Commercially Viable Net Zero Office Building

The Sustainable Energy Fund

LEARNING OBJECTIVES

1. Understand how using systems thinking helps successfully identify qualitative project goals, centering around the context of the site and the user's culture.

2. Explain how Net Zero Energy design and sustainability goals drove the selection of an air-source VRF system and various envelope components.

3. Analyze the role of energy modeling in the design, construction and operation of a Net Zero Energy Building. Develop an understanding of available energy modeling tools.

4. Understand the relationship between building cost and the cost of energy in creating an approach to cost-effective net zero design.

TEAM

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OWNER

THE SUSTAINABLE ENERGY FUND

Our mission is to promote, research, and invest in clean and renewable energy technologies, energy conservation, energy efficiency and sustainable energy enterprises that provide opportunities and benefits for PPL Electric ratepayers in Pennsylvania.

Non-Profit organization expands sustainable energy in PA through:

- **Financing**
- **Legal Advocacy**
- **Public Education**

PROJECT GOALS

- Demonstrate Commercial Viability / Prototype
- Display Conservation / Efficiency / Renewable Technologies
- Offer Healthy Motivating Work Environment
- Attract Targeted Tenants

Intro to
Design Process

How we start a project?

Sustainability Framework

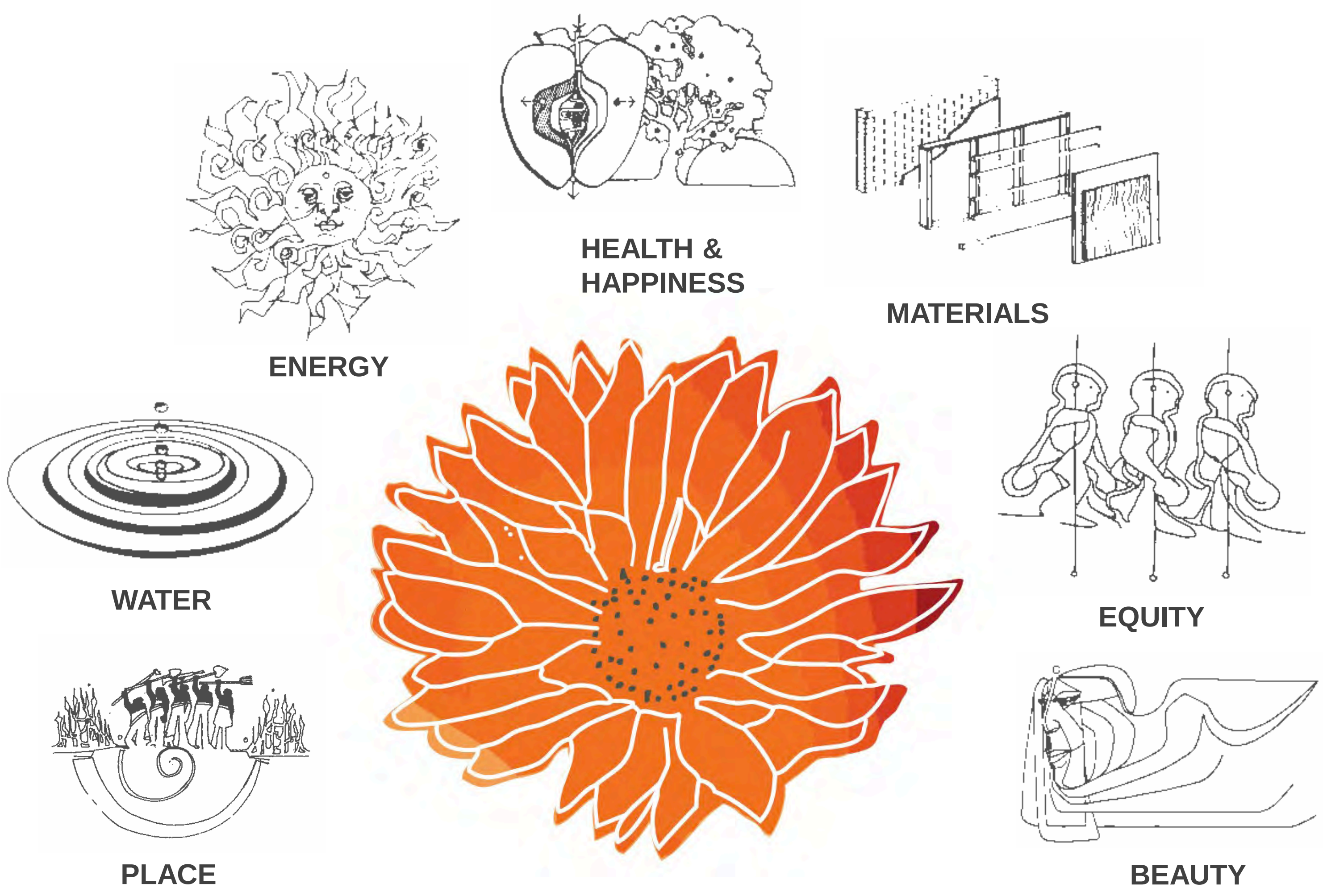
Defining Priorities is the key to project success

Sustainability Framework – The Living Building Challenge

What Does Good Look Like?

Petals Framework

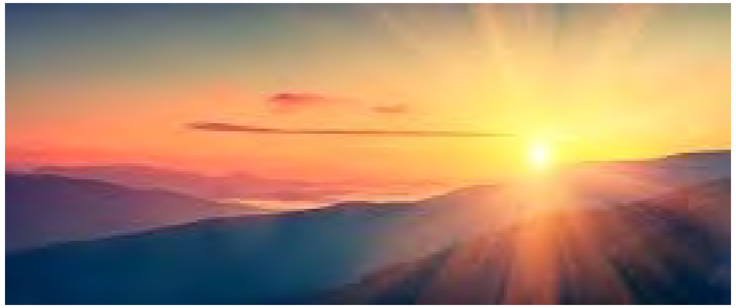
LBC is used as a discussion framework for holistic sustainability.



