

Solar Decathlon 2023

Retrofit Presentation

Appalachian State University

# High Country Goldfinches

SOLAR DECATHLON 2023



# Intro The Team

\*\*BS-Building Science



**Jonas Scott**  
BS Construction  
Management



**Lillie Bell**  
Interior Design



**Evan Hutchison**  
BS Architectural Technology  
& Design



**Casey Coughlin**  
BS Sustainable Building  
Systems



**Ethan Bodin**  
BS Sustainable Building  
Systems



**Jonathan Culpepper**  
BS Sustainable Building  
Systems



**Jakob Gibson**  
BS Construction  
Management



**Jonathan Kenzel**  
BS Construction  
Management



**Elijah Johnson**  
BS Construction  
Management



**Charis Hatcher**  
BS Architectural Technology  
& Design



**Denise Renteria**  
BS Architectural Technology  
& Design



**Rob Howard**  
M.S. Technology Building  
Science  
Faculty Advisor



**Jim Rogers**  
B.A. Architecture  
Faculty Advisor



# Intro The Team



# The Retrofit

Putting the County Issues into  
Context



..... Problem

..... Context

..... Solution



# The Problem

## Watauga Housing Crisis

### Rapidly Increasing Home Prices

Median Home Value in Watauga County

January 2020 - \$297,600

January 2023 - \$465,000



### Boone Population

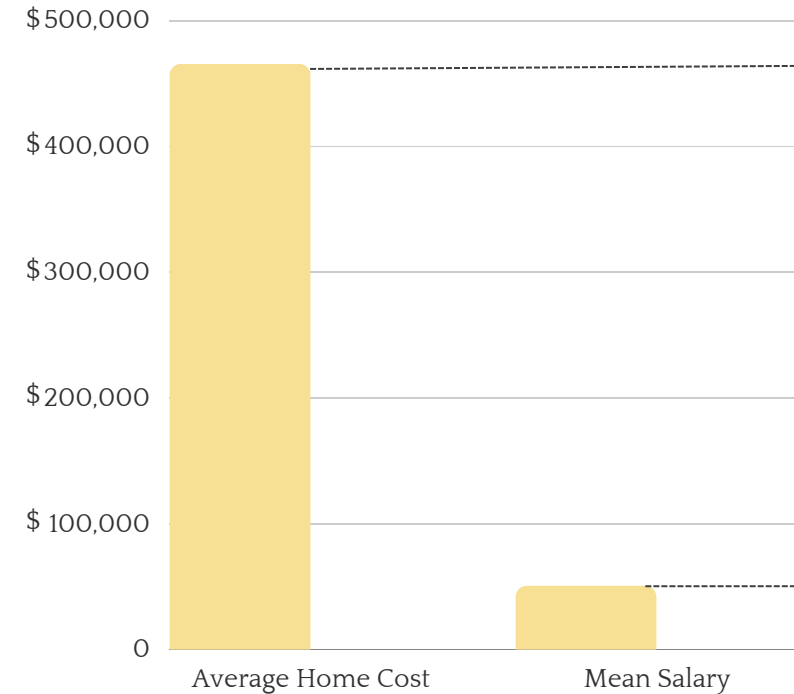
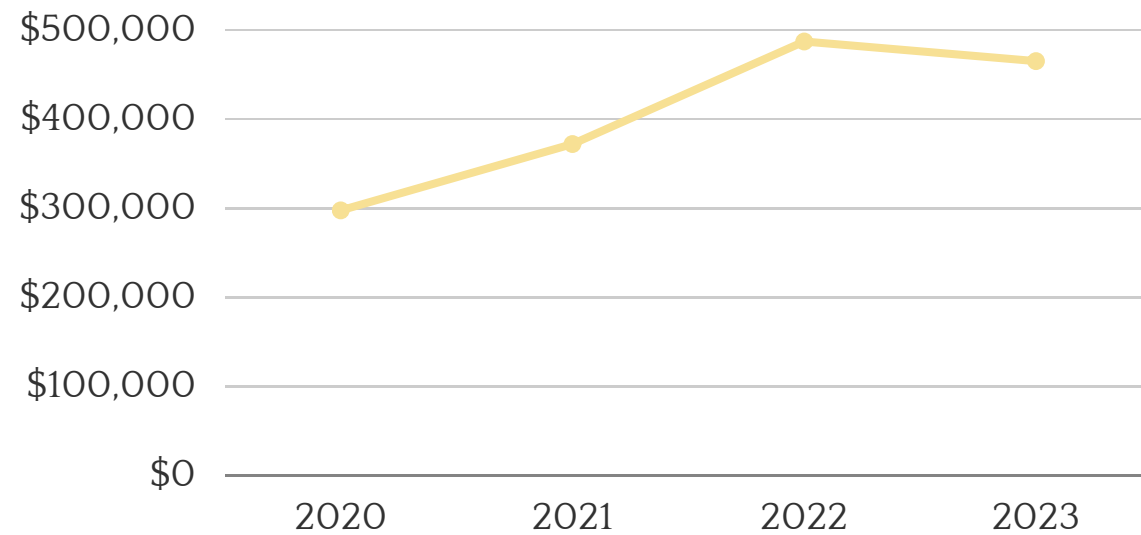
Population: 17,978

Town Size: 6.35 mi sq.

Population Density: 2,831 people/mi sq.

### Watauga County Avg. Costs

Based on High County Association of Realtors



9.3 Home price-to-income Ratio

5.8 NC Average Home price-to-income Ratio

39.3% Poverty Rate




# The Problem

## Watauga Housing Crisis

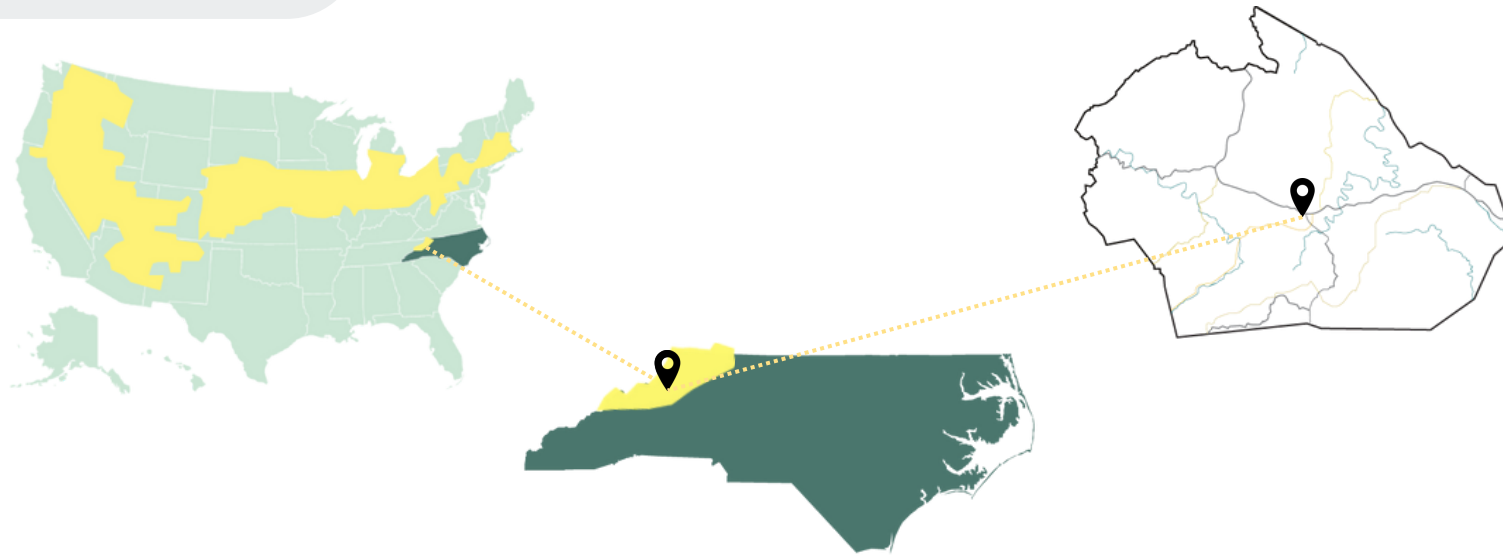


### An Abundance of Homes That Don't Meet The Current Code

There is a large quantity of outdated homes that are in desperate need of updating and renovations, especially in the high country. Ideally, a retrofit system design will be developed that can be replicated and accommodate other houses to improve their performance



# Context Site



# Climate

## High Winds

**6 Month Wind Season\***  
Recordings Reaching  
Above 70+mph



## Large Amounts of Rainfall

**54 Inches per Year\***  
17% Higher than NC  
Average



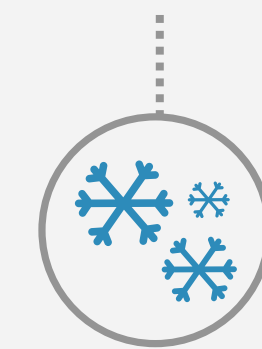
## Low Drying Potential

Surrounded by  
trees with little  
Sun



## Cold & Wet Winters

**35.3 Inches of Snow  
Annually\***  
86% Higher than NC  
Average



## Concept Birdhouse

# The Birdhouse

Realize The Potential of The Existing Home

### Fostering The Nest Egg

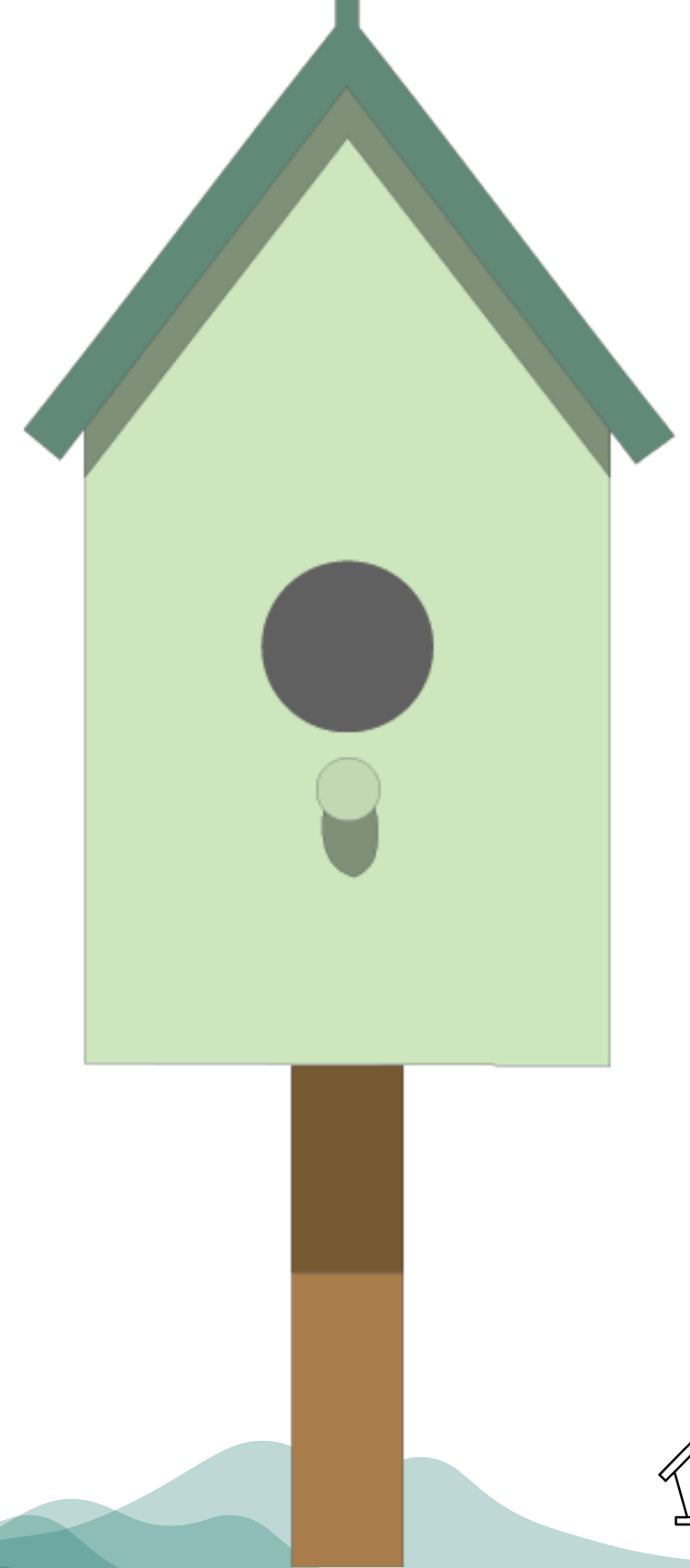
Invest in old, poorly constructed homes selling below the median cost and retrofit it into a High Performance Home and increase home security.

### Replicable

Birdhouses are easily built. Our goal is to create a system that can be easily replicated for each of these homes in the area.

### Individualized

Different birds need different homes. **Each home's needs can be catered to while fitting within the overarching retrofit system.**





# Context

## Sarah Grady's Home



**Sarah Grady**  
Construction Manager for Watauga  
Habitat for Humanity

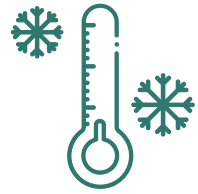
Bought for  
**\$90,000** in 2016

Currently Appraised at  
**\$275,000**



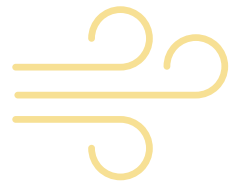
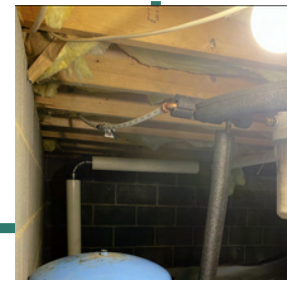
# Context

