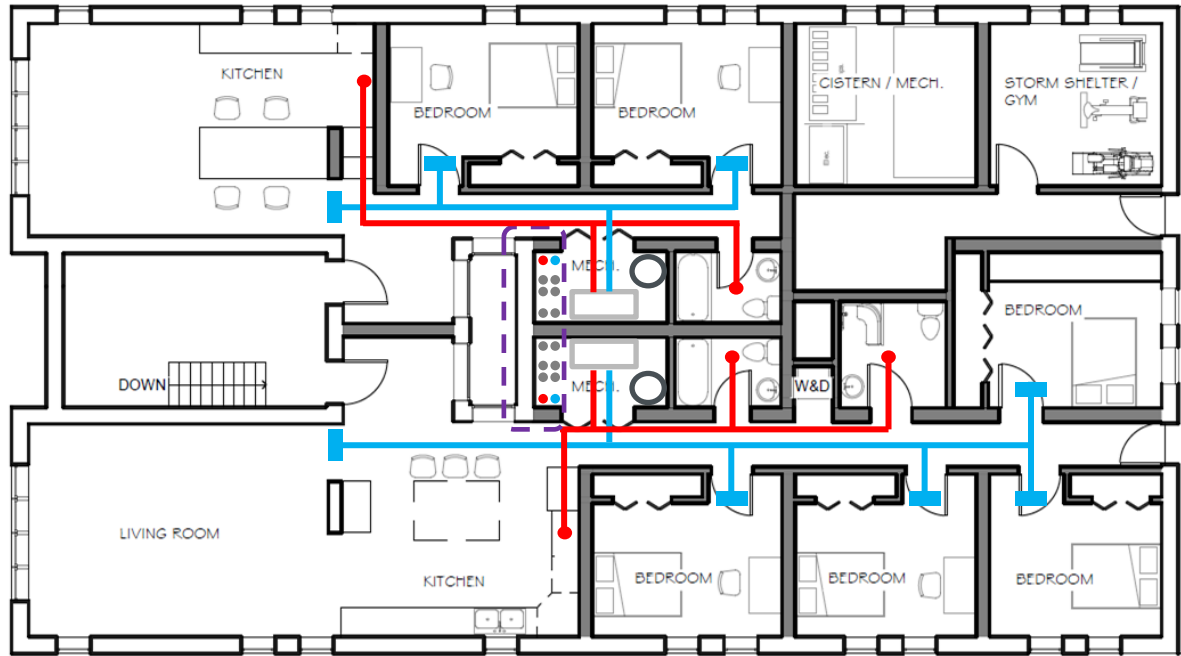


Coefficient of Performance (COP)  
 5.4 (without fan power) / 4.0 (with fan power)  
 Energy Efficiency Ratio (EER) = 19.3 Btu/W-hr  
 Total Cooling Capacity = 1803 W  
 Compressor Power = 335 W  
 Fan Power = 120 W