Sustainability & Resources

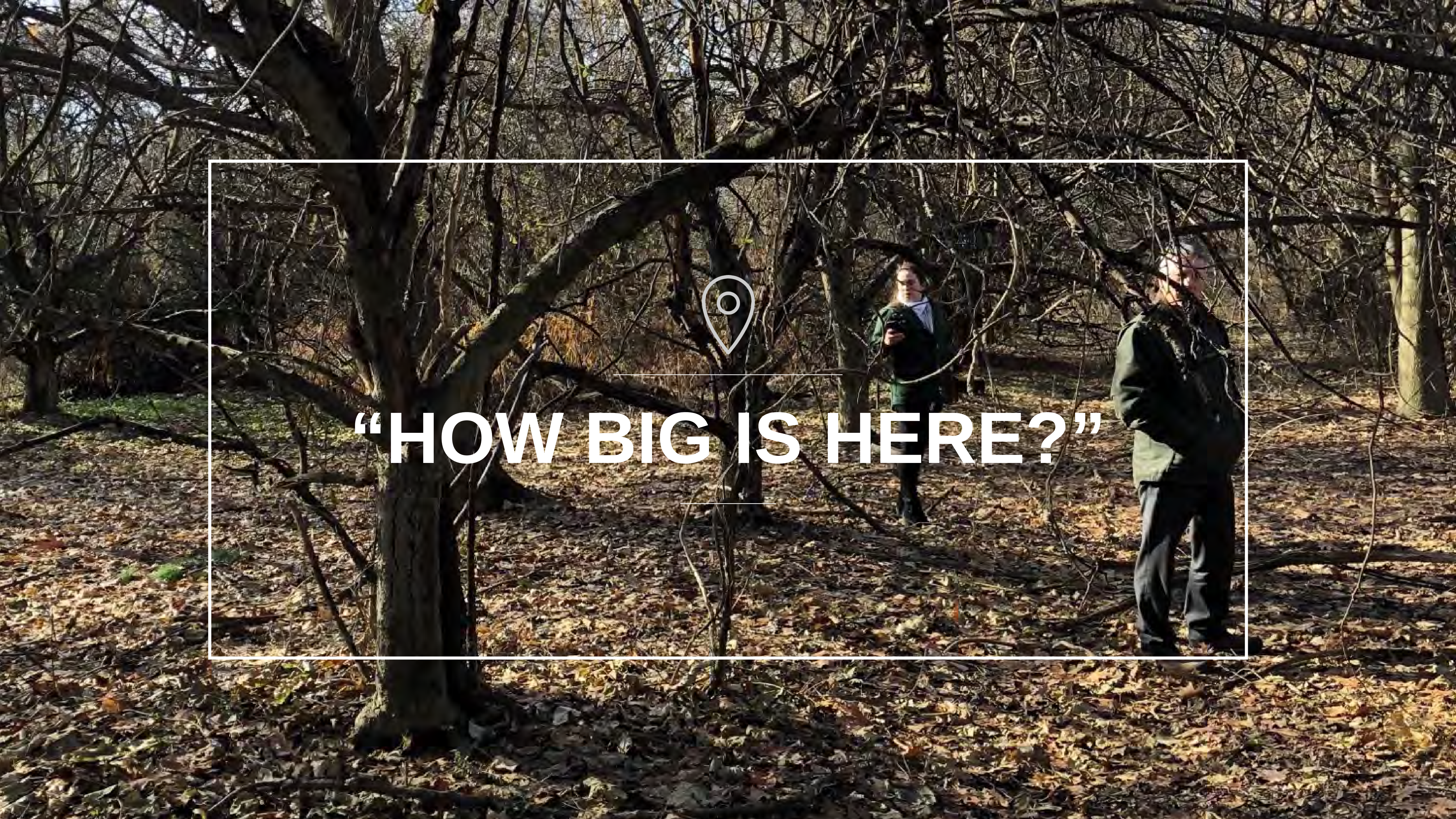
- Water
- Materials
- Light
- Land
- Ecology
- Beauty





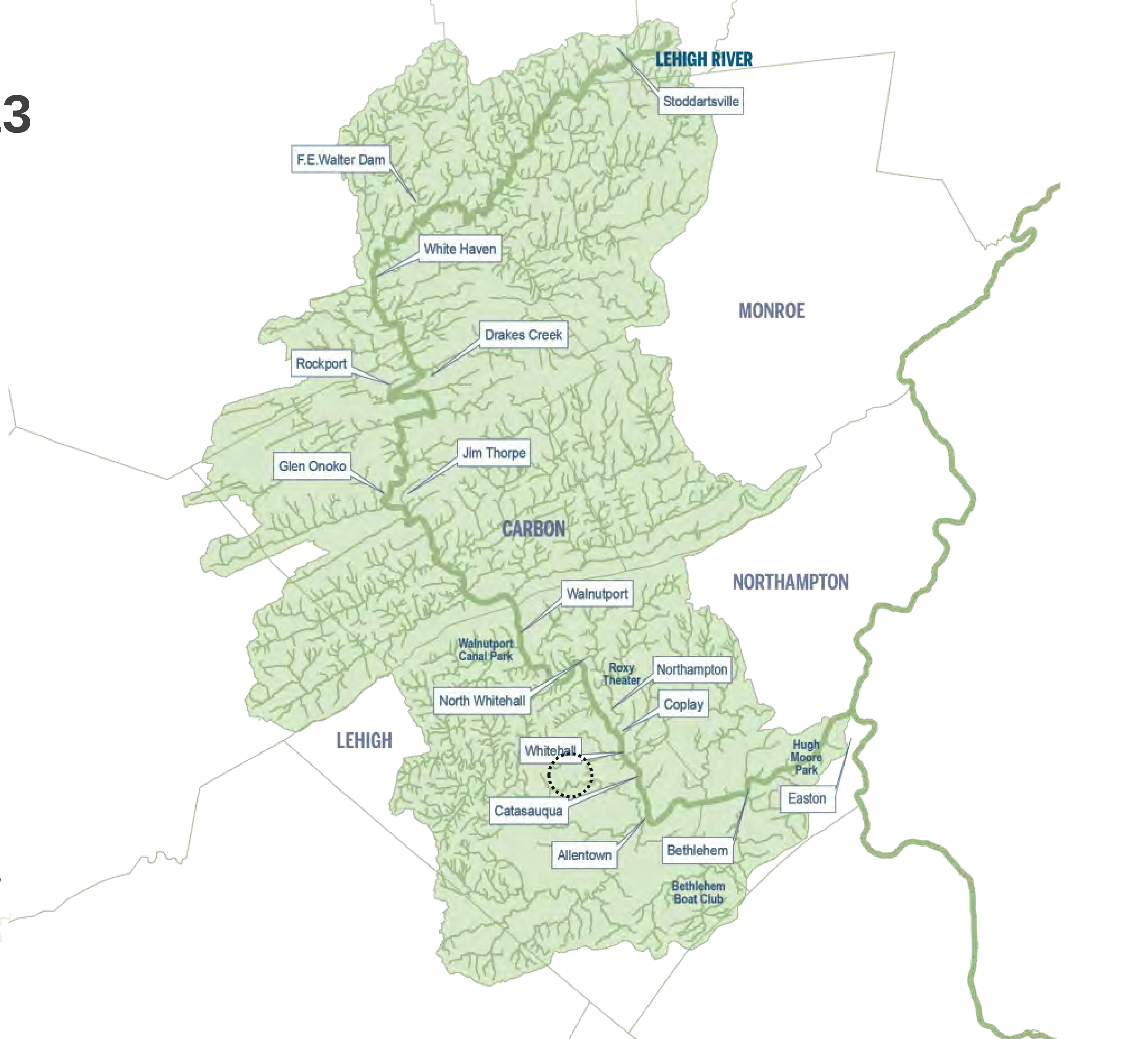

Enhancing Society

Understanding the Project Needs


"HOW BIG IS HERE?"