## Existing Conditions



### Minimally Insulated

R-11 Walls, R-26 Ceiling,  
R-15 Floors



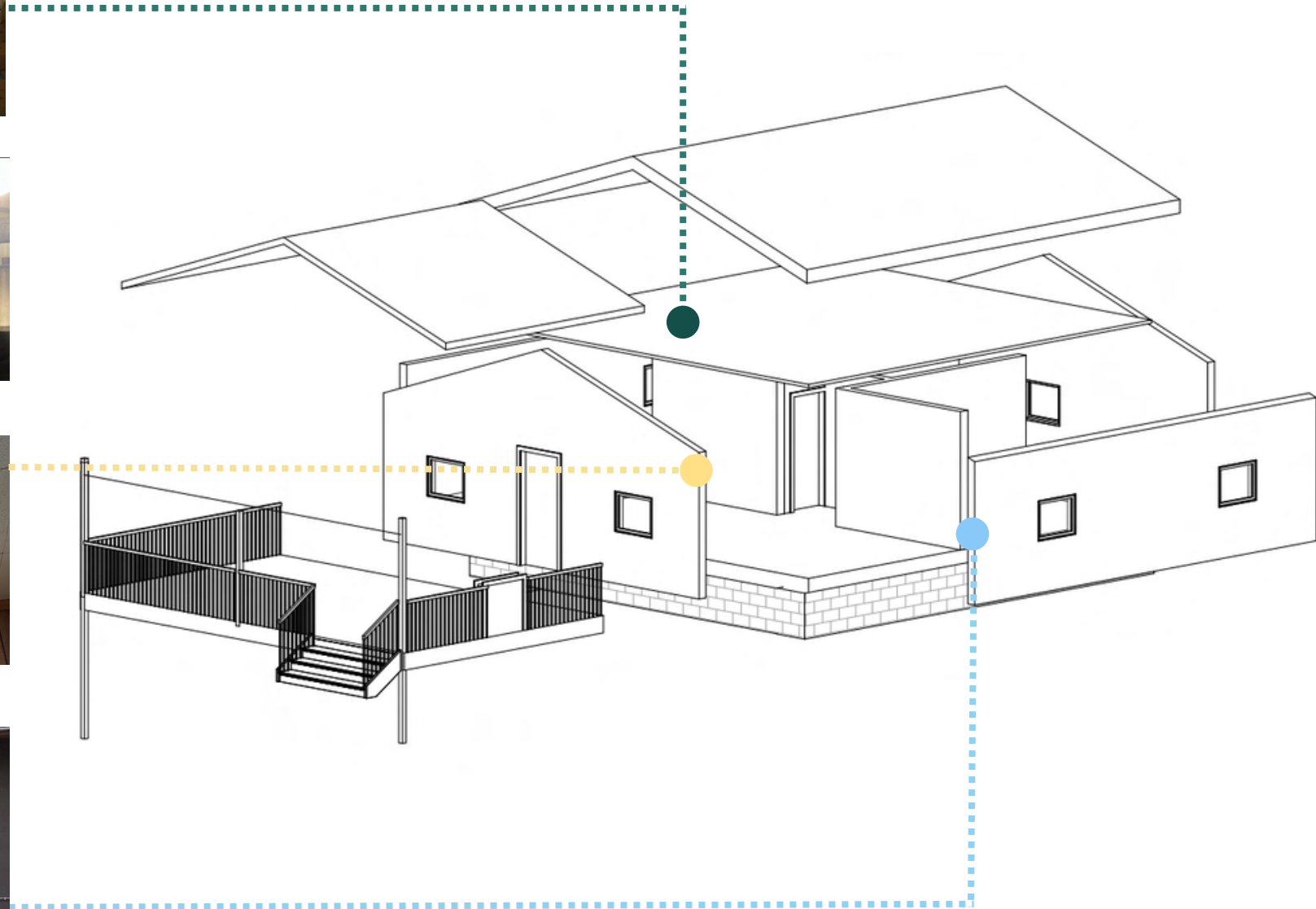
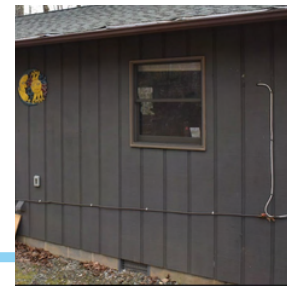
### Lack of Air Sealing

25 ACH 50



### Poor Waterproofing

No House Wrap



# Context

## Existing Conditions

### The Performance:

HERS

104

Heating Design Load (kBTU/h)

19

Cooling Design Load (kBTU/h)

9

Annual CO2 Emissions (Tons)

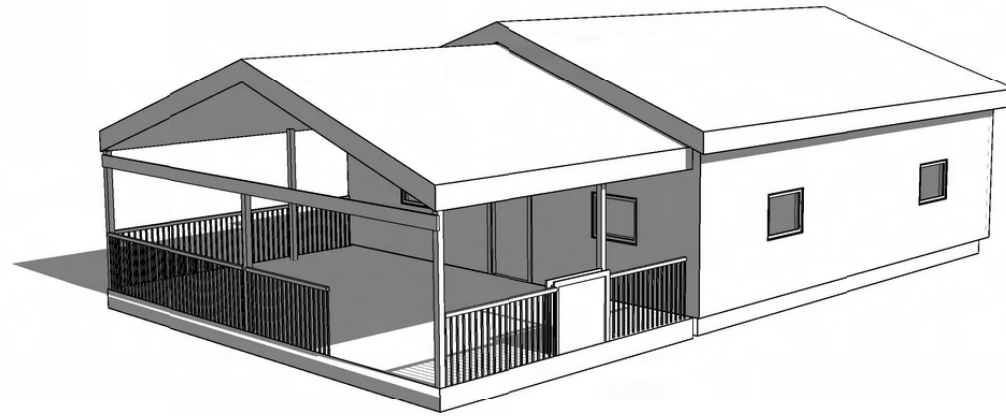
5.6

Trees to Offset

402

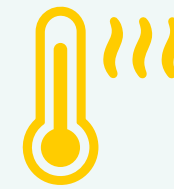
Square Footage

702



Existing Energy Bill:

**\$1,587**



62%



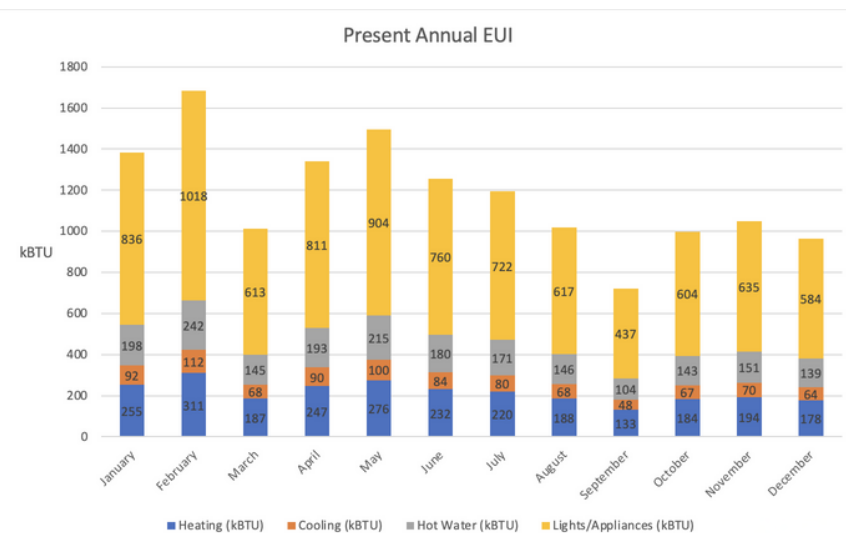
0%



5.5%



32.5%



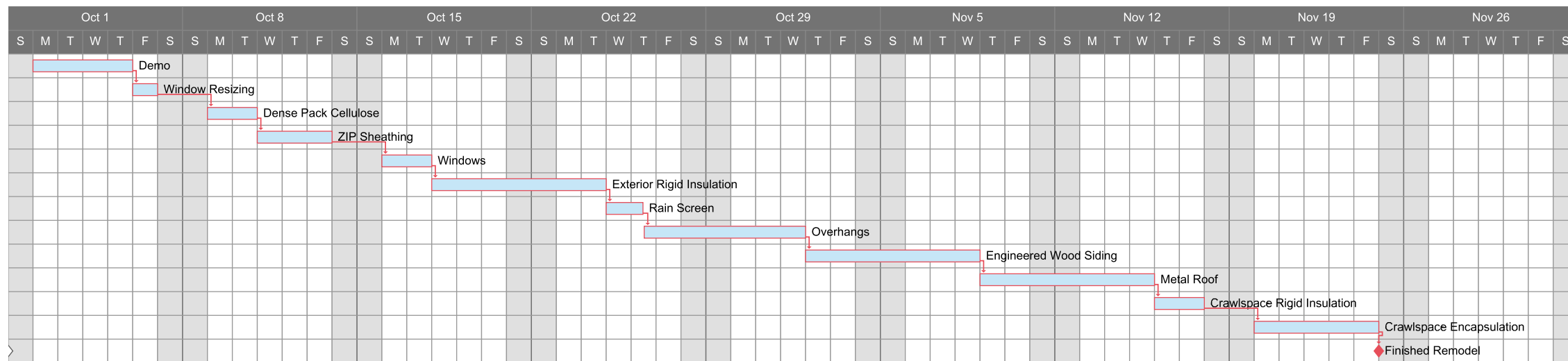
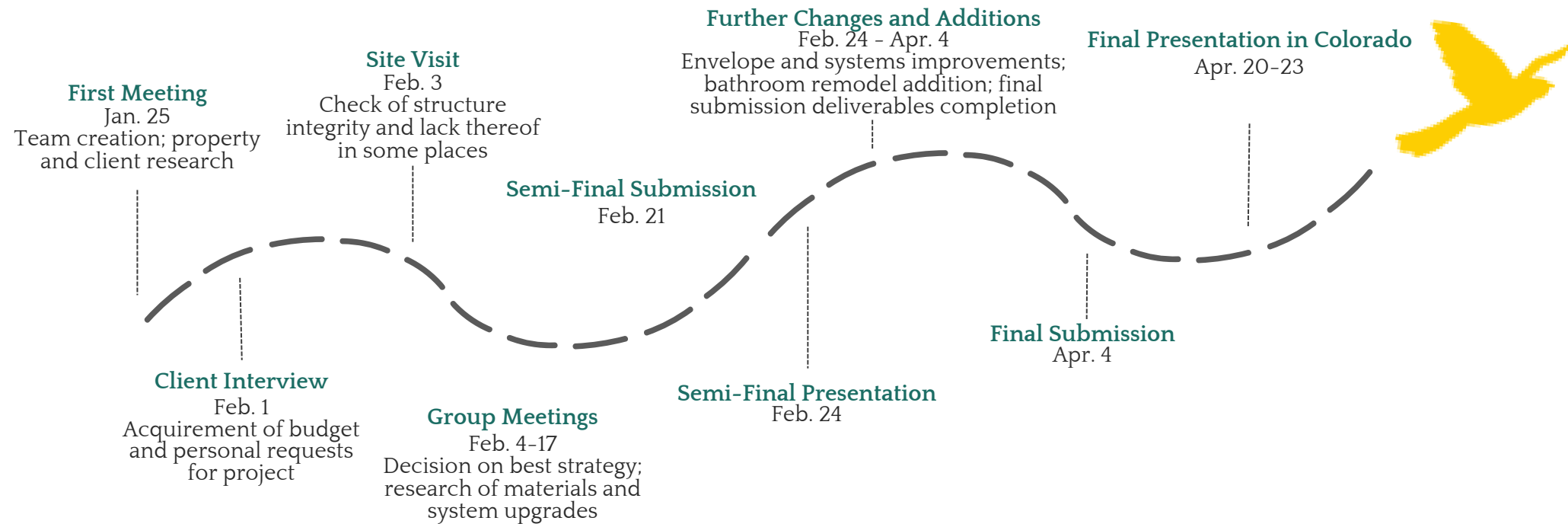
Existing Annual EUI:  
79.15 kBTU/ft<sup>2</sup>

Whole Wall R - Value  
12.61

Whole Roof R - Value  
25.45



# Context Timeline



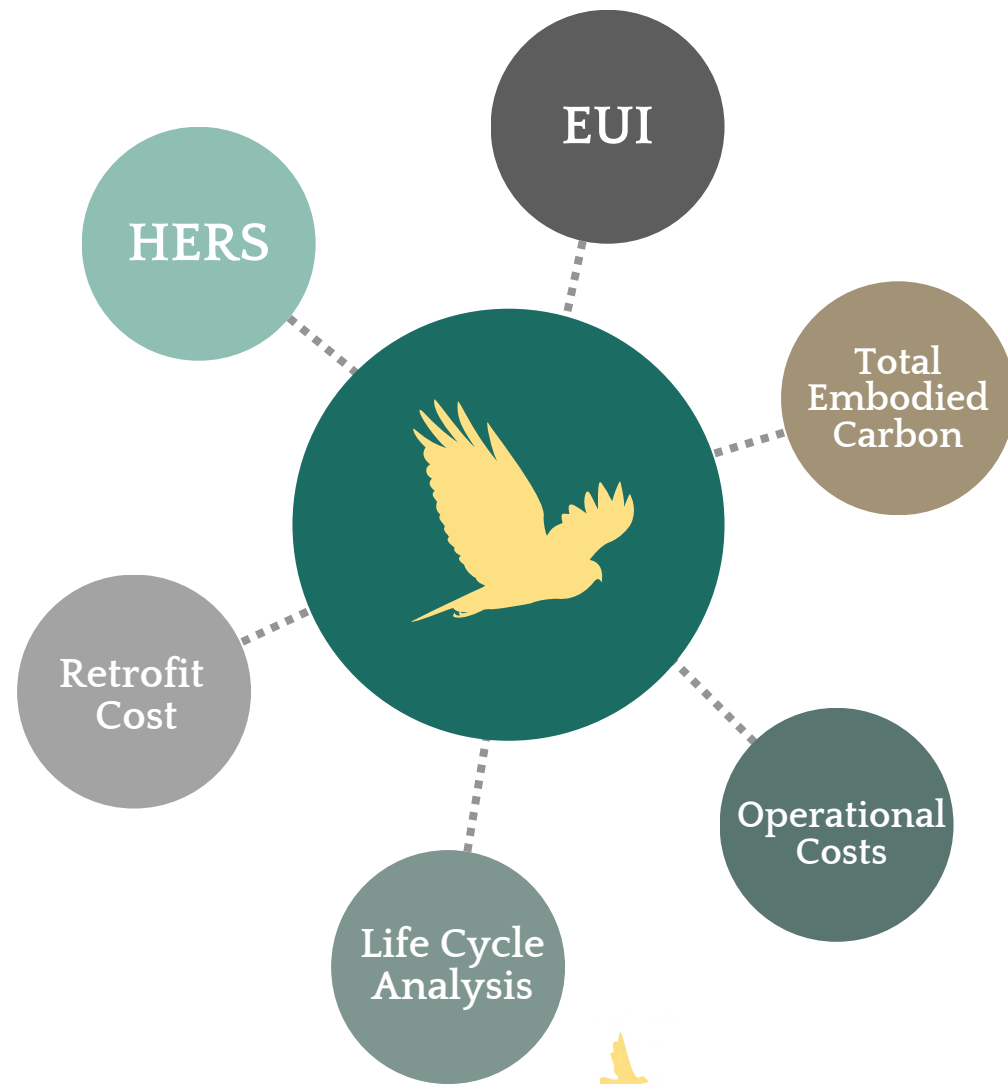
The projected construction timeline is 8 weeks from Demo to finish with a crew of four people, working 40 hours per week.



# Solution

## The Gold Finch Score

The Gold Finch score is a method of integrating all aspects of the building envelope into a singular scoring system.