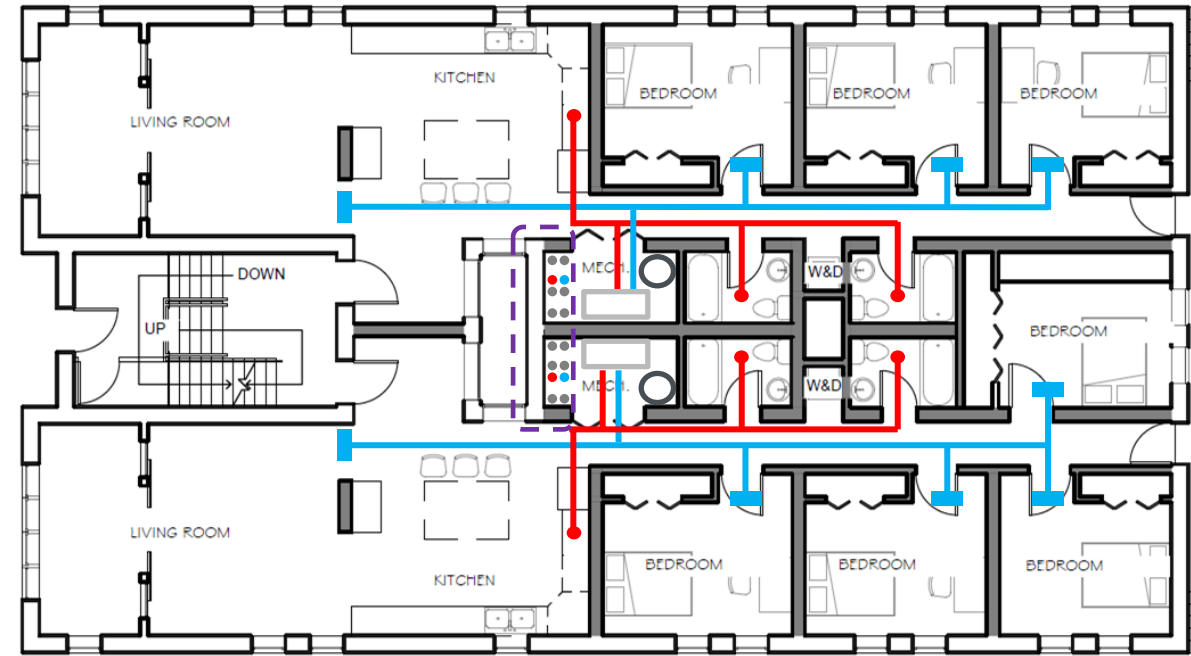


**Conditioning Module**

# HVAC SYSTEMS OVERVIEW



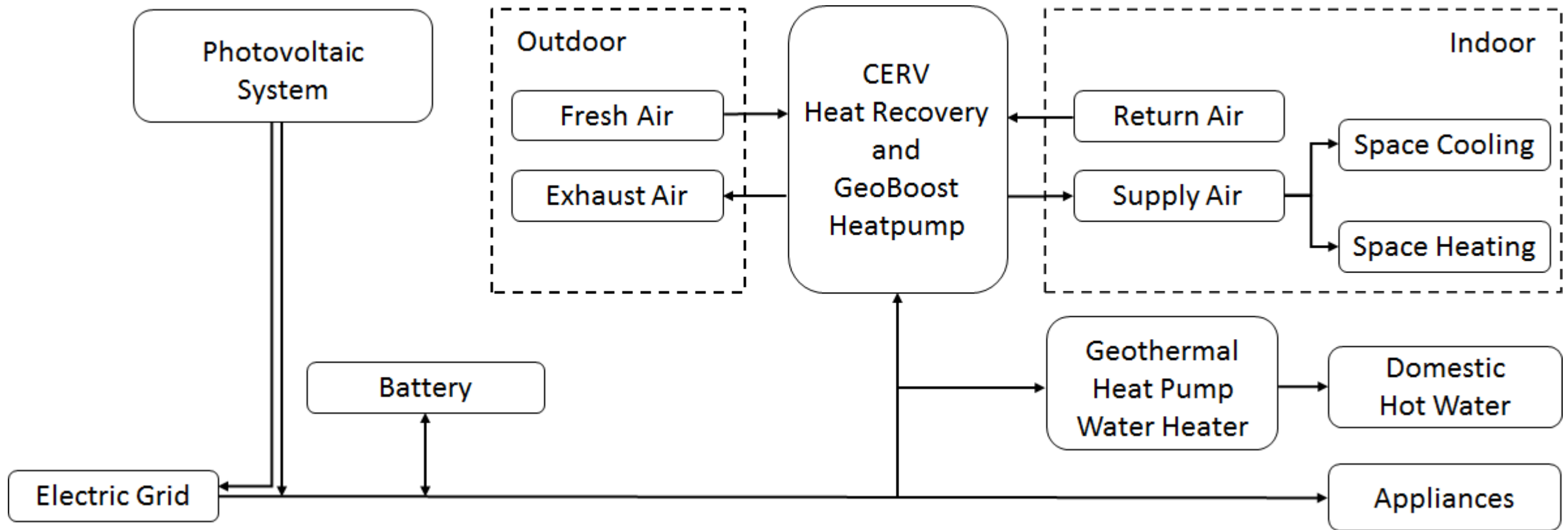
Basement Floor Plan



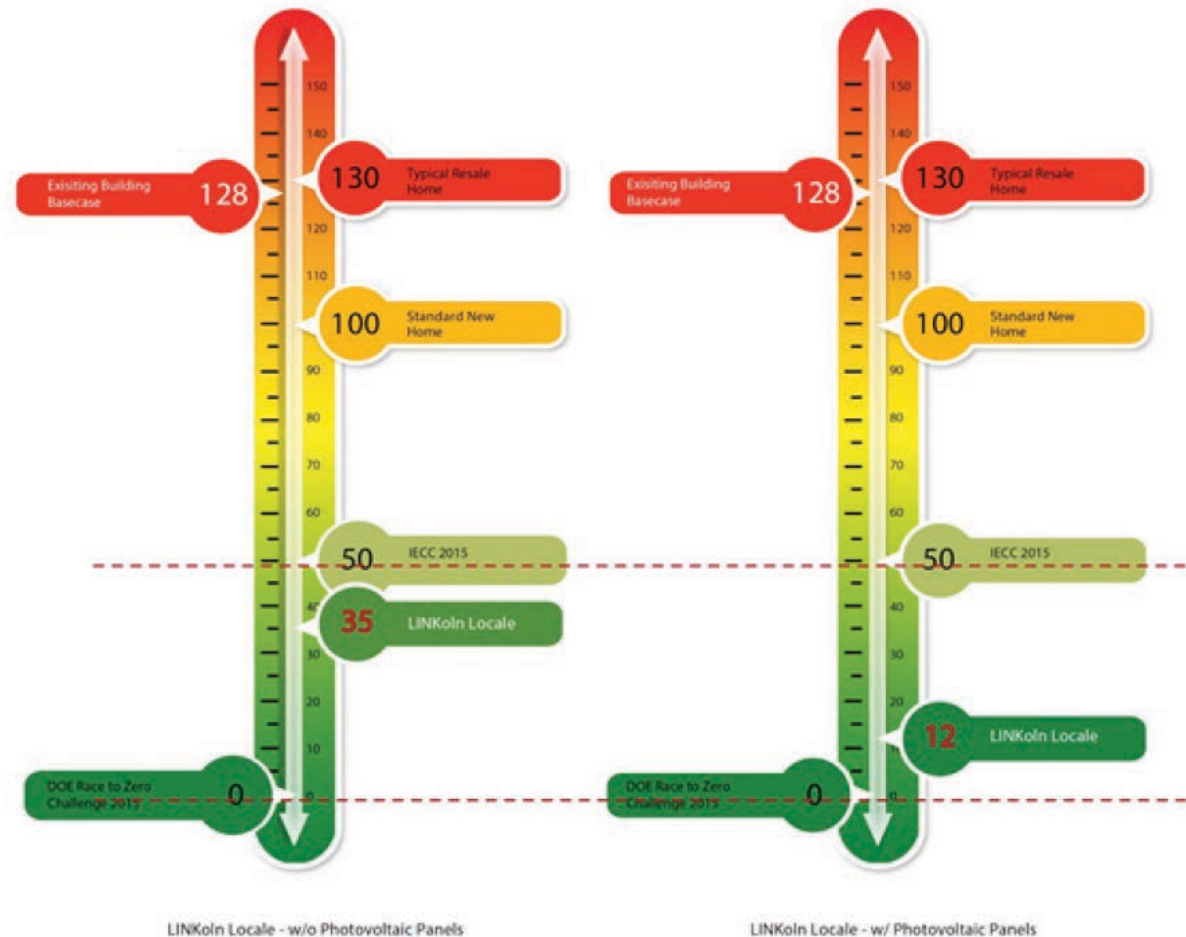
Typical Floor Plan



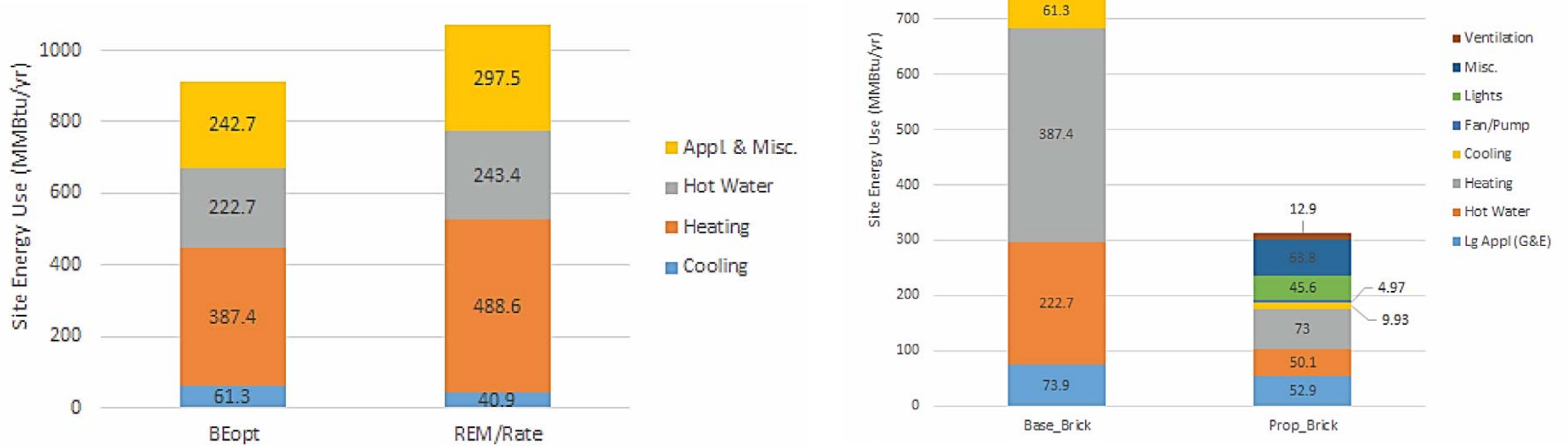
# HVAC SYSTEMS OVERVIEW



# WHOLE-HOUSE ENERGY SIMULATION RESULTS

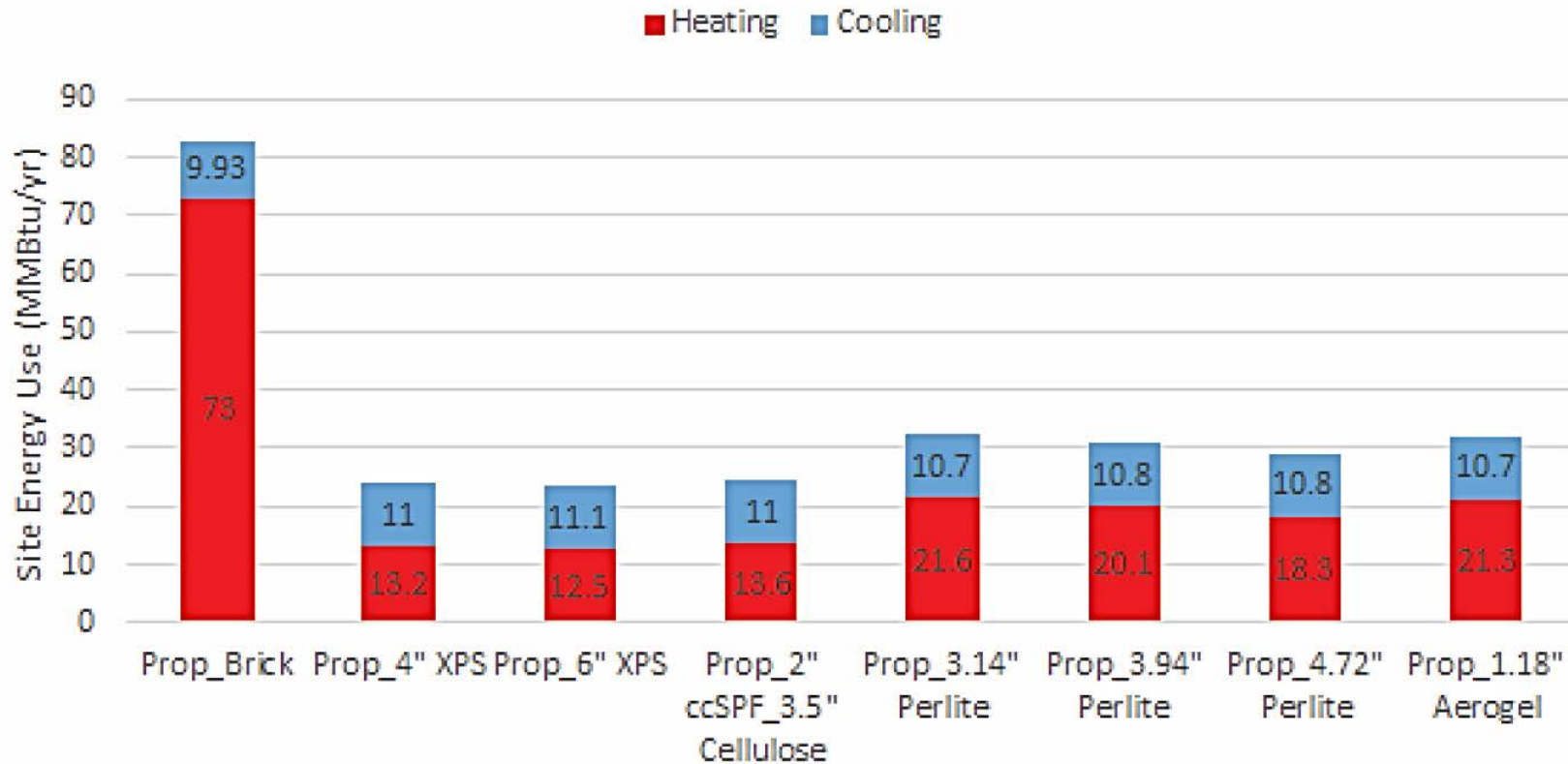


# WHOLE-HOUSE ENERGY SIMULATION RESULTS





# WHOLE-HOUSE ENERGY SIMULATION RESULTS



# PHOTOVOLTAIC MODULES

- **Sunpower SPR-X21-255**

Nominal Efficiency:	21.5%
Maximum Power:	254.666 Wdc
Max Power Voltage:	42.8 Vdc
Max Power Current:	5.9 Adc
Open Circuit Voltage:	51 Vdc
Short Circuit Current:	6.3 Adc

- **Advantages:**

- Highest Efficiency
- Proven Technology
- Thousands Sold
- 25 Years Warranty



# MICRO-INVERTER

## Enphase Energy: C250 220V

Weighted Efficiency:	96.4%
Maximum DC Input Voltage:	60 Vdc
Nominal Output AC Voltage:	220 Vac

### Advantages:

- Low loss due to shading, debris or snow
- Reduces module to module mismatch
- More resistant to whole system failure
- Monitoring of each solar panel via powerline communication
- Simple design, installation, and management