Park View Dr
Jefferson Dr
Independence Dr
Carbon Lehigh Intermediate
Family Dermatology
Independence Dr
Carl St
309
Schnecksville Fire
Carl St
309

Topographical Map 2013



Wildlands Conservancy

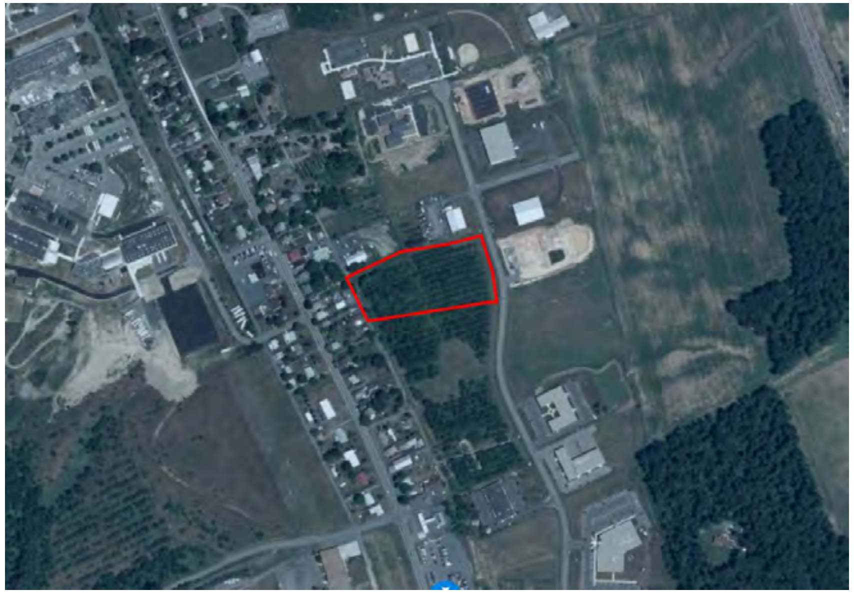
MAP OF LEHIGH RIVER WATERSHED

Site History

1938

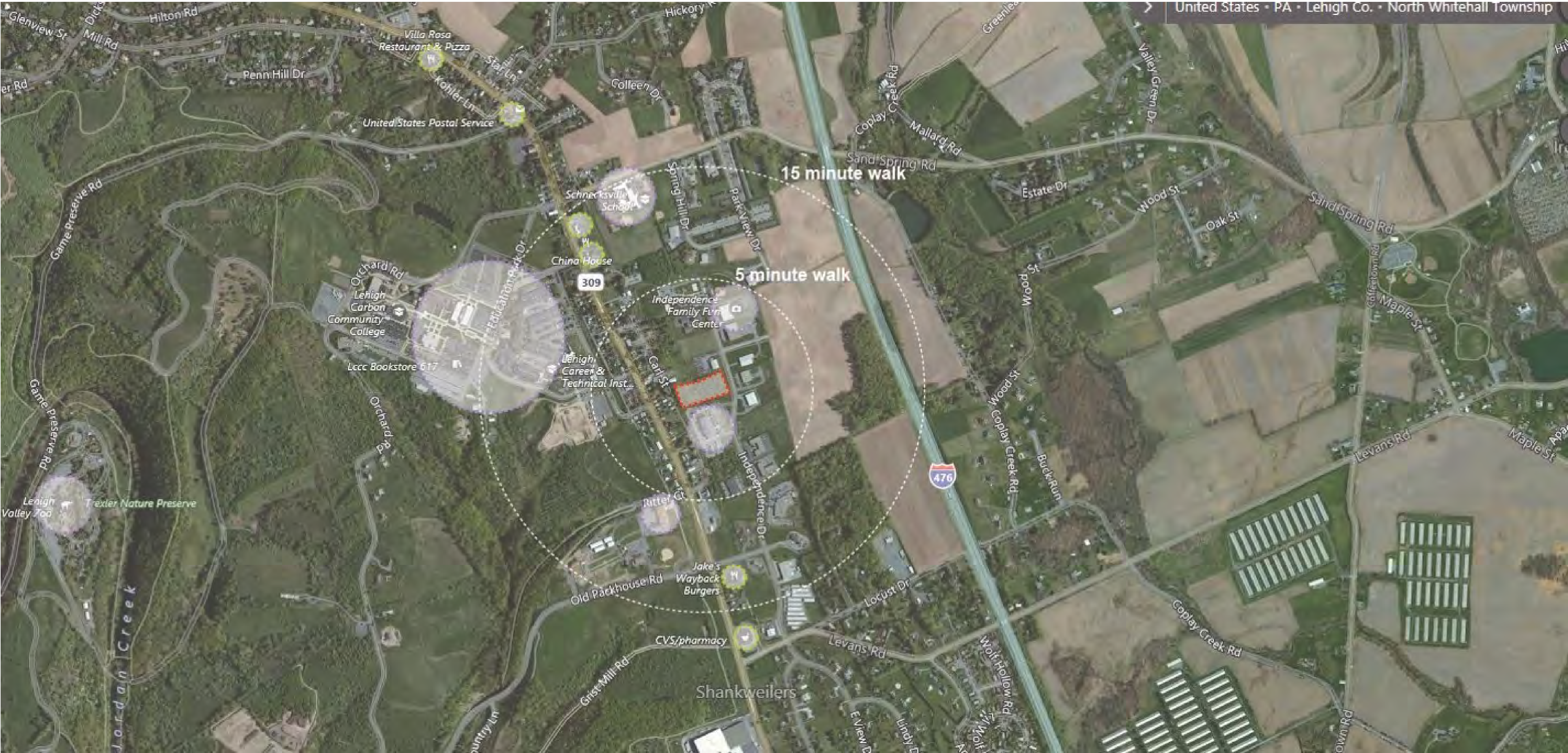
1962

1981



2005

SEF Site Walkable Area



Solar Access & Resources

Essence

Identify the essence of place

4-Whats

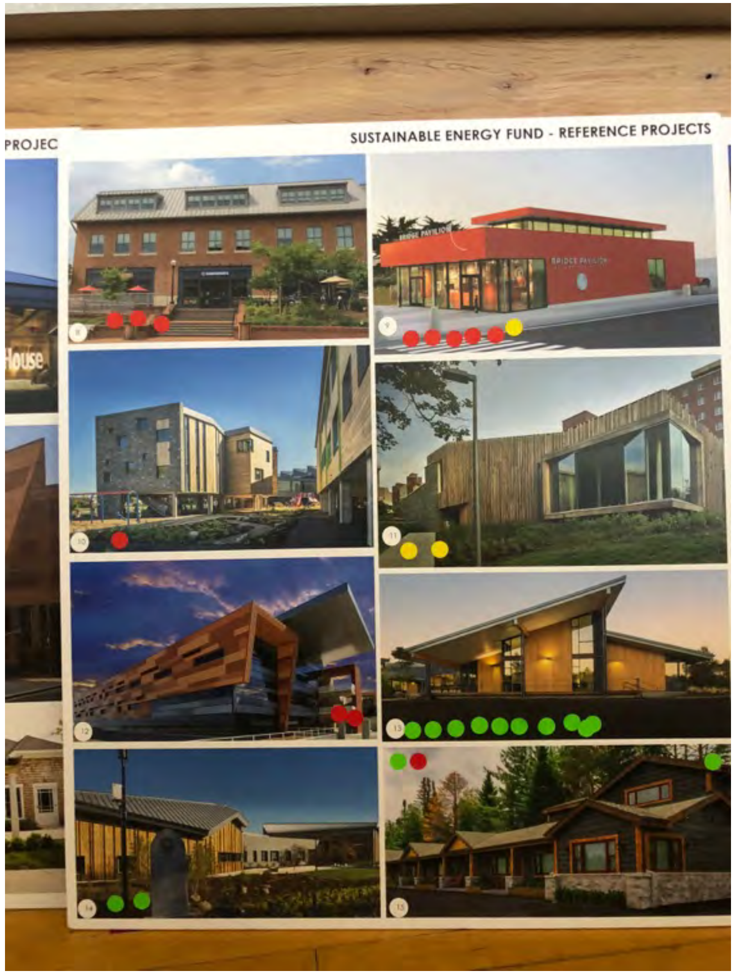