### HERS

The Energy Performance of the home, critical for the competition



### Retrofit Cost

Total Cost of the retrofit, essential to the feasibility of our project



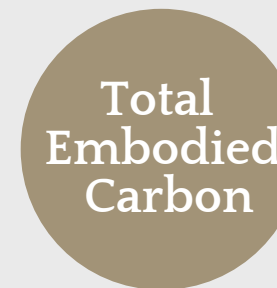
### EUI

Breaks down the energy use and shows how efficient each mechanical is and where improvements can be made



### Operational Costs

A key aspect of affordability



### Total Embodied Carbon

The amount of carbon released during the manufacturing process



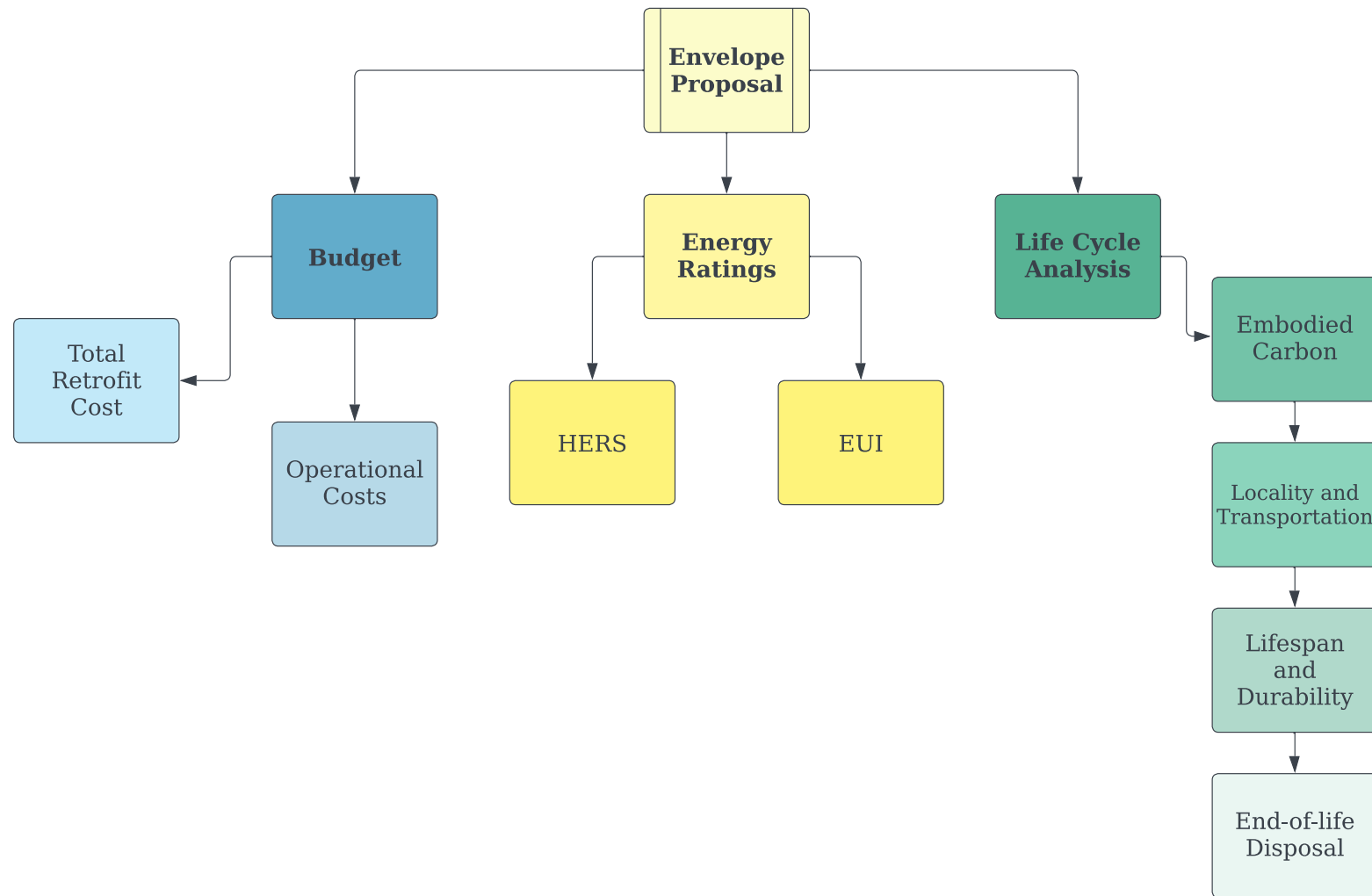
### Life Cycle Analysis

Necessary to choosing the most quality and environmentally friendly materials



# Solution

## The Gold Finch Score



8 or Above	Quality Design
8 to 6	Passing
6 or below	Scratch the Design, Start Over

The table is a 3x2 grid with a dashed border. The top row is green, the middle row is yellow, and the bottom row is red. The left column contains numerical score ranges, and the right column contains qualitative design status descriptions.



# Solution Budget

Client Budget  
Exterior Only

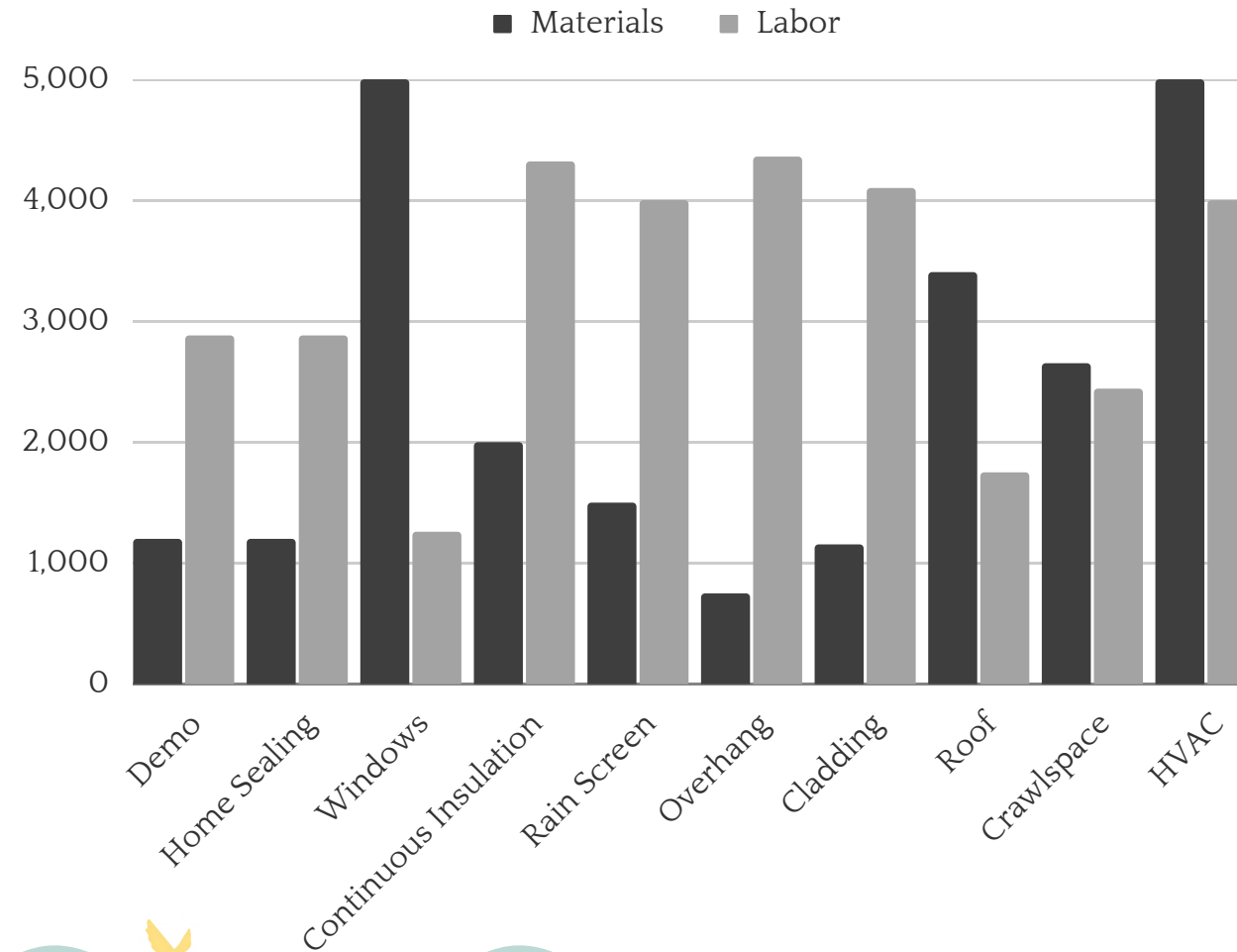
\$85.7 per  
sqft

72  
HERS

36,000  
Kg  
CO<sub>2</sub>e



Retrofit  
Cost



3.5  
Gold Finch  
Score



# Solution Budget

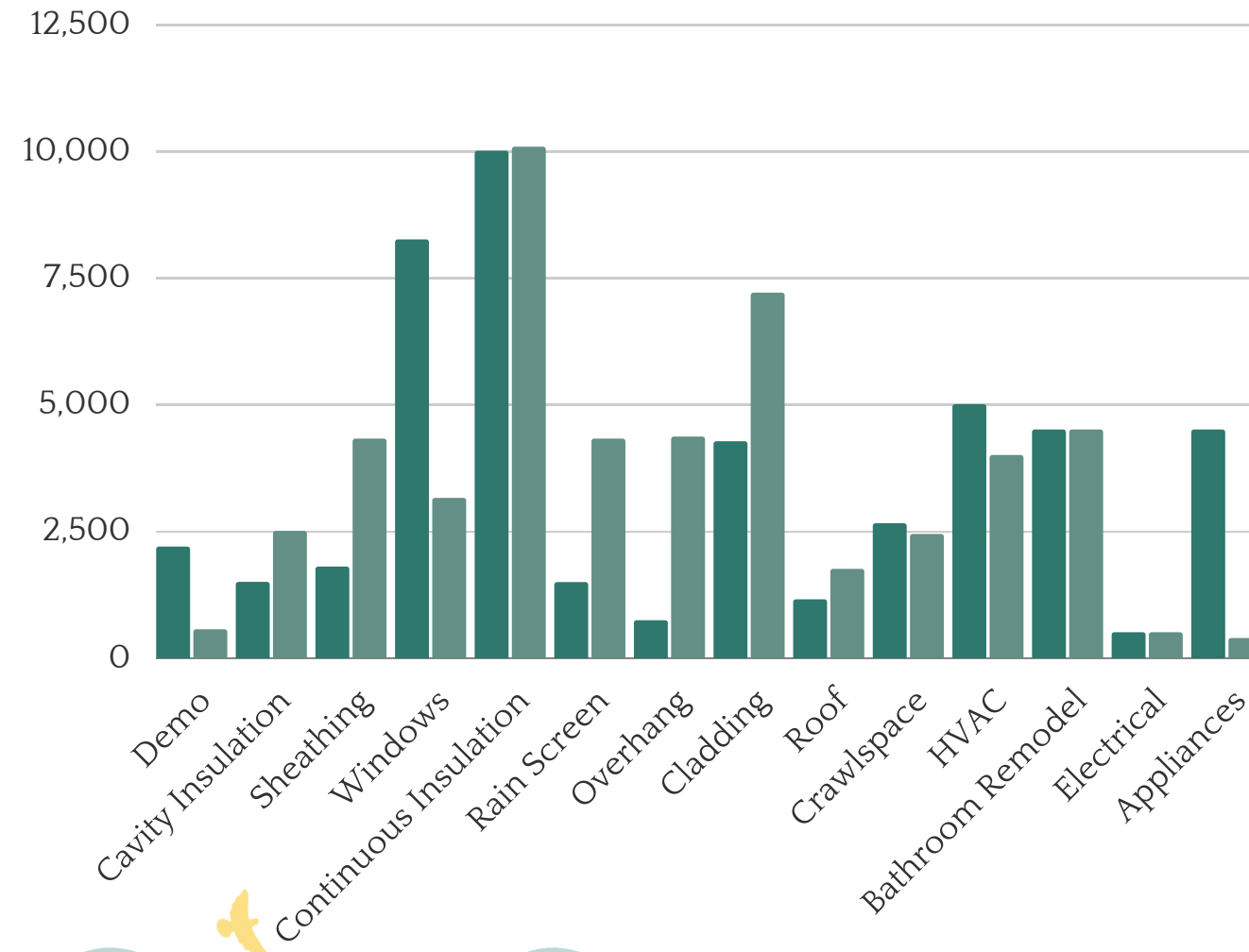
High Performance Budget  
Interior-Included