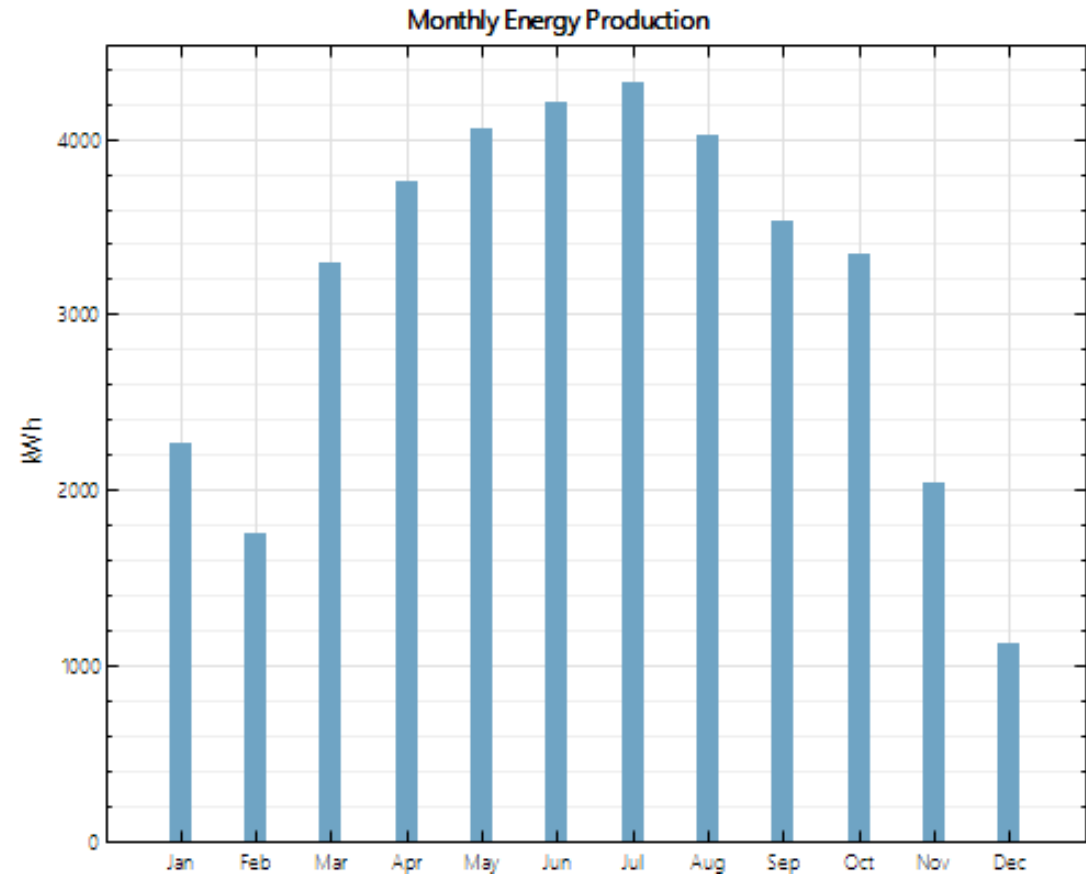




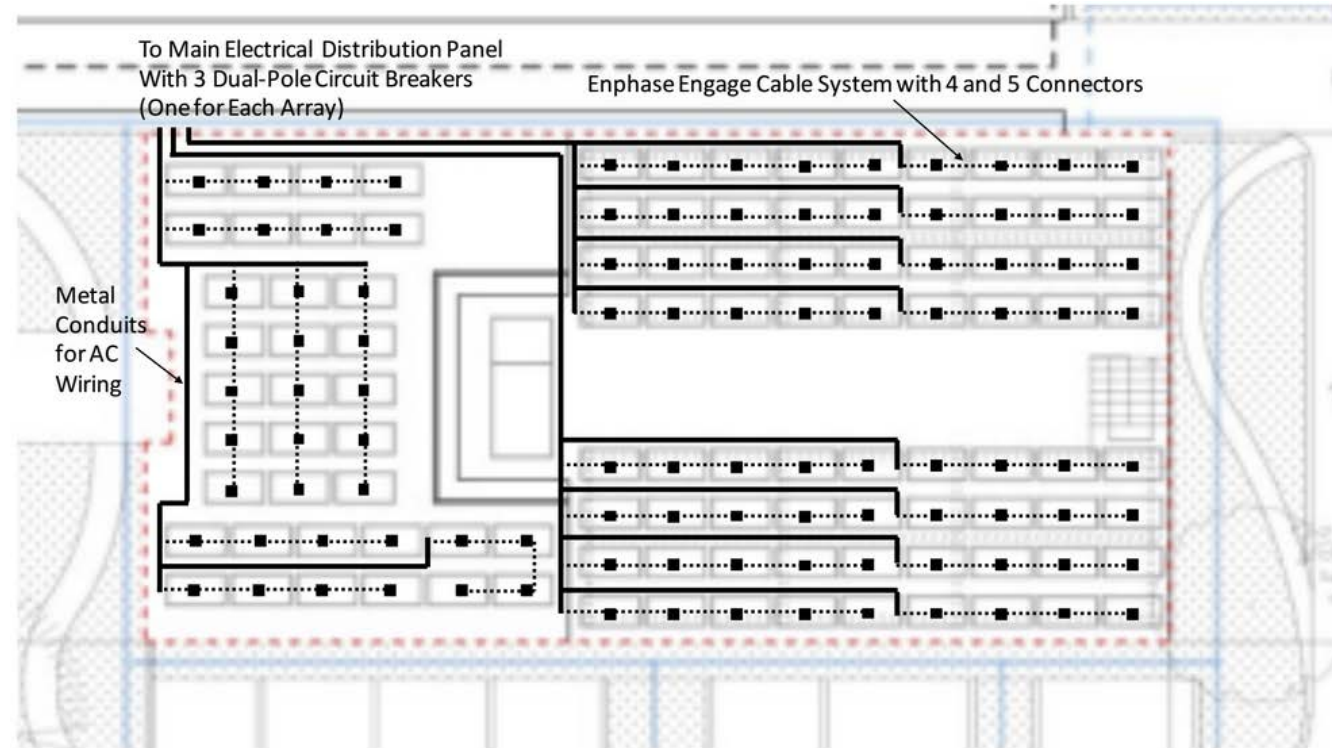
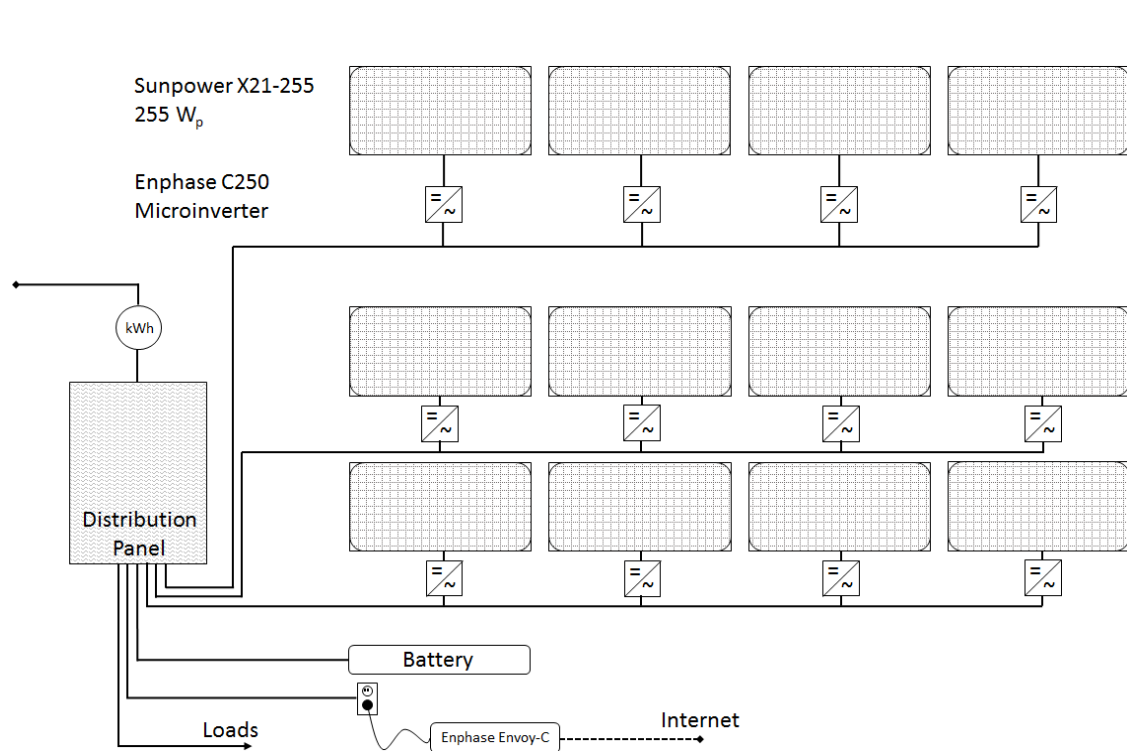
# PV SYSTEM DESIGN