Who we are and where we're going

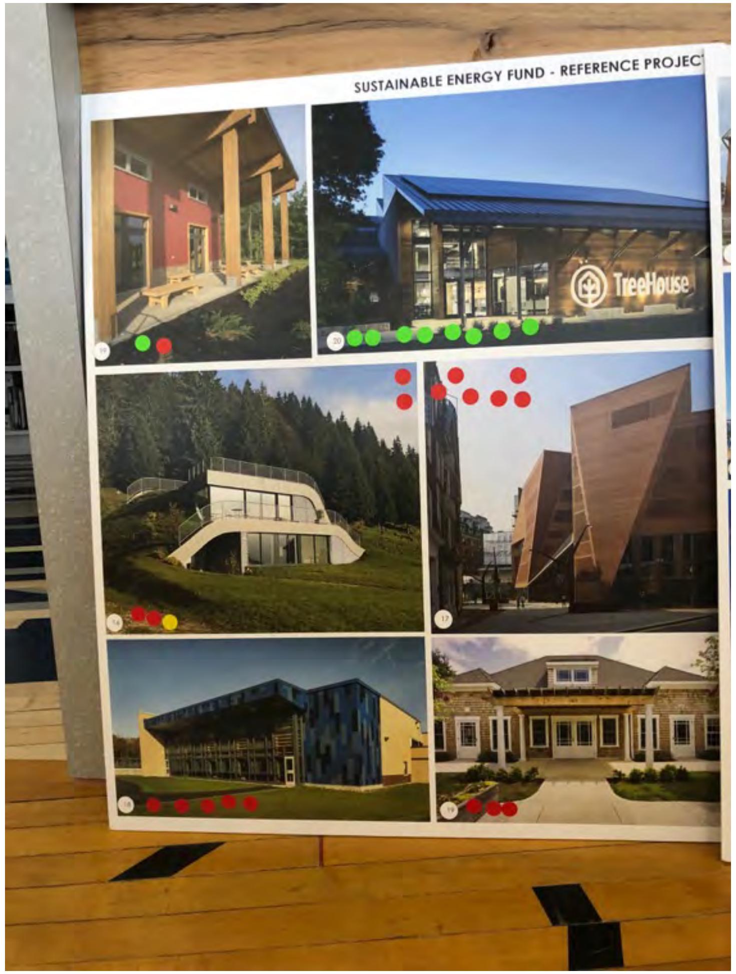
Understanding the SEF – Purpose Statement

"We will build a net zero energy building in a way that is unique, financially responsible and environmentally friendly so that it educates the community, demonstrates that net zero is economically feasible and sets a sustainable example for the region."

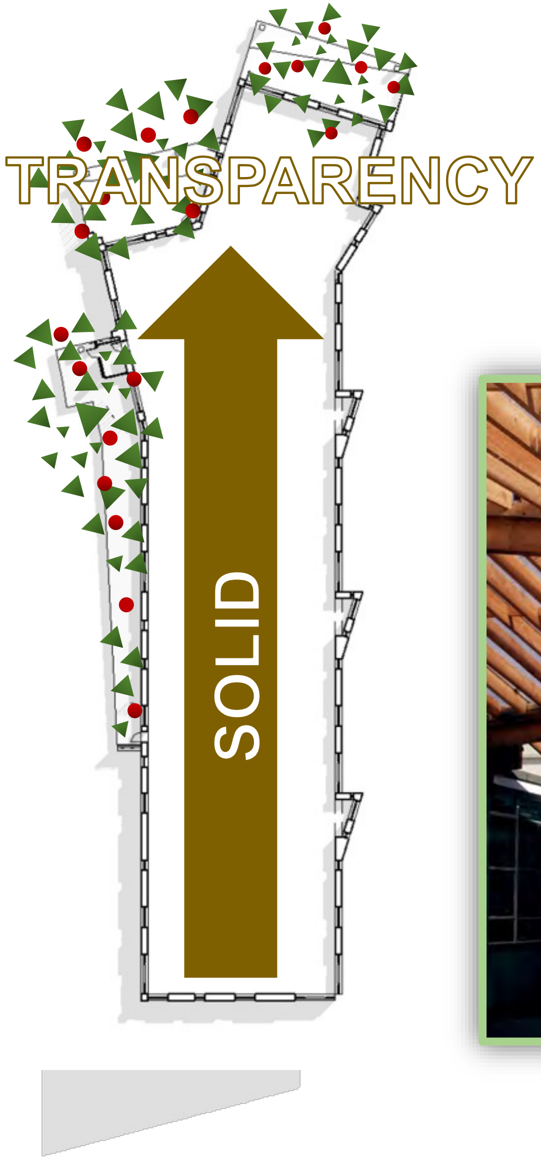
- Commercially-viable Net-Zero
- Demonstrate New Technology
- Push the Market