\$149.4 per sqft

-6  
HERS

4,626  
Kg  
CO<sub>2</sub>e

■ Materials ■ Labor



9.3  
Gold Finch  
Score

Retrofit  
Cost

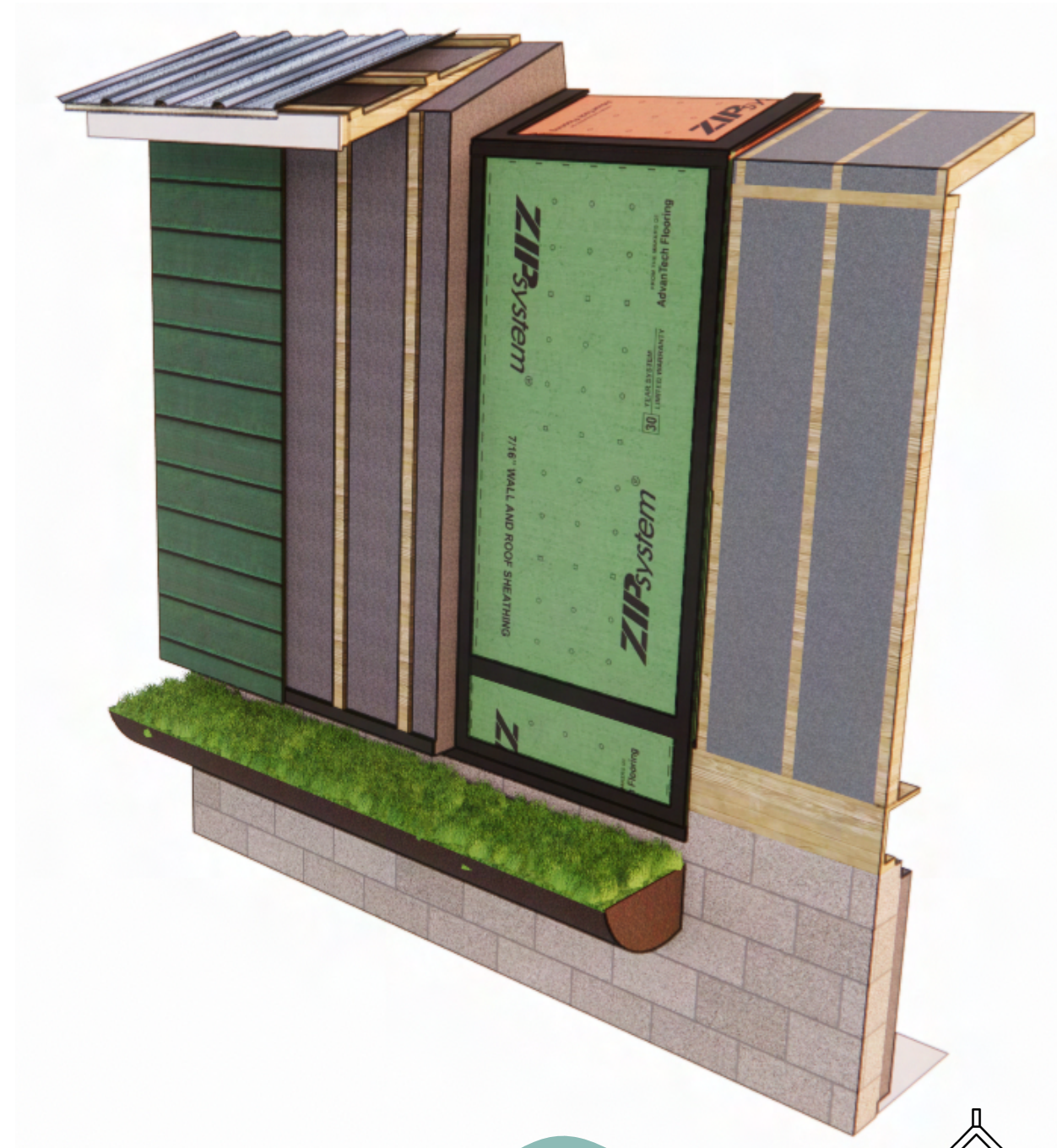




# Solution Material Selection



Life Cycle  
Analysis

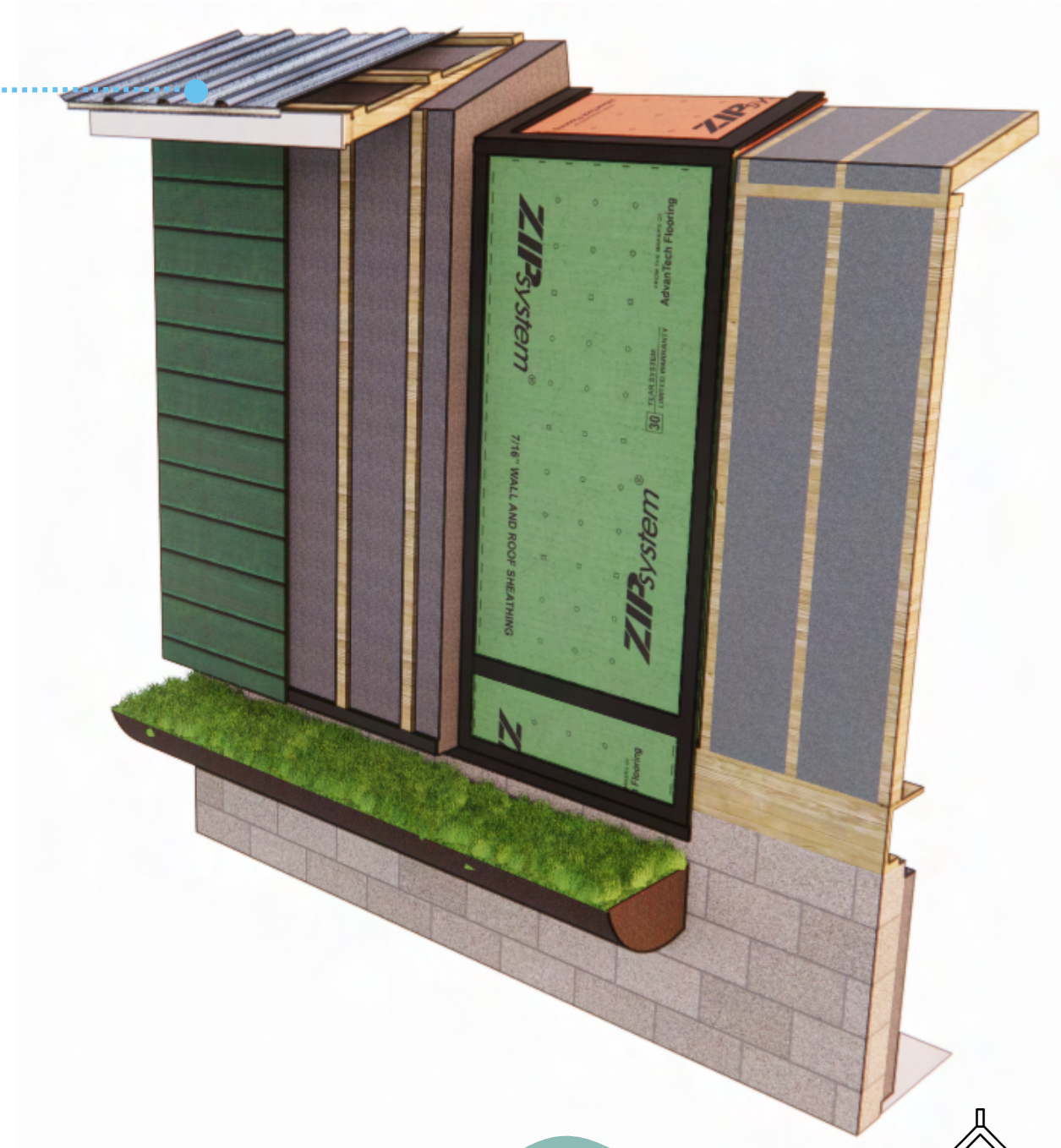


# Solution

## Material Selection

### Corrugated Metal Roofing

- 50+ year lifespan
- Local Manufacturing
- End-of-life recyclability



Life Cycle  
Analysis



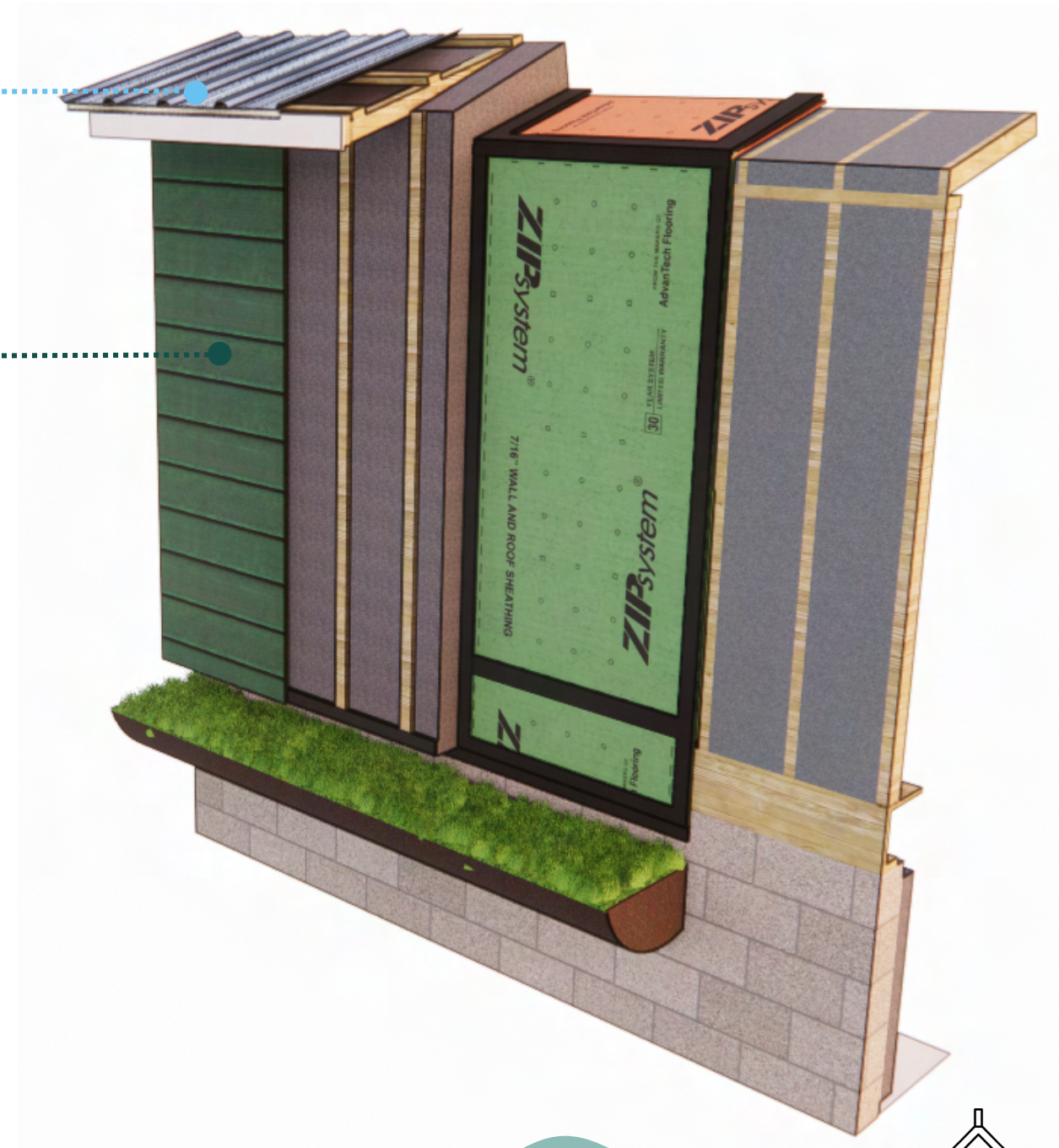
# Gold Finch Score Material Selection

## Corrugated Metal Roofing

- 50+ year lifespan
- Local Manufacturing
- End-of-life recyclability

## Engineered Wood Siding with Corrugated Metal on Gable Ends

- Community tie through visual appeal
- 60+ year lifespan



Life Cycle  
Analysis



# Gold Finch Score Material Selection



Life Cycle  
Analysis

## Corrugated Metal Roofing

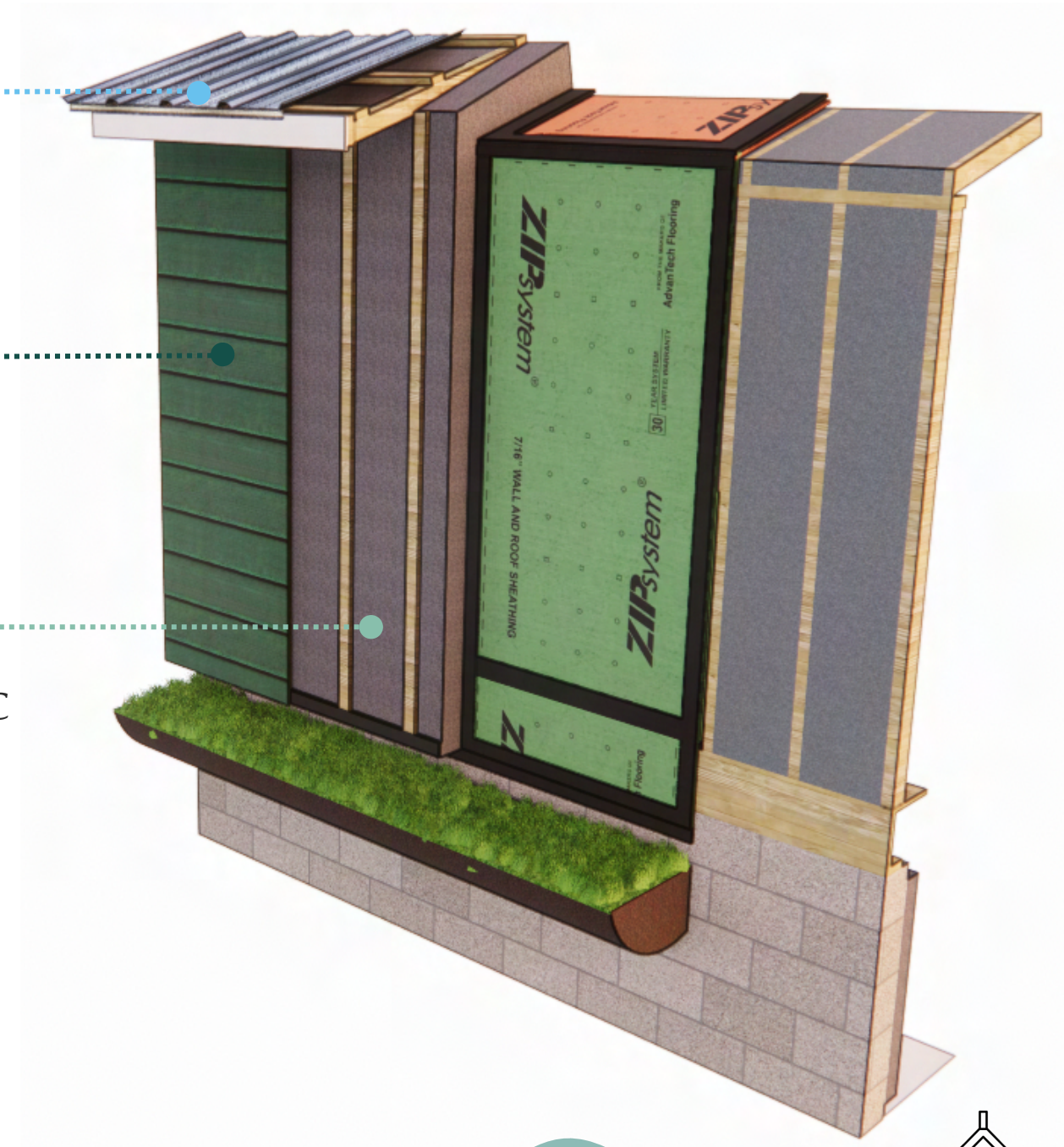
- 50+ year lifespan
- local manufacturing
- End-of-life recyclability

## Engineered Wood Siding with Corrugated Metal on Gable Ends

- Community tie through visual appeal
- 60+ year lifespan

## Graphite Expanded Polystyrene (GPS)

- No degradation of thermal Resistance
- Air as a blowing agent (as opposed to HFC and CFC)
- Low Embodied Carbon
- Low Cost and Local Supplier