107 Panels (27 kW)

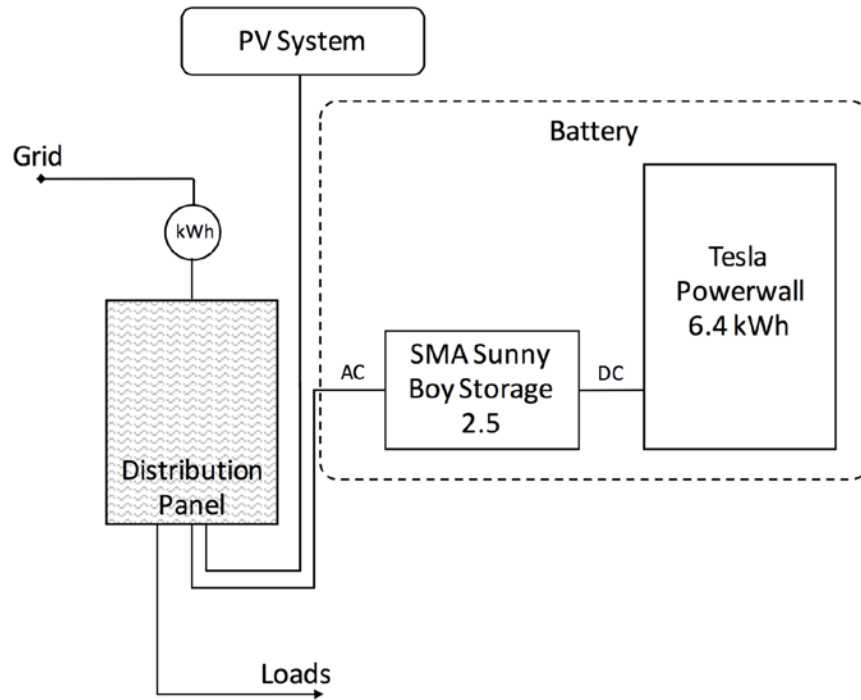
- 180° South at 29° Tilt
- Annual Energy Production 37,700 kWh
- \$ 70,580
- Offsets 92% of total consumption



# ELECTRICAL WIRING DESIGN



# LED LIGHTING BACKUP POWER



Available as of March 2016.



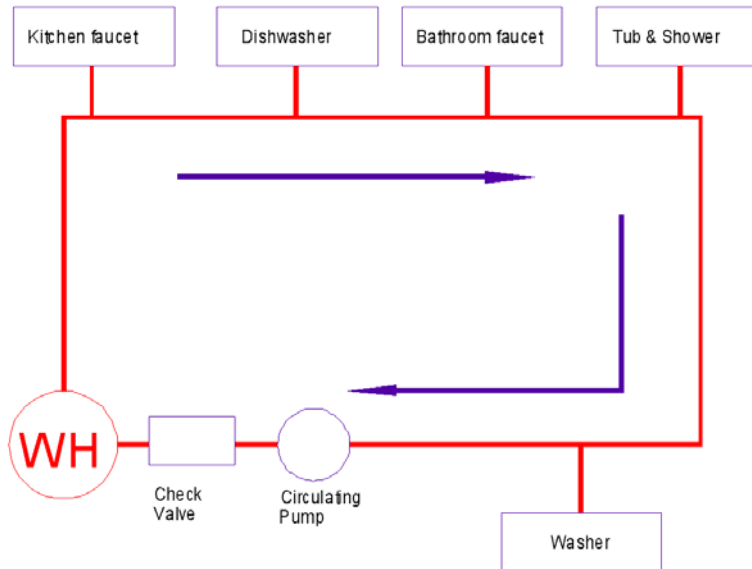


# DOMESTIC HOT WATER

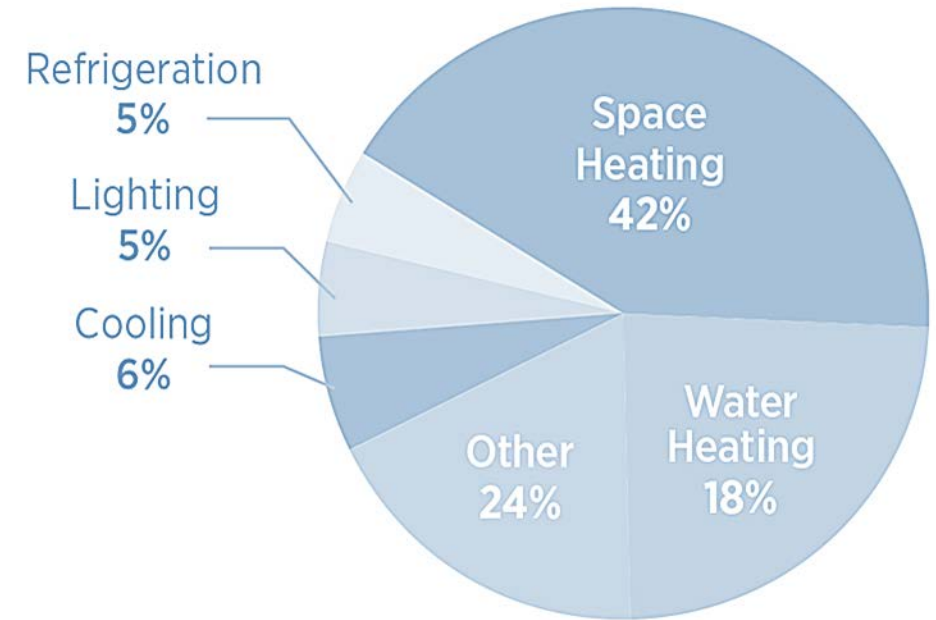
Save Energy and Water

Reduce the wait time for hot water

Return the ambient-temperature water  
back to the heater



- Shortest pipe run length
- Better loop location
- CPVC SCH 40 tubing



# DOMESTIC HOT WATER

- 50-gallon water heater
- Energy Factor 3.25>2.0
- Save \$370-\$490 water heating cost annually
- Four operating modes

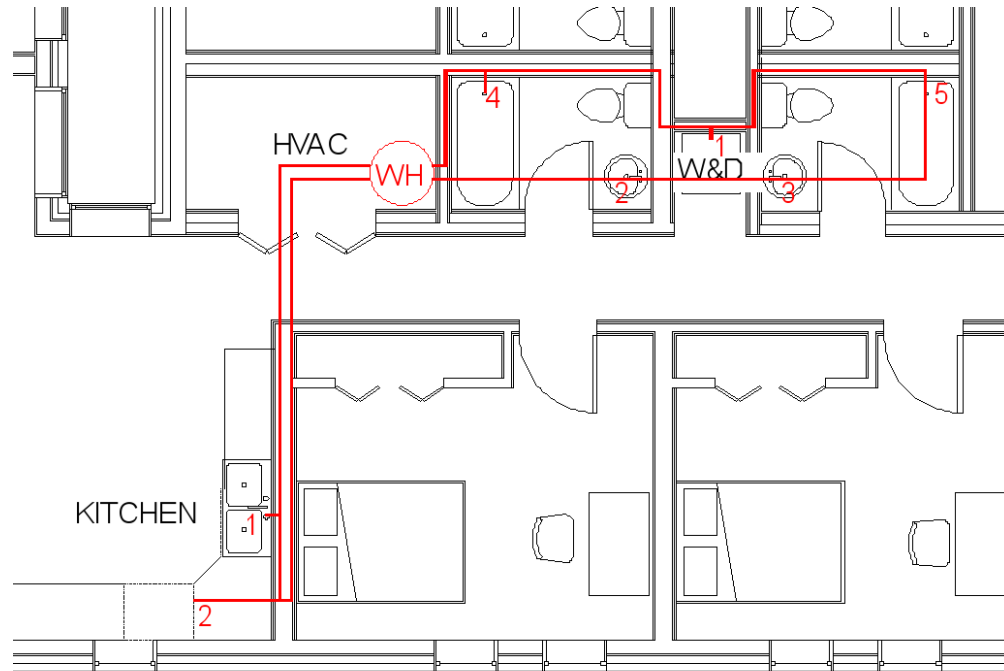
Team LINKoln chose the GeoSpring™ Hybrid Electric Water Heater model # GEH50DFEJSR.