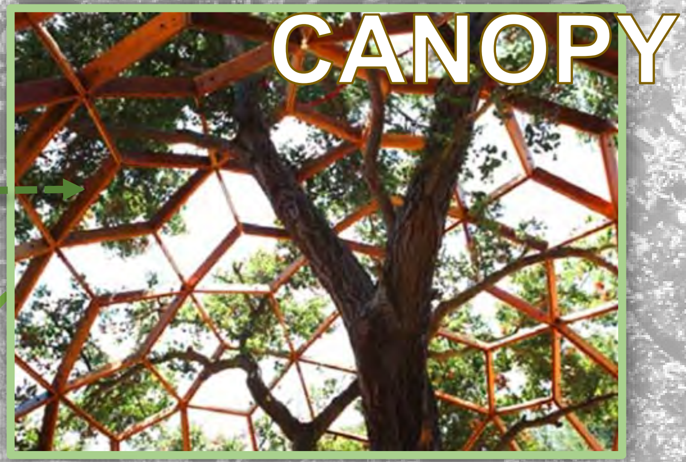
Aesthetic Boards





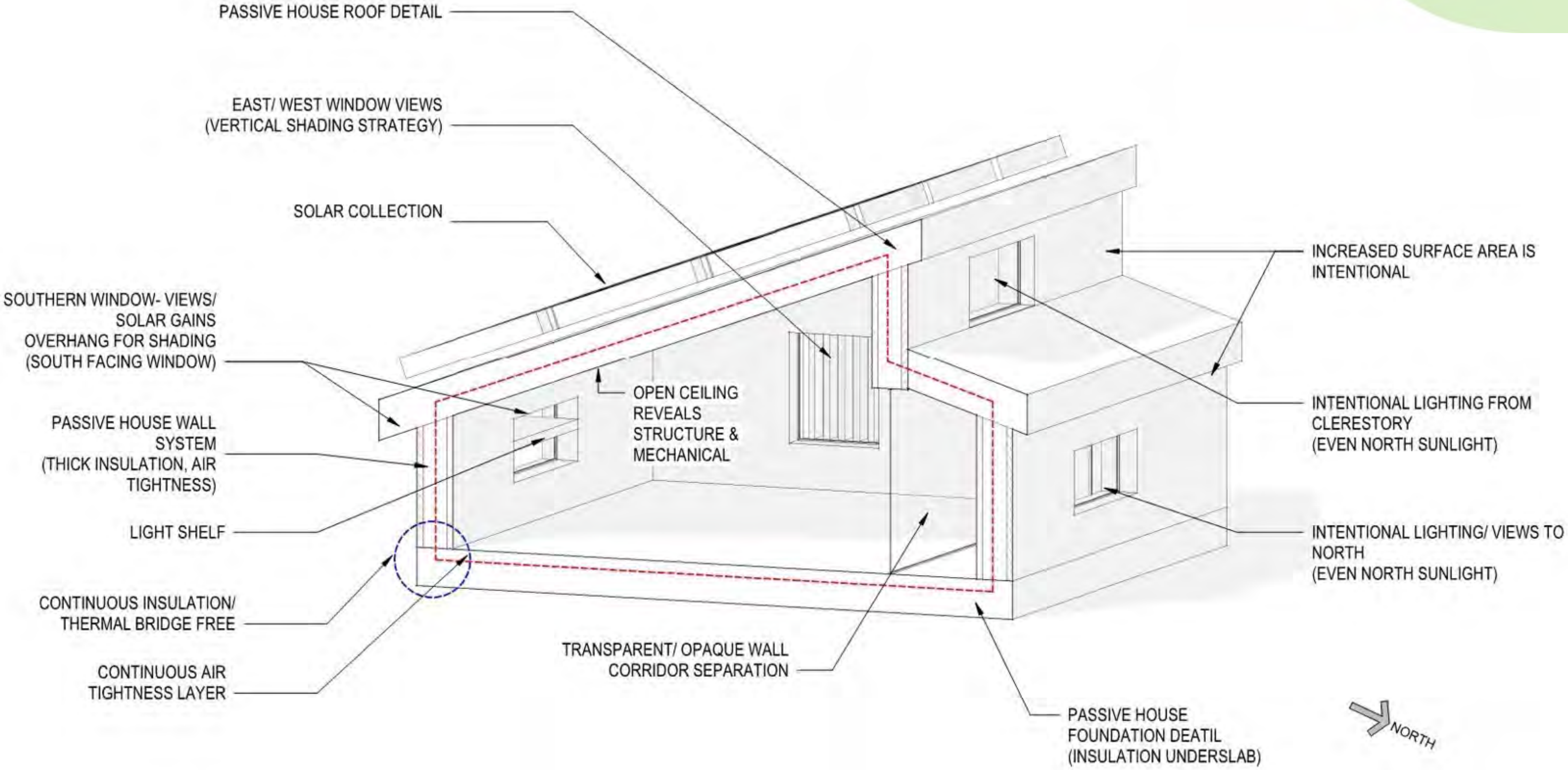
Apple Tree Concept



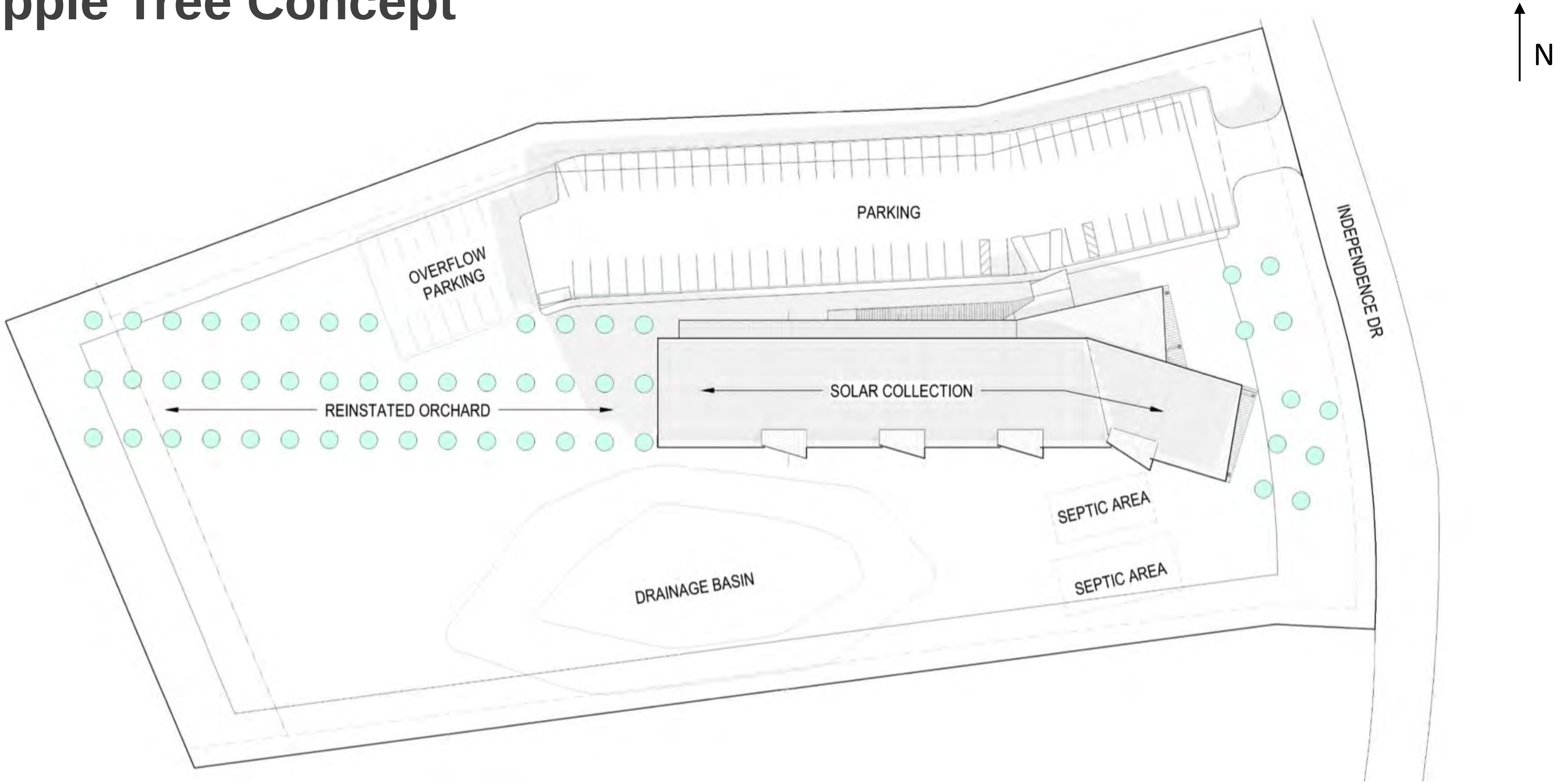


Apple Tree Concept

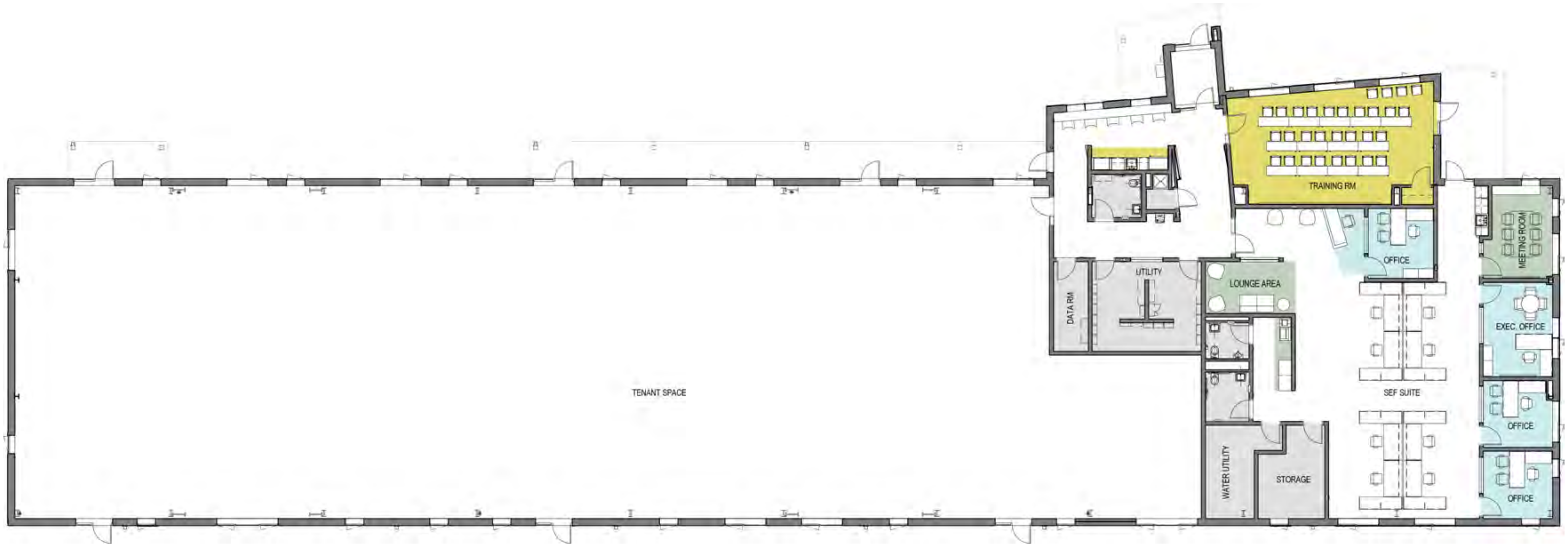
Solar Roof Shape



Apple Tree Concept



SEF Floor Plan




NET ENERGY ZERO

Building Systems: Mechanical

System	Pros	Cons	
Packaged Rooftop with VAV Boxes	- Very affordable	- Uses more energy - Not as easy to zone (small tenants) - All in one system	Excluded
Mini Split System with ERVs	- Flexible and scalable - Separates heat/cool from ventilation - Saves some energy - Affordable	- Potential for lots of outdoor units - Not as energy efficient	
VRF System with Fan Coil Units and ERVs	- Flexible and scalable - Separates heat/cool from ventilation - Saves more energy	- Not as affordable as Mini-Split System - Maintenance may be more difficult	
Geothermal Heat Pump System with ERVs	- Flexible and scalable - Easy to maintain - Separates heat/cool from ventilation - Saves energy - Can make hot water too	- Most expensive - Payback not as good as other systems - Disruptive to install	Excluded