# Solution

## Material Selection



Life Cycle  
Analysis

### Corrugated Metal Roofing

- 50+ year lifespan
- Local Manufacturing
- End-of-life recyclability

### Engineered Wood Siding with Corrugated Metal on Gable Ends

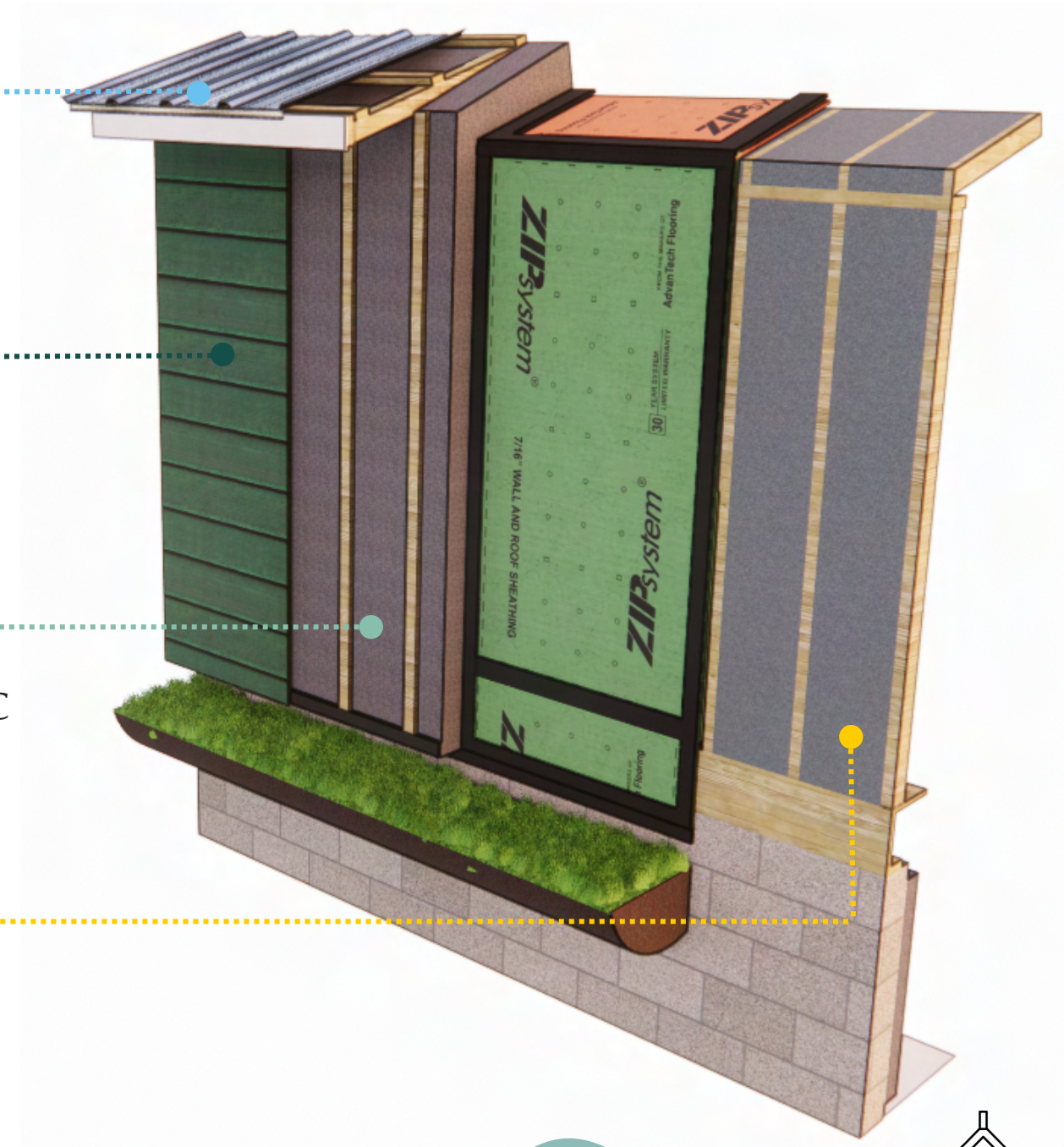
- Community tie through visual appeal
- 60+ year lifespan

### Graphite Expanded Polystyrene (GPS)

- No degradation of thermal Resistance
- Air as a blowing agent (as opposed to HFC and CFC)
- Low Embodied Carbon
- Low Cost and Local Supplier

### Dense Pack Cellulose

- Embodied carbon storing
- Fills all voids and avoid Interstitial Loops



# Solution

## Continuous Barriers

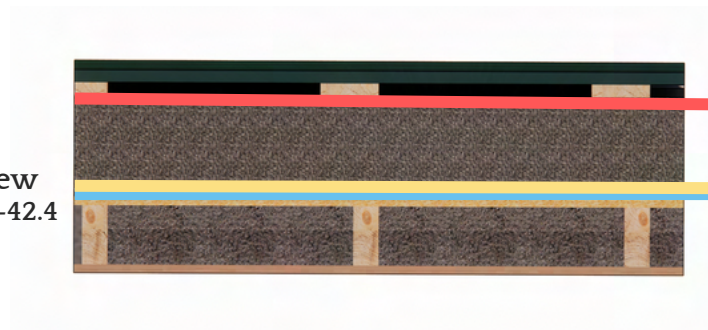


Life Cycle Analysis

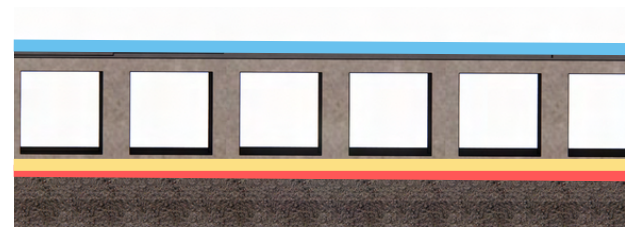
Roof Section View  
Effective R-53.1



Wall Plan View  
Effective R-42.4



Foundation Plan View  
Effective R-20



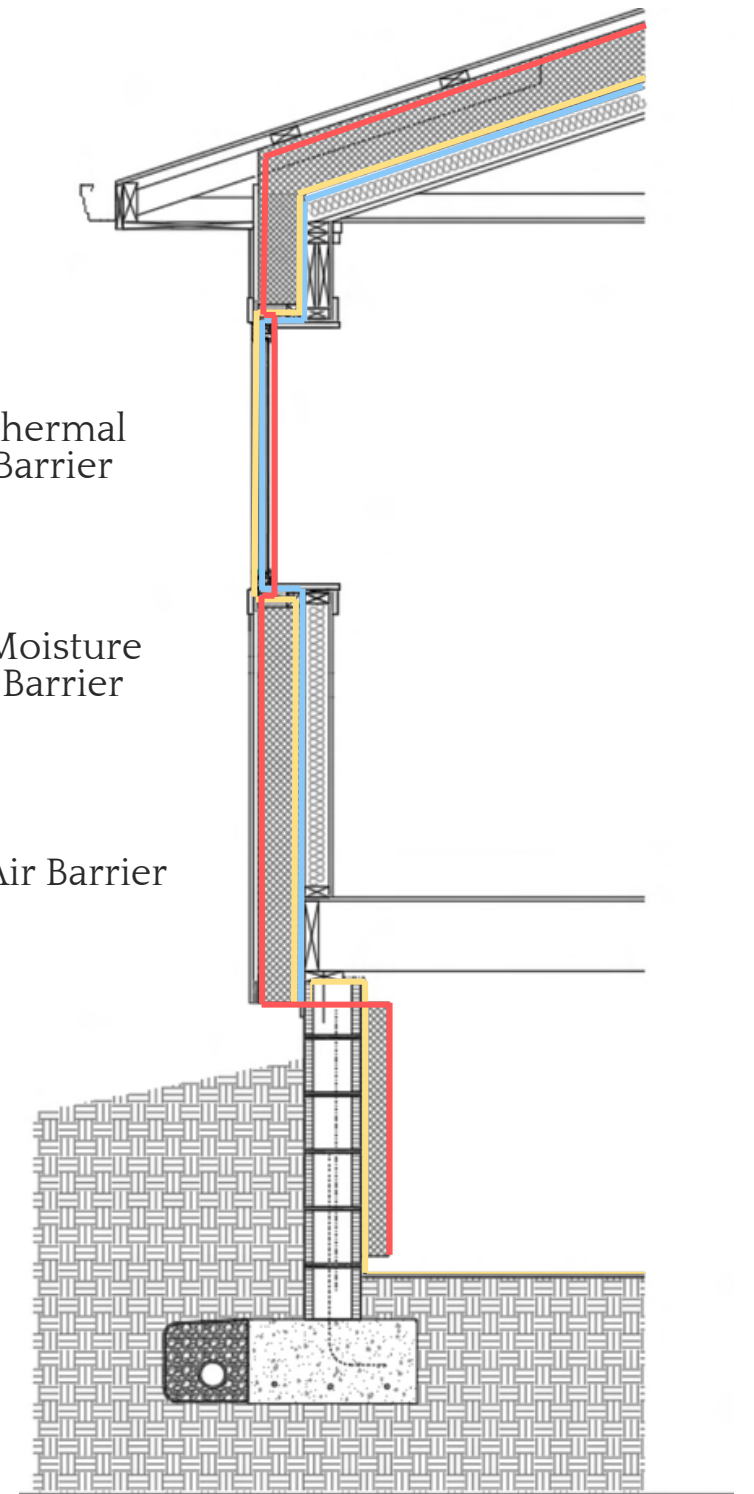
Thermal Barrier:  
GPS Rigid Board  
Dense Pack  
Cellulose

Air and Water  
Barrier:  
Huber Zip System

● = Thermal Barrier

● = Moisture Barrier

● = Air Barrier



# Solution

## Window Upgrades



Existing Windows:  
SHGC - .4 - .5  
Double Pane,  
Vinyl, Low E

Replacement Windows:  
**Alpen Tyrol TR-6  
Tilt-Turn**  
U-Factor: 0.16  
SHGC: .23  
VT: 0.38  
Triple Pane

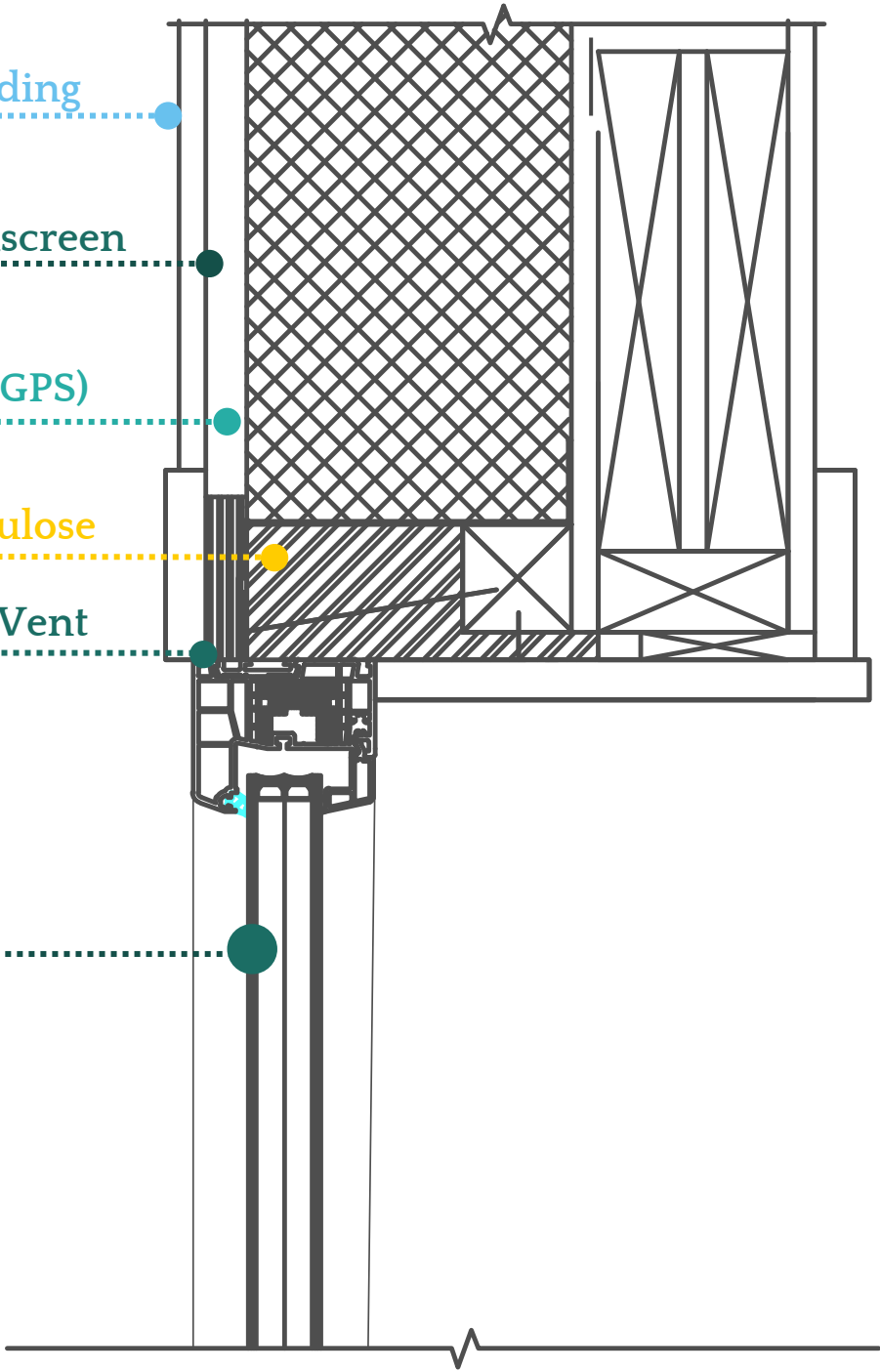
Graphite Expanded Polystyrene (GPS)

Dense Pack Cellulose

SV-5 Rainscreen Siding Vent

Cladding

Rainscreen



# Solution

## Interior Renovations



Life Cycle  
Analysis





# Solution

## Interior Renovations



Life Cycle  
Analysis



# Solution

## Interior Renovations



Life Cycle  
Analysis

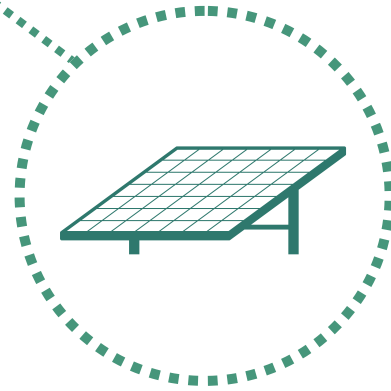


# Solution

## Energy Bills



Operational Costs



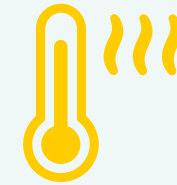
Blue Ridge Energy Community Solar



Sarah Grady's Home

Solar Breakdown	
Total Annual Cost	\$630.00
kWh Produced/year	6048
Number of Panels	14
Savings/year	\$79.00

New Community Solar Bill:  
**\$630**



18.5%



6.7%



14.4%



60.66%



# Solution

## Material Selection



Total Embodied Carbon



Roofing  
929 Kg CO<sub>2</sub>e

Cladding  
342 Kg CO<sub>2</sub>e

Exterior Continuous Insulation  
2859 Kg CO<sub>2</sub>e

Sheathing  
258 Kg CO<sub>2</sub>e

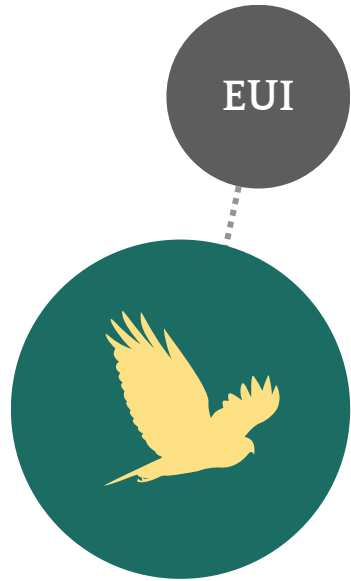
Cavity Insulation  
-865 Kg CO<sub>2</sub>e