Tank Capacity	Tank Diameter	Tank Height	Energy Factor	Fuel Type	First Hour Delivery
50 gal.	21.75 in.	59.5 in.	3.25	Electric	67 gal.



GeoSpring™ Hybrid Electric Water Heater

# DOMESTIC HOT WATER PLAN



- Hot Water Delivery System Layout
- 0.5 gallons storage limit in piping satisfied
- ASPE acceptable performance of 10 seconds waiting for hot water

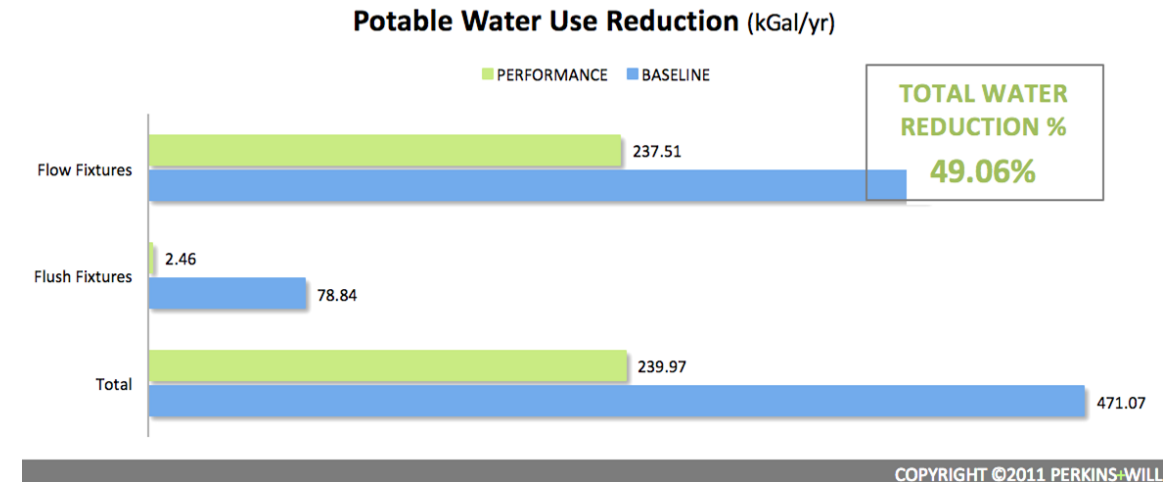
Fixtures	Pipe Segment	Pipe Diameter (in)	Water Capacity (oz/ft)	Pipe Length (ft)	Water Volume (gal)
Washer	Drop from Loop	1/2	1.89	10	0.15
	1	1/2	1.89	1	0.01
Total Water Volume (gal)					0.16
Hot Water Wait Time (sec)					4.42
Bath 1 Sink	Drop from Loop	1/2	1.89	10	0.15
	2	1/2	1.89	1	0.01
Total Water Volume (gal)					0.16
Hot Water Wait Time (sec)					6.49
Bath 2 Sink	Drop from Loop	1/2	1.89	10	0.15
	3	1/2	1.89	1	0.01
Total Water Volume (gal)					0.16
Hot Water Wait Time (sec)					6.49
Bath 1 Tub	Drop from Loop	1/2	1.89	10	0.15
	4	1/2	1.89	1	0.01
Total Water Volume (gal)					0.16
Hot Water Wait Time (sec)					6.49
Bath 2 Tub	Drop from Loop	1/2	1.89	10	0.15
	5	1/2	1.89	1	0.01
Total Water Volume (gal)					0.16
Hot Water Wait Time (sec)					6.49

Fixtures	Pipe Segment	Pipe Diameter (in)	Water Capacity (oz/ft)	Pipe Length (ft)	Water Volume (gal)
Kitchen Sink	Drop from Loop	1/2	1.89	10	0.15
	1	1/2	1.89	1	0.01
Total Water Volume (gal)					0.16
Hot Water Wait Time (sec)					5.41
Dishwasher	Drop from Loop	1/2	1.89	10	0.15
	2	1/2	1.89	1.5	0.02
Total Water Volume (gal)					0.17
Hot Water Wait Time (sec)					7.82

# WATER SAVING

Fixtures	Manufacturer	Model#	Price	Other Information
Kitchen Faucet	Delta	B2310	\$85.35	1.80 gpm @ 60 psi
Bath Faucet	Delta	21C154	\$102.80	0.50 gpm
Tub & Shower	Delta	T13420-SO S-H2OT	\$126.80	1.50 gpm @ 80 psi
Toilet	Nepon	Foam-Flush Toilet		3-ounce

- Energy Star products
- Acceptable prices



- Based on the water fixture we selected, we calculated the flow rate. Compared with fixtures of IPC/UPC (CODE), our apartment can save almost 50% portable water usage.



# RAINWATER COLLECTION

- Collecting water

Average monthly precipitation. Urbana, IL. ( inches)

Jan	2.05	July	4.69
Feb	2.13	Aug	3.94
Mar	2.87	Sept	3.15
Apr	3.66	Oct	3.27
May	4.88	Nov	3.46
June	4.33	Dec	2.72

- Precipitation is on an average around 3.43” of rainfall every month.
- The estimated catchment area for the roof is 3500 ft<sup>2</sup> and for the parking place is 13298 ft<sup>2</sup>.