Building Systems: Mechanical

Outdoor Unit

+

Wall-Mounted	Floor-Mounted	1-Way Ceiling Suspended
6 MBH – 30 MBH nominal cooling	6 MBH – 24 MBH nominal cooling	15 MBH – 36 MBH nominal cooling
		
1-Way Ceiling Cassette	4-Way Ceiling Cassette	Concealed Horizontal Ducted
6 MBH – 15 MBH nominal cooling	8 MBH – 48 MBH nominal cooling	6 MBH – 96 MBH nominal cooling
		

Various Indoor Units

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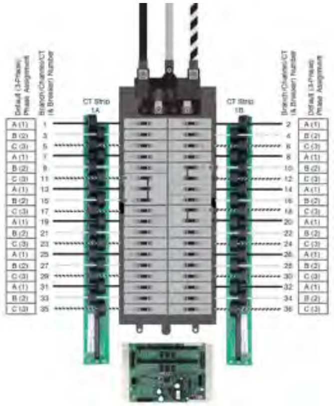
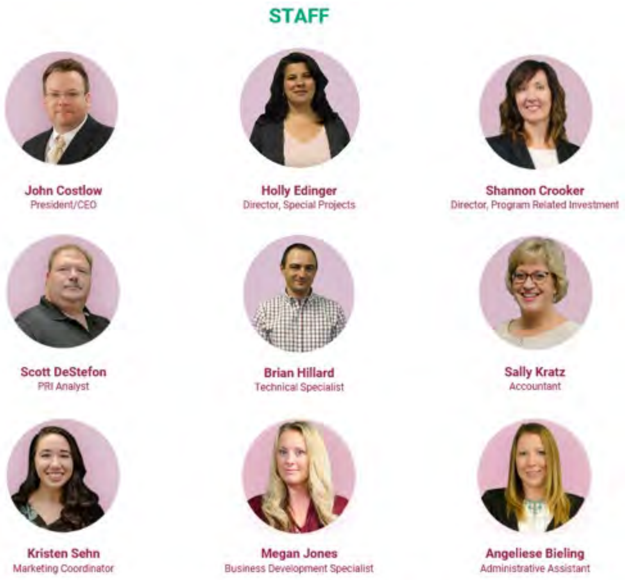
ERV (ventilation)

Building Systems: Electrical & Lighting



Advanced Metering and Dashboards

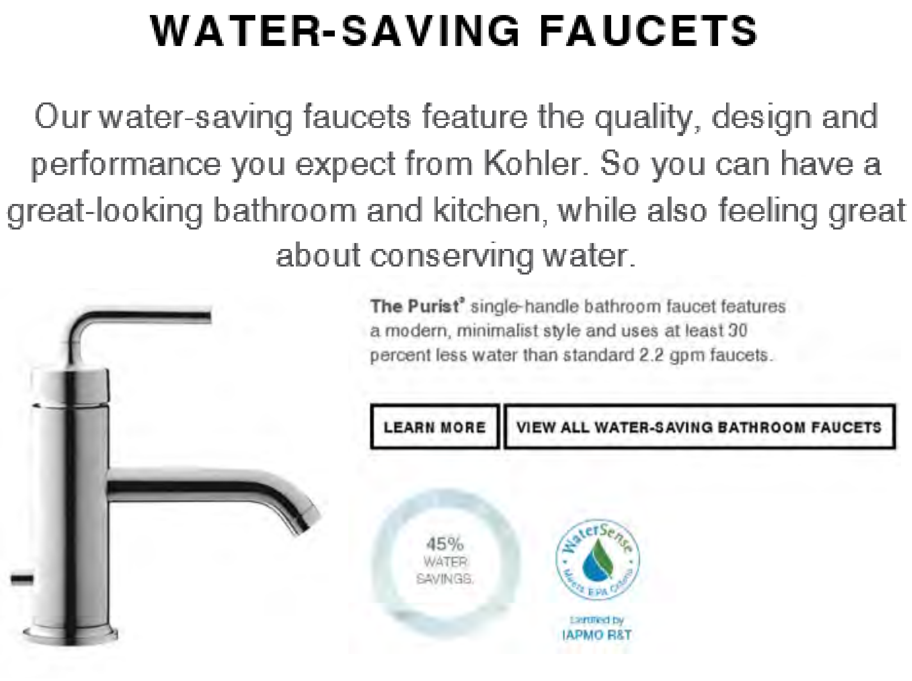
LED Lighting Just Enough Light Controls



Working with Occupants Plug Loads

PV Panels on sloped roof

Building Systems: Plumbing



Low Flow Fixtures

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Centralized Efficient Hot Water Heating

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Drinking Fountains Not Water Coolers

What are the challenges and opportunities?

DEFINE NET ZERO

1. Net zero-energy building
2. Zero net site energy use
3. Net Zero Source Energy Building
4. Grid Tied Net Zero
5. Storage Net Zero
6. Off Grid Net Zero

ILFI – Zero Energy Certification

INTERNATIONAL LIVING FUTURE INSTITUTE[SM]

"One hundred percent of the buildings energy needs on a net annual basis must be supplied by on-site renewable energy. No combustion is allowed."

Generating an Energy Budget

Energy Used < Energy Made

How Much Energy Will We Use?

- Building Envelope, Systems, and equipment options may result in less energy but may cost more
- Need to determine energy savings vs first cost total

How Much Energy Can We Make?

- Space for PV panels may be a limiting factor. Sometimes energy generation sets the limit for how much energy the building can use.
- If space is not a factor, it is important to understand the first cost impacts – does an energy saving measure cost more than the amount of PV panels that it saves?

Generating an Energy Budget for SEF

Factors at play:

1. One story building
2. Lots of southern roof space
3. Owner wants PV ONLY on the roof (not over parking lot)
4. Office occupancy with standard business hours

Which factor do you think is driving the energy budget?