Total Embodied Carbon:  
4,626 Kg CO<sub>2</sub>e

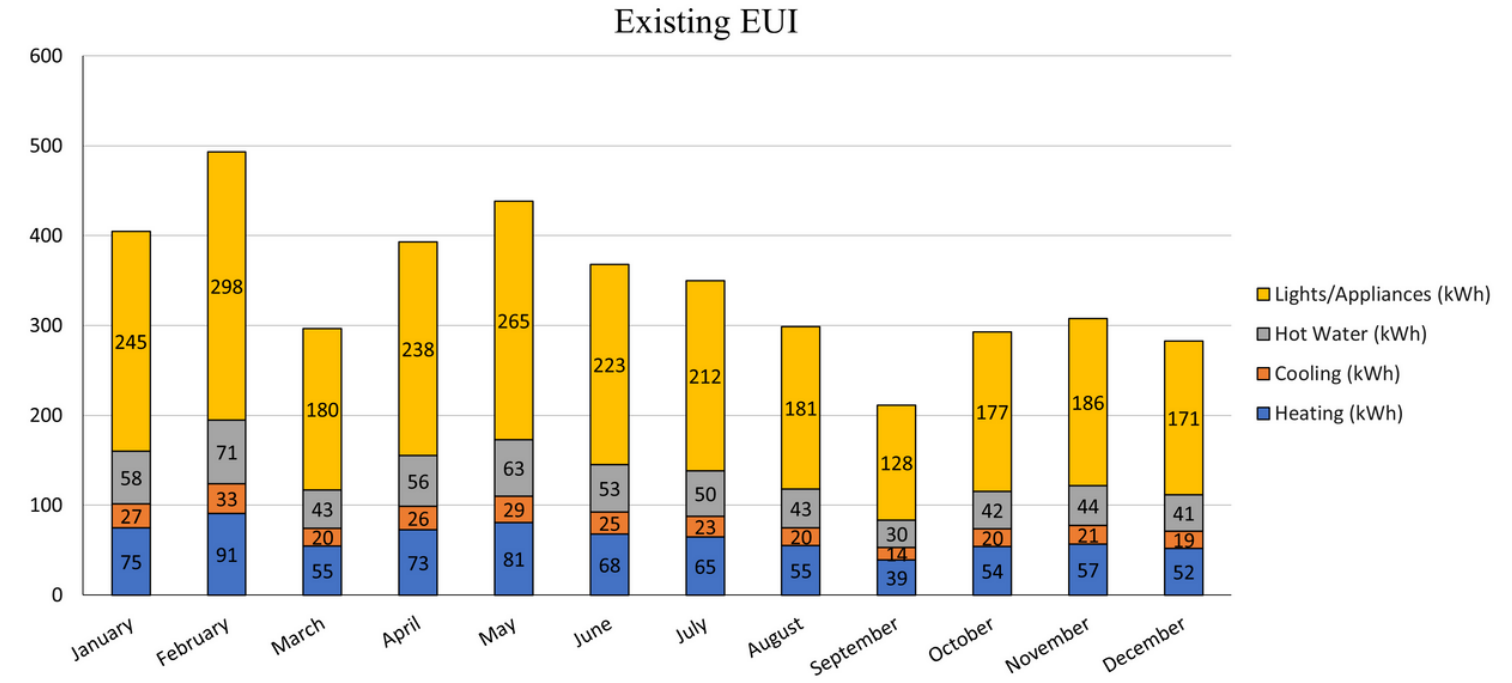


# Solution

## Energy Use Intensity

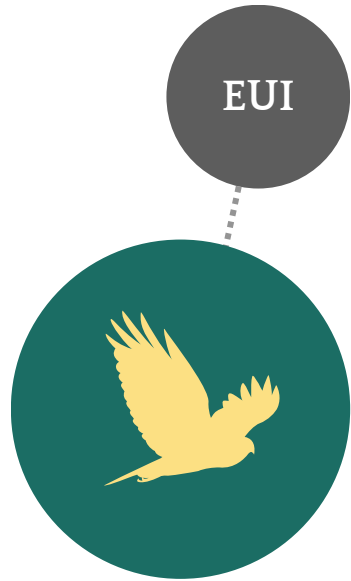


Existing EUI:  
79.15  
kBTU/Year



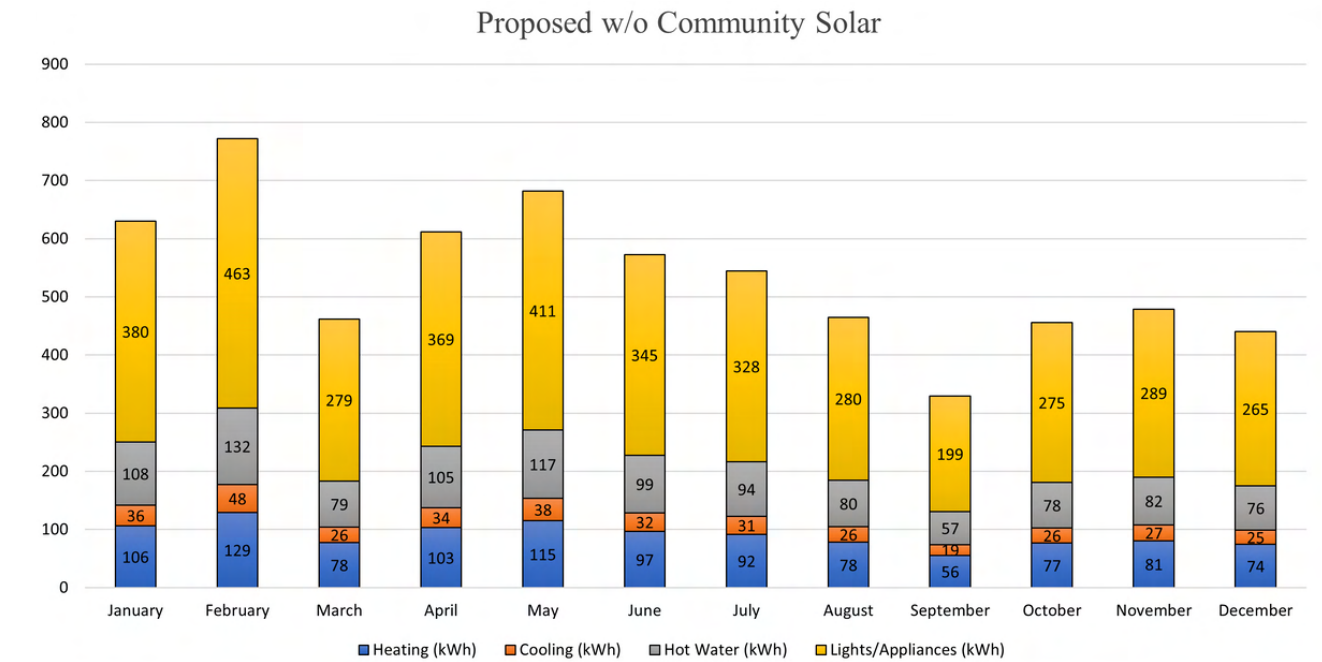
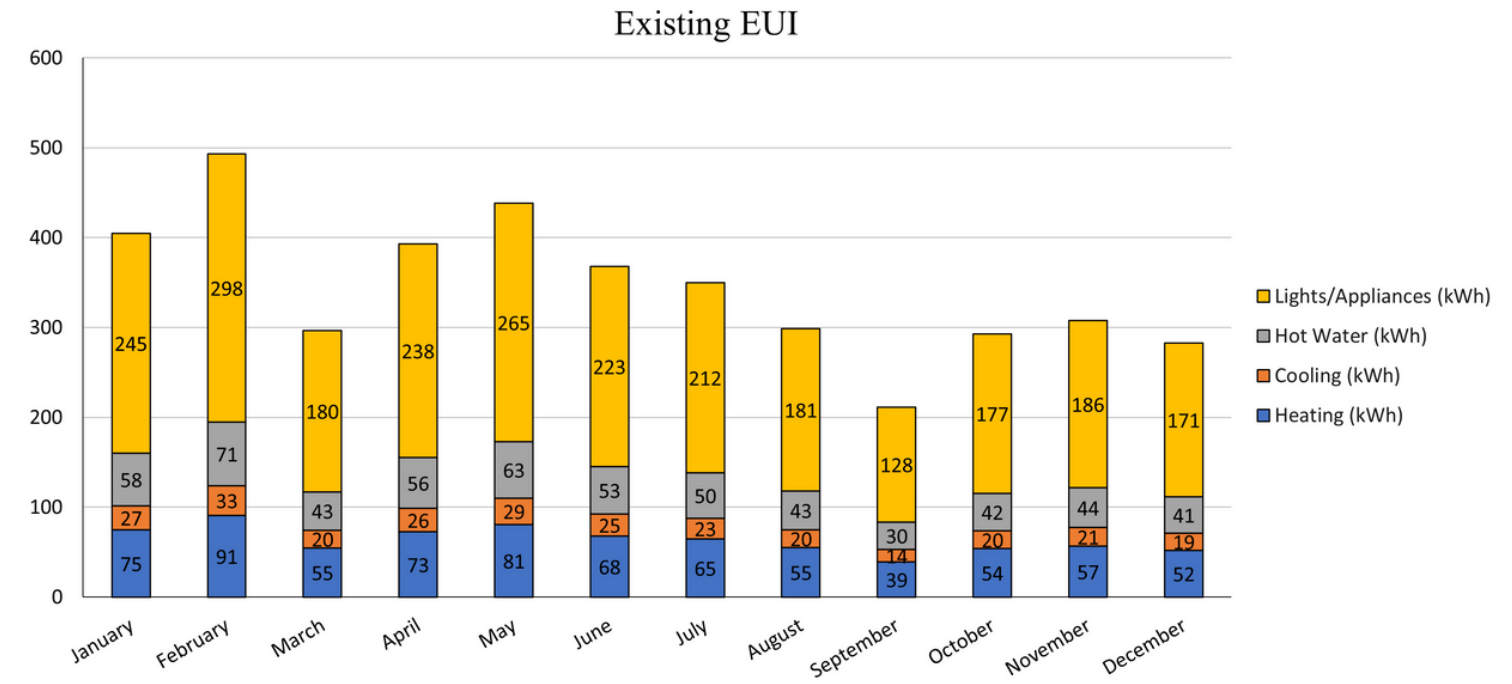
# Solution

## Energy Use Intensity



Existing EUI:  
79.15  
kBTU/Year

Proposed EUI:  
28.72  
kBTU/Year



# Solution

## Energy Use Intensity

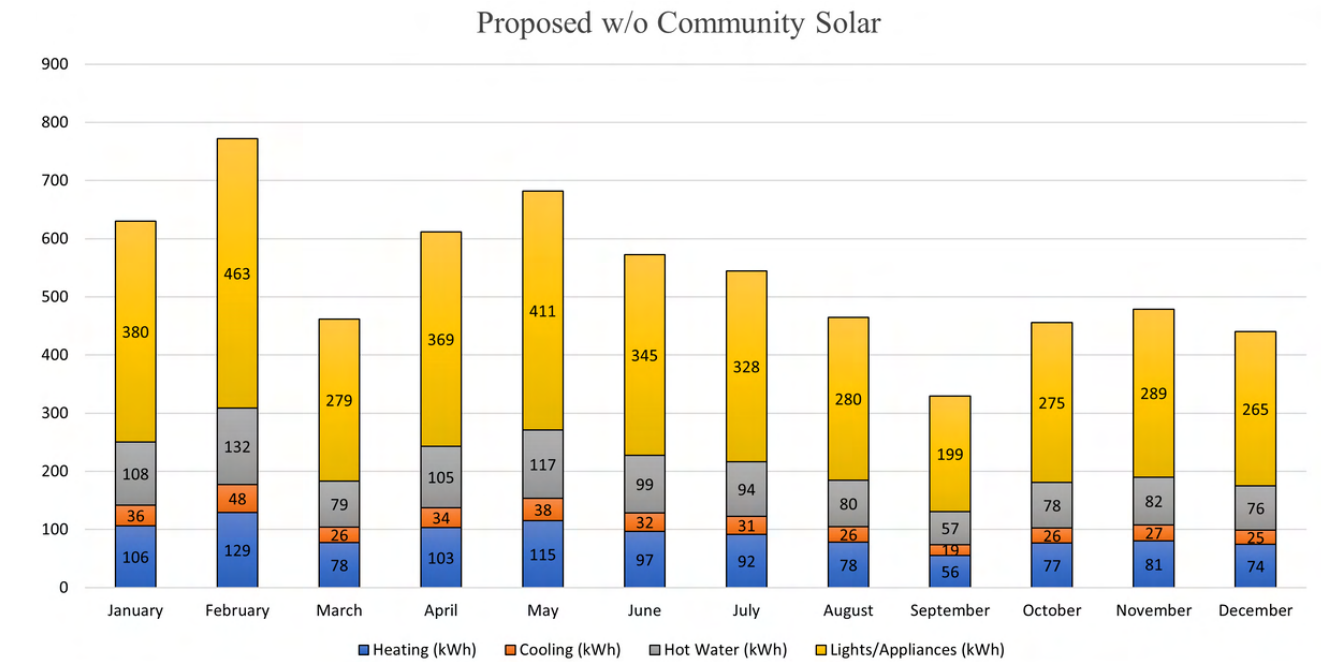
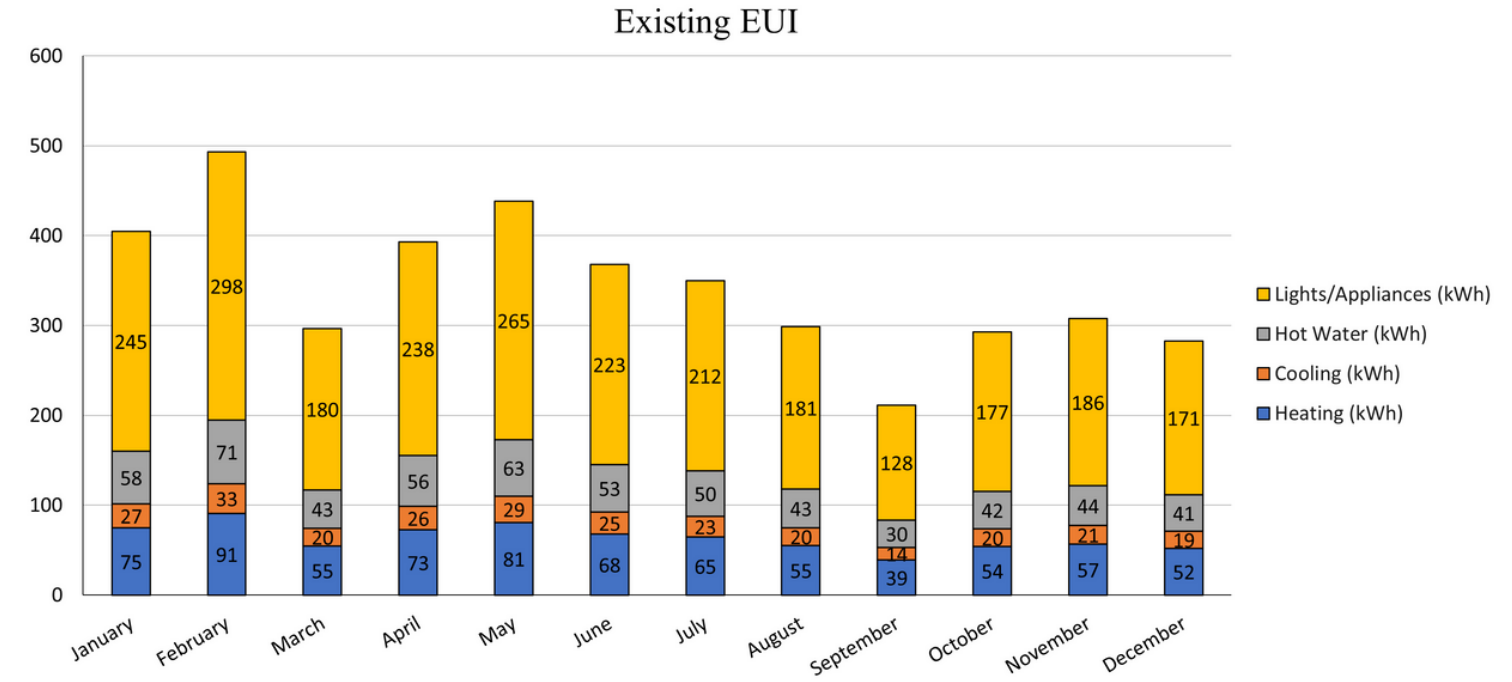
EUI