- Water Usage

Category	Estimated Usage gal/month
Faucet	5160
Toilet	4872
Shower	9552
Dishwasher	384
Clothes washer	1392
Leaks	4704
Other	1008
Indoor hot	8056.11
Total indoor	27024
Outdoor	969

- Rainwater Catchment: Roof & Ground.
- Used for flushing (Roof)
- Used for irrigation (Ground)
- Cistern located outside of the apartment

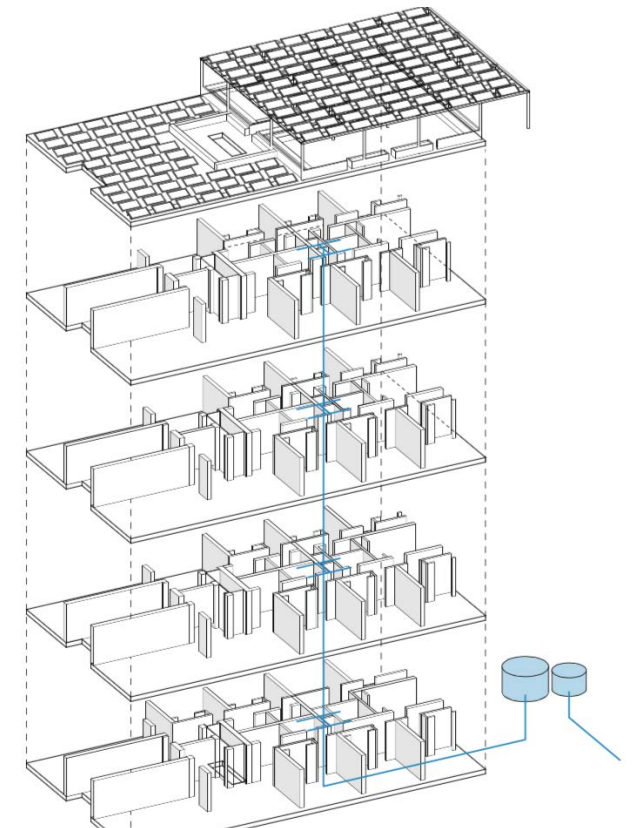
# RAINWATER COLLECTION

- Reclaimed water collection and reuse



Rainwater collection	Highest gal/month		Lowest gal/month		Average gal/month	
	Roof	Parking	Roof	Parking	Roof	Parking
	10647.3	40453.6	4472.7	16993.8	7483.6	28433.5
Reuse	Flushing gal/month			Irrigation gal/month		
	4972			969		

- The average monthly rainwater collection can satisfy flushing usage
- For the month with lowest rainfall, it demands only 500 gallons of potable water
- Cistern Storage is 5000 gallons: two 2635 gallons cisterns  
 $L \times W \times H = 140 \text{ in.} \times 90 \text{ in.} \times 72 \text{ in.}$
- Parking place: 1000 gallons cistern:  $L \times W \times H = 90 \text{ in.} \times 78 \text{ in.} \times 55 \text{ in.}$



# APPLIANCES LIST

- Energy Star
  - Fridge + Freezer
  - Dishwasher
  - Clothes Dryer
  - Washing machine
- Energy Efficient
  - Induction Range (400kWh/yr)
  - Clothes washer (109 kWh/yr)
  - Dishwasher (258 kWh/yr)
  - Clothes dryer (531 kWh/yr)
- Cost Efficient

Appliance	Cost	Brand	Energy Consumption	Energy Star
Clothes Dryer	\$ 943.2	Whirlpool WED99HE DW	531.0 kWh/yr	Yes
Washing Machine	\$ 799.2	Whirlpool WFW95HE DW	109.0 kWh/y	Yes
Induction Range(with Oven)	\$1799.10	GE PHB920SJ SS	Stovetop 1: 3.7kW Stovetop 2: 2.5kW Stovetop 3: 1.8kW Stovetop 4: 2.5kW Stovetop 5: .1 kW Oven Bake: 2.85 kW Oven Broil: 3.8 kW	N/A
Microwave	\$310	LG LMV2031S T	1kWh 121.545kWh/year (assuming 20 min/day)	N/A
Refrigerator + Freezer	\$2000	LG LTCS24223 S	501kWh/year	Yes
Dishwasher	\$538.2	LDF7774ST	258 kWh/year	Yes