Existing EUI:  
79.15  
kBTU/Year

Proposed EUI:  
28.72  
kBTU/Year

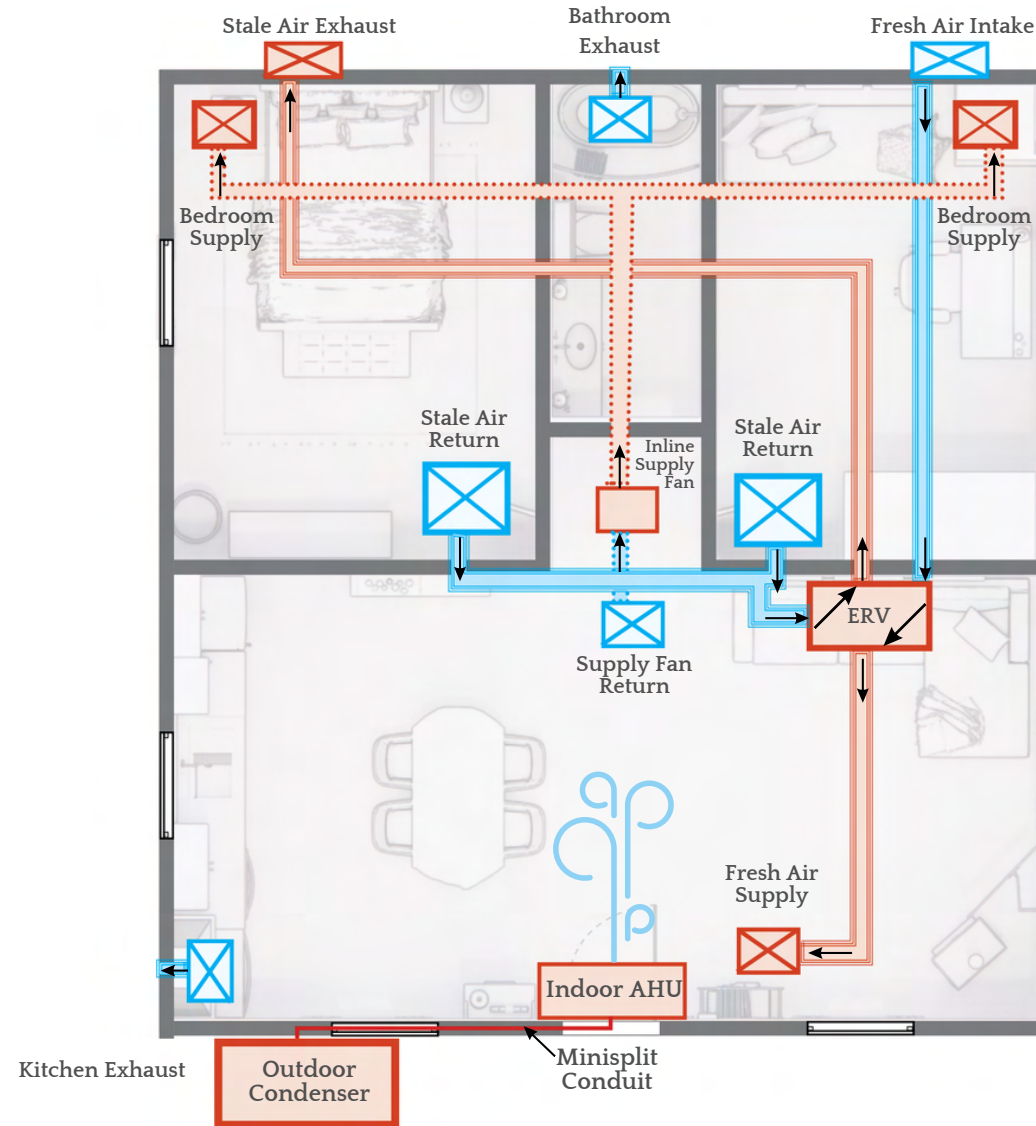
Proposed EUI w/  
Community Solar:  
-0.68  
kBTU/Year




# Solution

## Mechanical Plan

EUI



 = ERV Ductwork

 = Inline Supply Fan Ductwork

Properly sized mini-split AHU

Energy recovery ventilator (ERV) supplies fresh air in main room near conditioned air from mini-split

Inline supply fan moves air from the main room to the bedrooms while also providing MERV 13 filtration

ERV exhausts stale air back outside while transferring otherwise wasted thermal energy to the incoming fresh air

### Mechanical Calculations

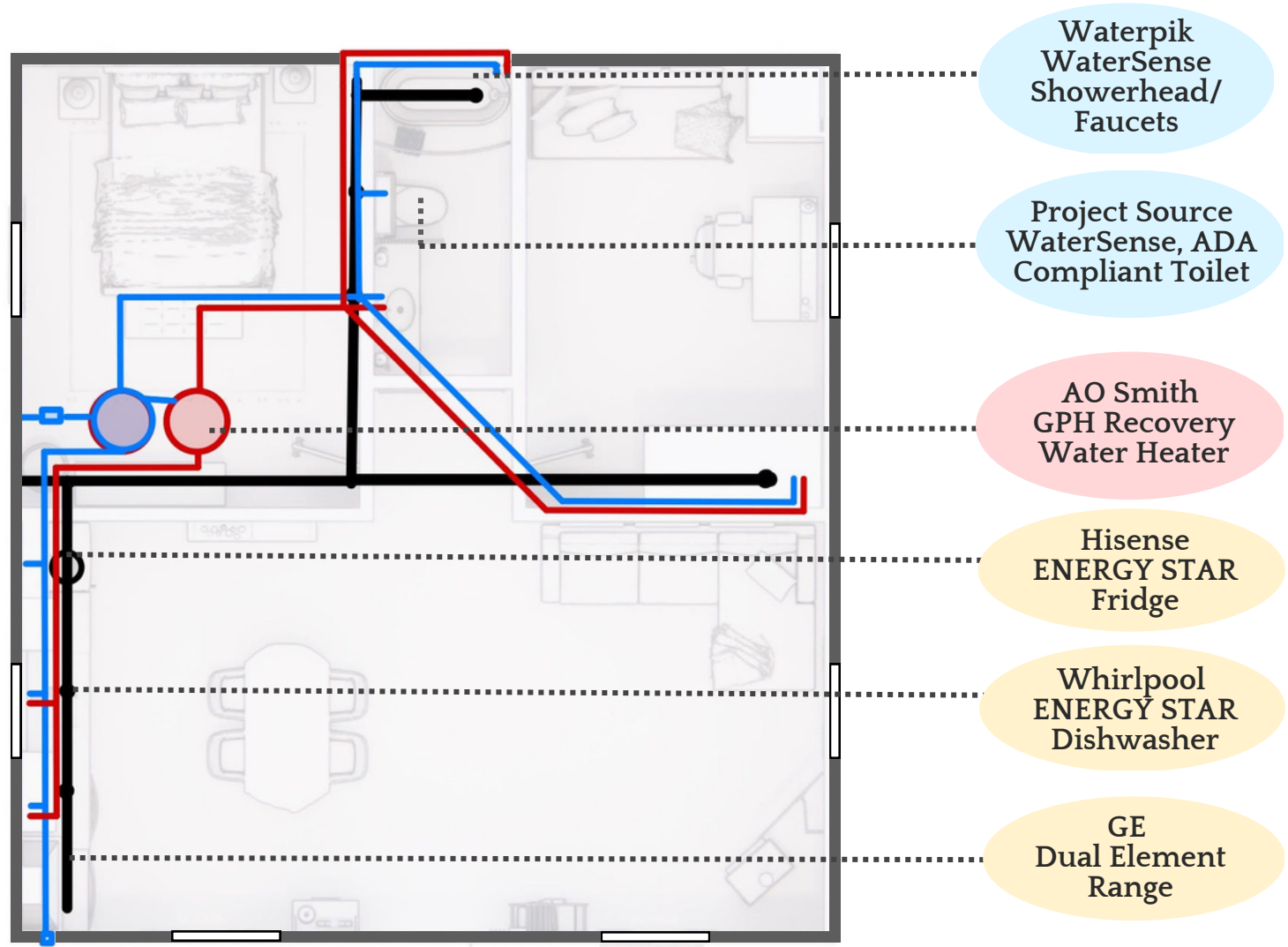
- Manual J calculations computed a load of 13 kBTU/hr for the entire home
- Our energy model in Ekotrope produced a heating design load of 7 kBTU/hr, and a cooling design load of 6 kBTU/hr.
- Our Mini Split has a cooling rating of 6 kBTU, and a heating rating of 8.7 kBTU.





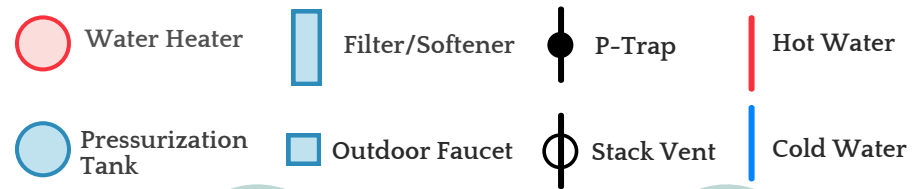
# Solution Plumbing Plan

EUI



Plumbing/Appliance Schedule	
Component	Specification
Dishwasher	Whirlpool, ENERGYSTAR, 21.3 ft <sup>3</sup> , 55-dBA.
Fridge	Hisense, ENERGYSTAR, 17.2 ft <sup>3</sup>
Low-Flow Faucet Aerators	Waterpik, WaterSense, -1.5 GPM
Low-Flow Showerhead	Waterpik, WaterSense, -1.5 GPM
Toilet	Project Source, WaterSense, ADA compliant, 1.48 GPF
Hot Water Heater	AO Smith, 40 Gallon, 0.92 UEF, 20.7 GPH Recovery @ 90F, 6-year warranty
Range/Oven	GE, 30", 5.3 ft <sup>3</sup> , 9"/12" Dual Element, Warming Zone, Self clean.

Plumbing plan



# Solution HERS

HERS



Existing  
HERS:  
104

## Home Energy Rating Certificate

Projected Report  
Based on Plans

Rating Date:  
Registry ID:  
Ekotrope ID: d4rJg9y2

### HERS® Index Score:

**104**

Your home's HERS score is a relative performance score. The lower the number, the more energy efficient the home. To learn more, visit [www.hersindex.com](http://www.hersindex.com)

### Annual Savings

**\$283**

\*Relative to an average U.S. home

**Home:**  
392 Harris Drive  
Boone, NC 28607  
**Builder:**



# Solution HERS

HERS



Existing  
HERS:  
104

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\*Relative to an average U.S. home

**Home:**  
392 Harris Drive  
Boone, NC 28607  
**Builder:**

Proposed  
HERS:  
37

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Projected Report  
Based on Plans

Rating Date:  
Registry ID:  
Ekotrope ID: d4rJg9y2

### HERS® Index Score:

**37**

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### Annual Savings

**\$1,383**

\*Relative to an average U.S. home

**Home:**  
392 Harris Drive  
Boone, NC 28607  
**Builder:**



# Solution HERS

HERS



Existing  
HERS:  
104

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**\$1,383**

\*Relative to an average U.S. home

**Home:**  
392 Harris Drive  
Boone, NC 28607  
**Builder:**

Proposed  
HERS w/  
Solar:  
-6

## Home Energy Rating Certificate

Projected Report  
Based on Plans

Rating Date:  
Registry ID:  
Ekotrope ID: d4rJg9y2

### HERS® Index Score:

**-6**

Your home's HERS score is a relative performance score. The lower the number, the more energy efficient the home. To learn more, visit [www.hersindex.com](http://www.hersindex.com)

### Annual Savings

**\$2,092**

\*Relative to an average U.S. home

**Home:**  
392 Harris Drive  
Boone, NC 28607  
**Builder:**



# Solution Final



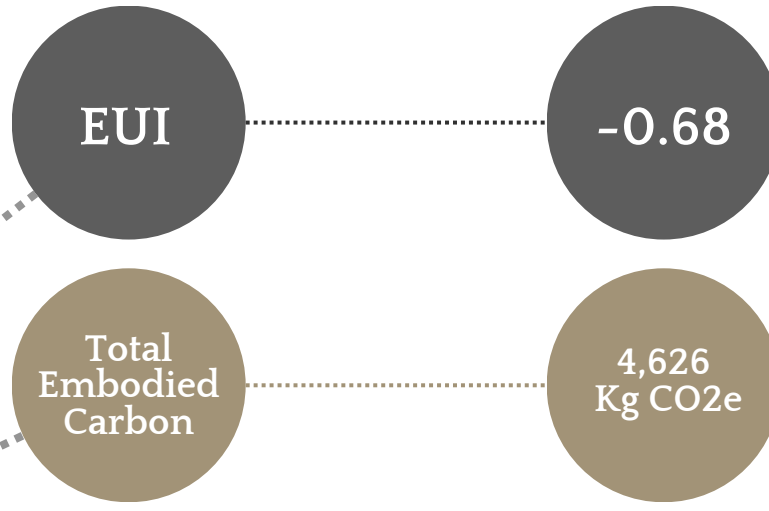
# Solution Final

EUI

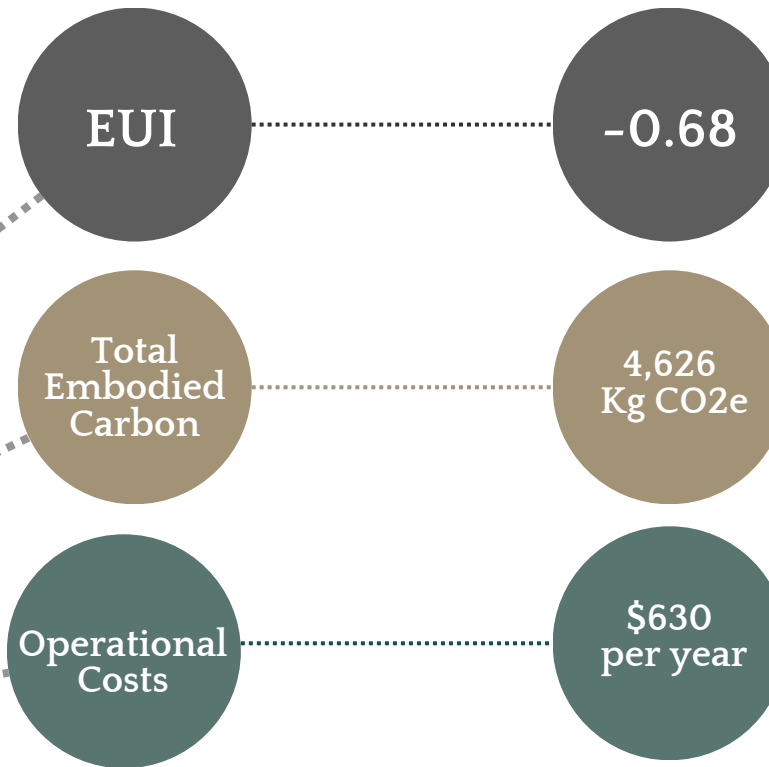
-0.68



# Solution Final

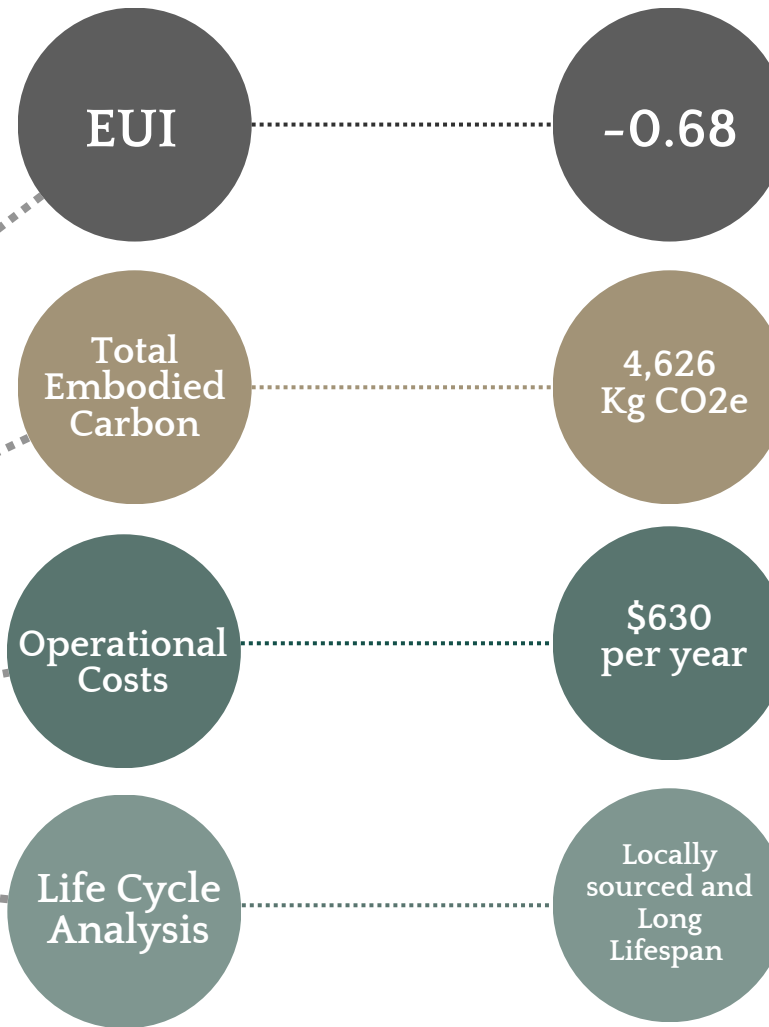


# Solution Final

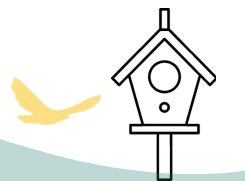
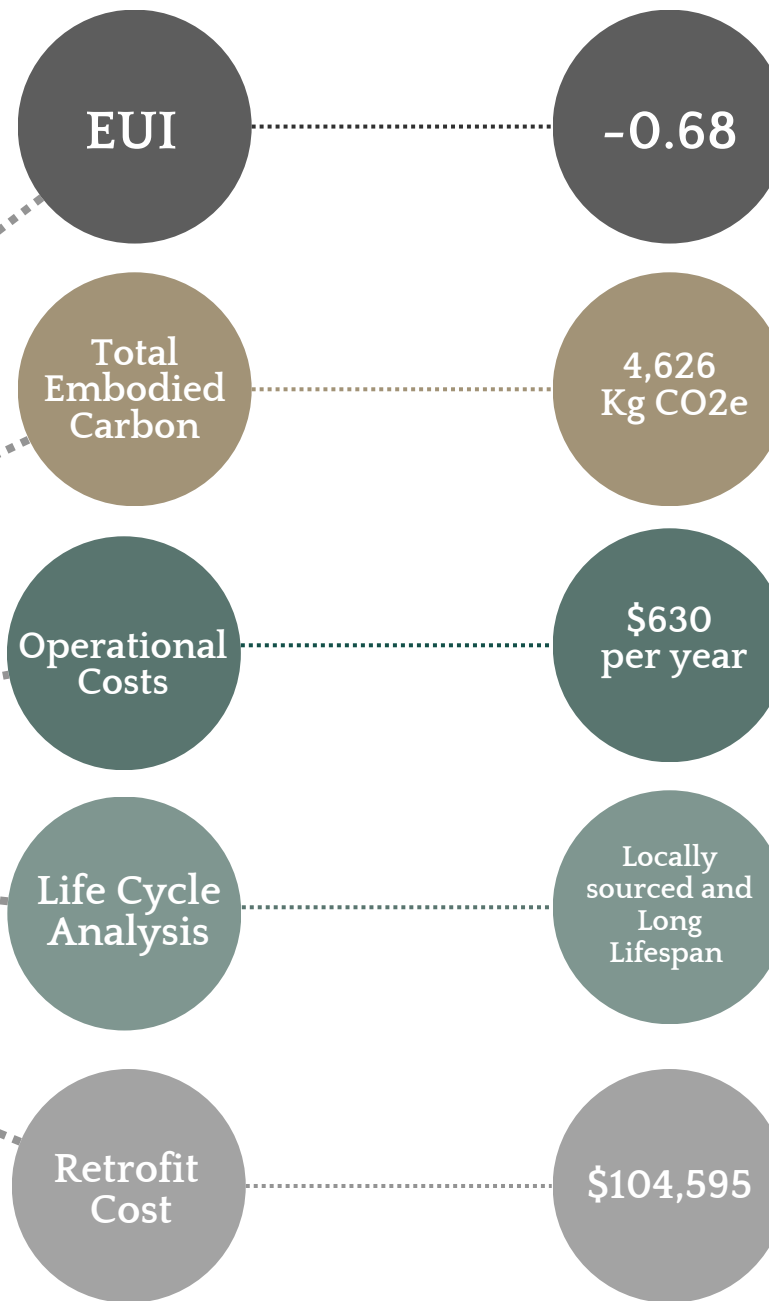




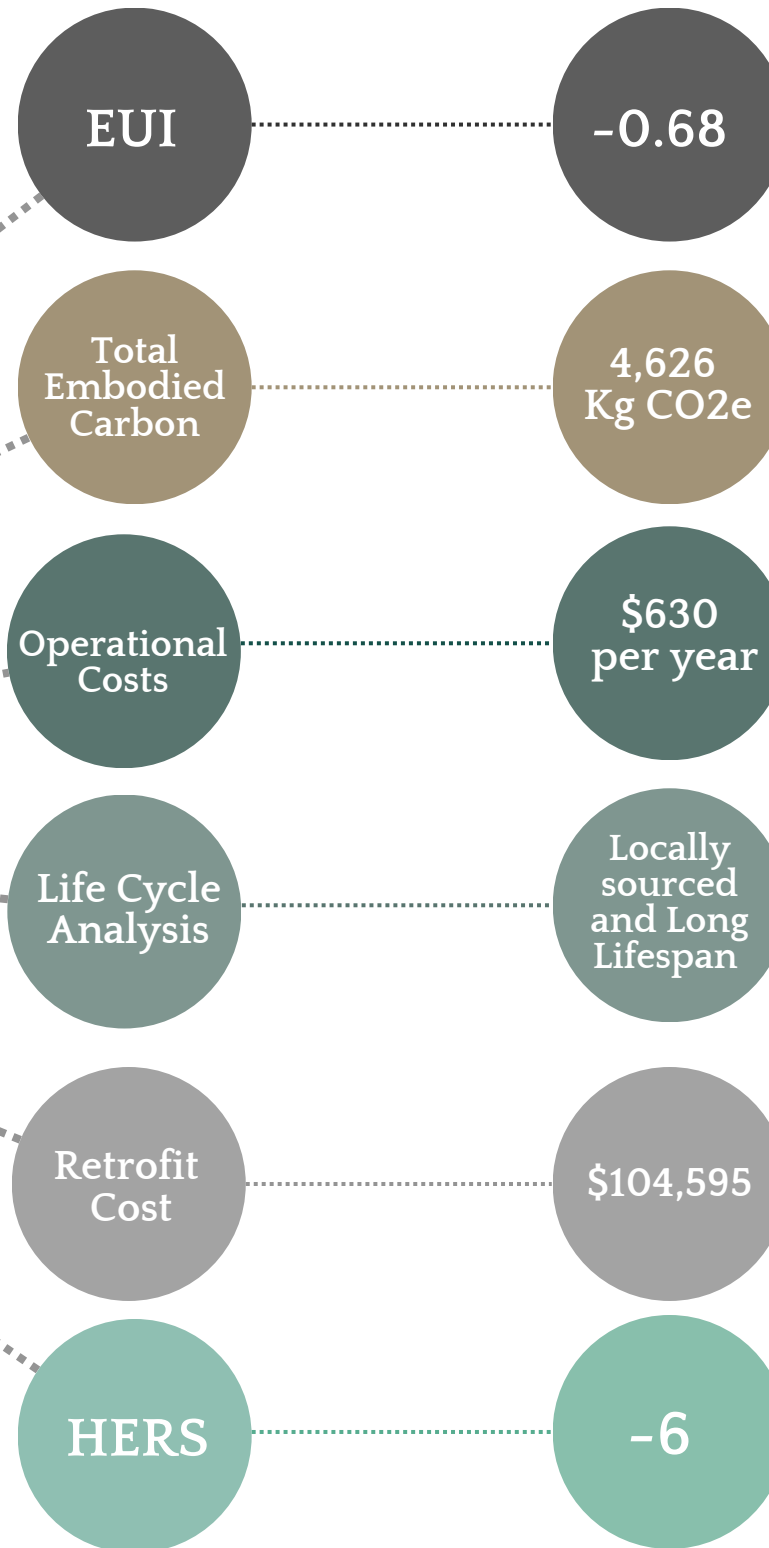
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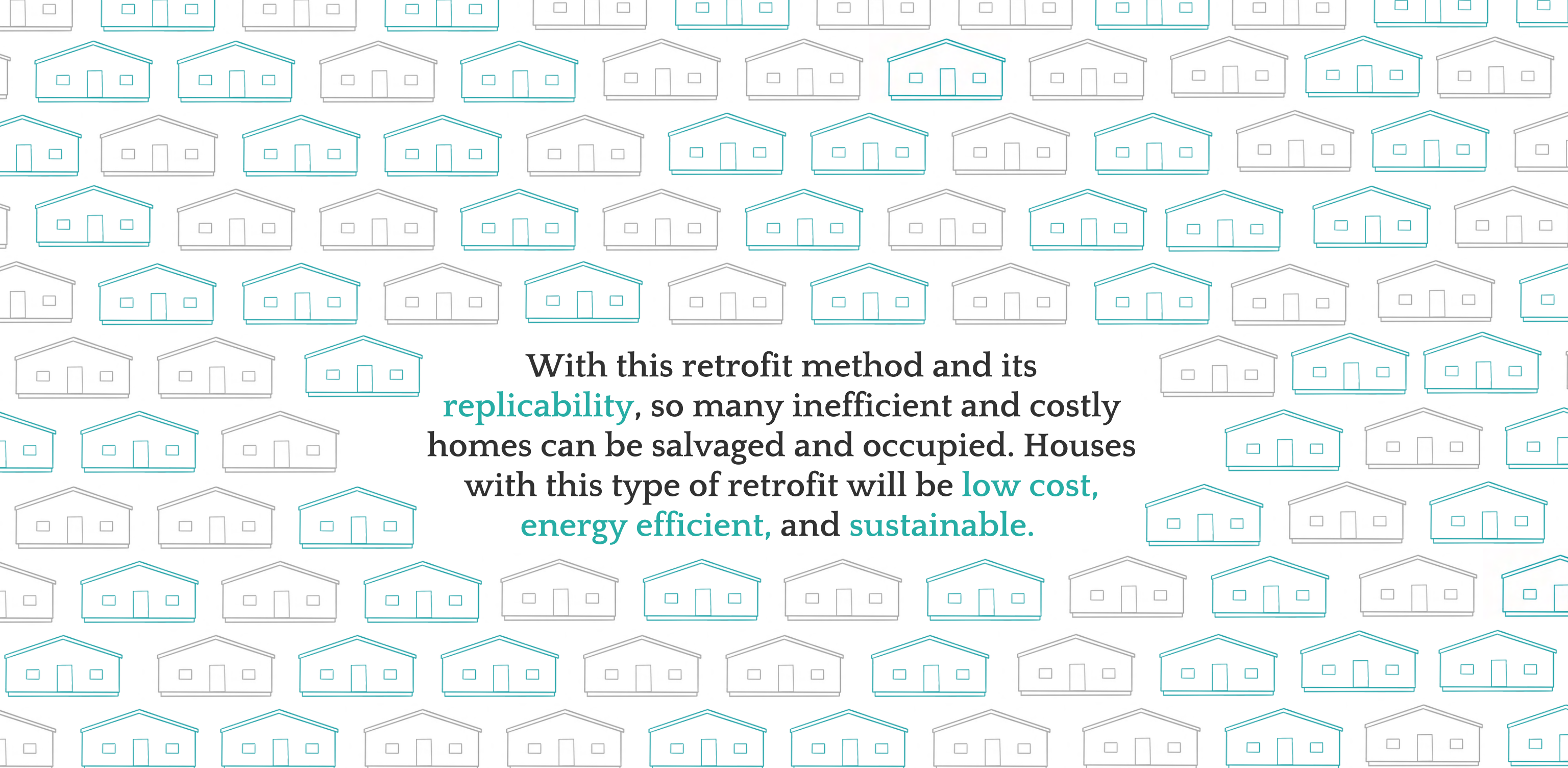


# Solution Final



Final Gold  
Finch Score  
**9.3**





With this retrofit method and its **replicability**, so many inefficient and costly homes can be salvaged and occupied. Houses with this type of retrofit will be **low cost**, **energy efficient**, and **sustainable**.