## EXISTING APPLIANCES



## PROPOSED APPLIANCES

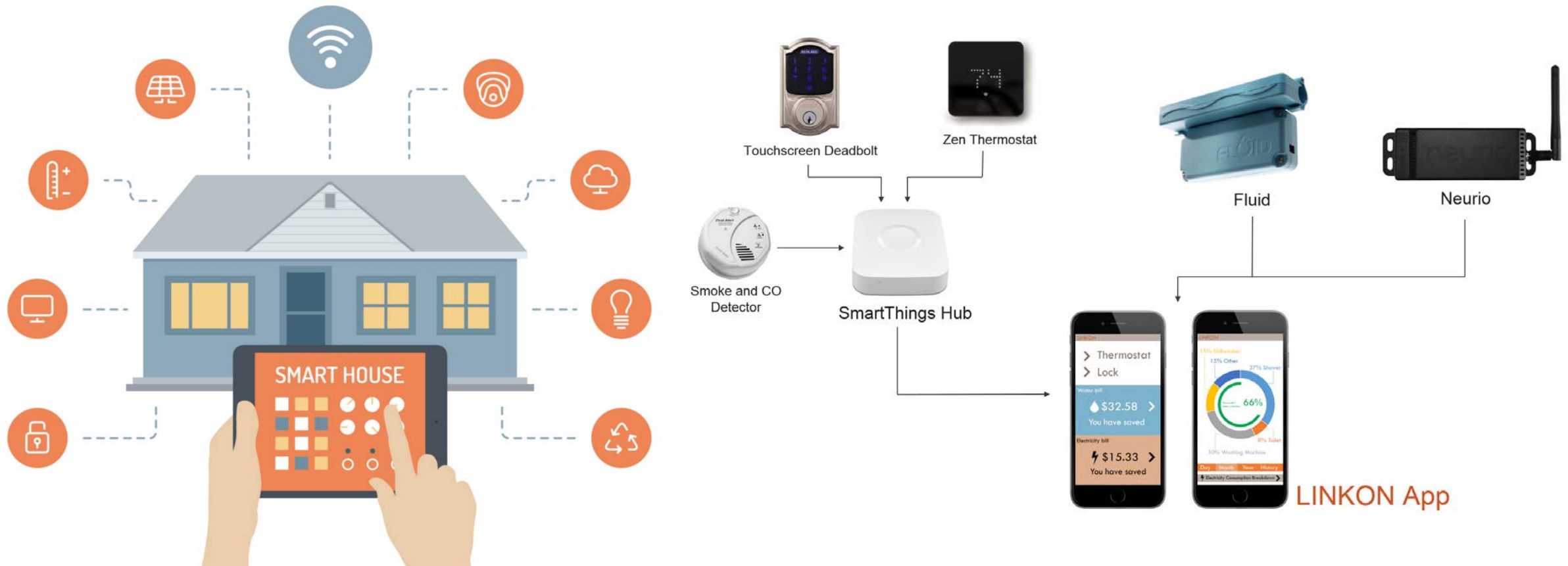




# APPLIANCES/INTERIOR DESIGN

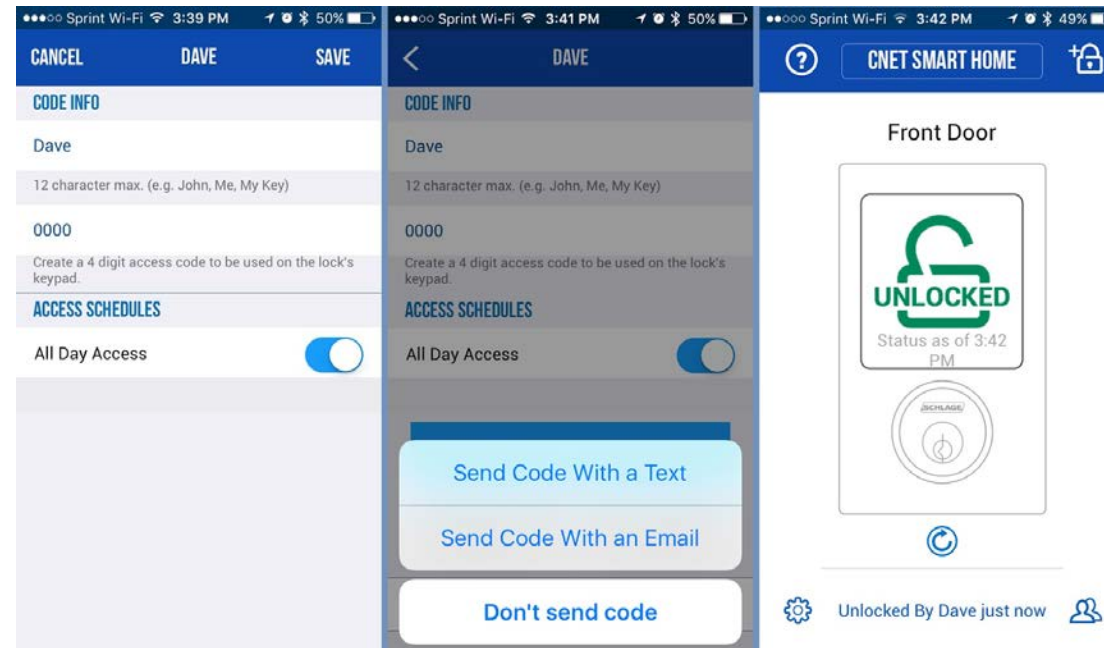


# HOME AUTOMATION SYSTEM



# CONNECT CAMELOT TOUCHSCREEN DEADBOLT

- Durable Resistive Touchscreen
- Anti-pick shield
- LED backlight
- Remote control



# SMARTTHING HUB AND APP

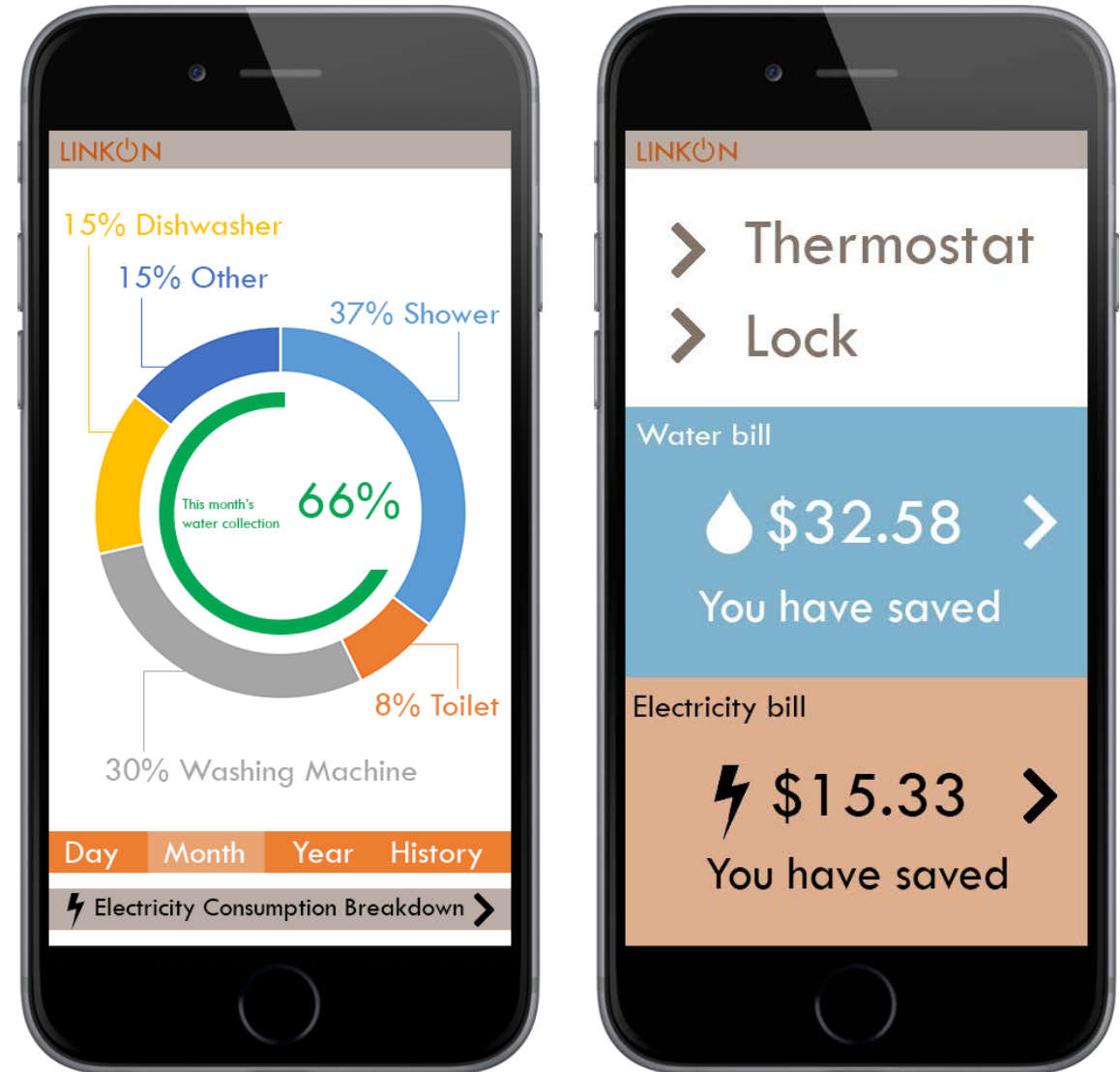
- Heart of your home
- Sensor, light, and lock control
- Automate your home's lighting and save money on energy costs
- Simple Set-up
- Controlled through your smart phone with SmartThings app





# LINKON APP

- Easy Installation
- Increase Awareness
- Understand Usage
- Consumption habits and behavior
- Set Goals
- Detect Leaks
- Signature-water consumption



# INNOVATION

- ❖ Roof Garden
- ❖ Three Rain Gardens (North-East, South-East, and West)
- ❖ Double skin facade on south
  - Highly exposed to rain runoff
  - Walls need to dry out and adding such component on south side will increase the drying rate as well as it eliminates concerns of freeze thaw damage
- ❖ Hybrid interior Insulation Retrofit
- ❖ Applying water repellent coats on all exterior building elements, specifically bricks
- ❖ Selling out extra water collected on ground for irrigation purposes in neighborhood
- ❖ Application and Design of CERV in multifamily buildings
- ❖ Enhancing building resiliency



Thank You  
LINKoln Locale

TEAM LINKoln

U.S. DEPARTMENT OF ENERGY RACE TO ZERO STUDENT DESIGN COMPETITION