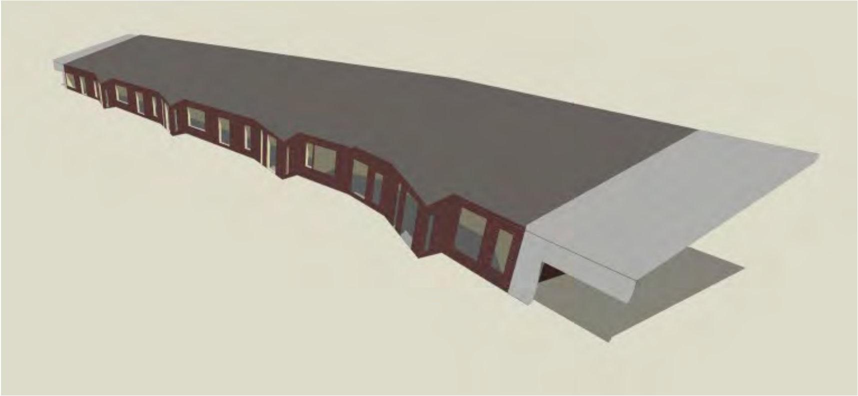
Energy Used or Energy that can be made?

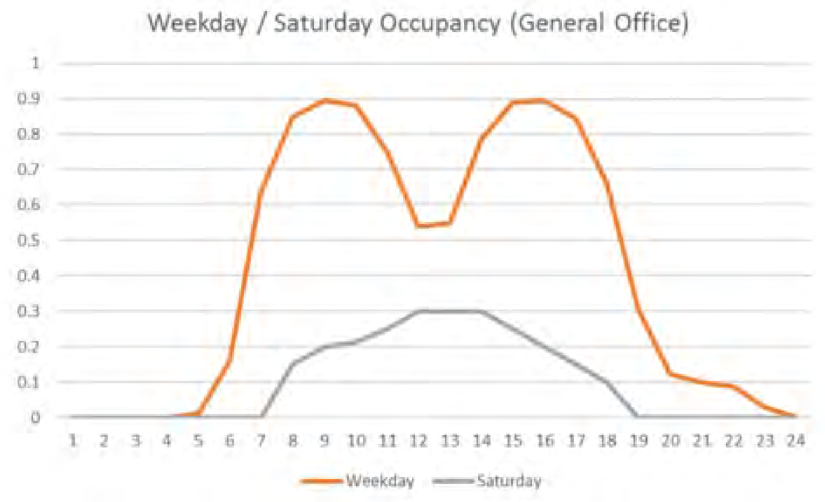
Calculating Predicted Energy Usage

Modeling completed using DesignBuilder - an Energy Plus based software program

In the preliminary design, focus is on:

1. Building footprint, height, openings and orientation
2. Building envelope construction
3. Building Schedule
4. Building Systems
5. Occupant Equipment and behavior assumptions





Adding an Energy Contingency

1. **Energy Modeling Accuracy**: We know energy modeling is not 100% accurate and will have inconsistencies and errors in it. This is particularly true at the early conceptual model phase.

2. **Design Evolution & Implementation**: As the design evolves, performance tends to slip as cost estimates impact design choices, constructability factors impact design, and a better understand of occupant impact typically result in an increase in energy predictions.

3. **Building Construction**: The construction of the building may result additional energy usage due to material substitutions, field conditions that alter the design and the resolution RFIs. There may also be performance issues in terms of improperly installed systems and components.

4. **Occupant Behavior and Building Operations**: Actual building operations and occupancy generally vary from the projections at the start of the project.

5. **External Factors**: External factors such as weather variations from the typical year energy model basis as well as un-planned equipment outages impact performance.

Adding an Energy Contingency

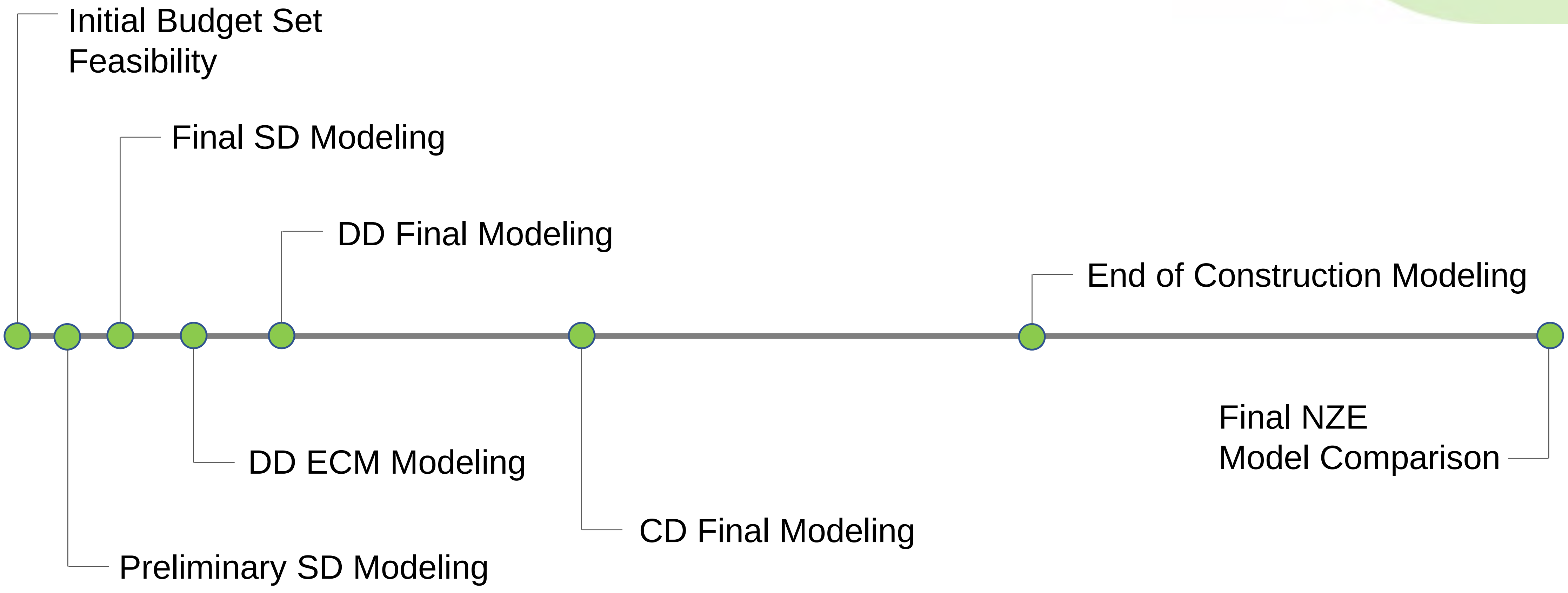
AKF/In Posse Typical Recommended Contingency Value: **20%**

SEF Preferred Contingency Value: **30%**

Pre-contingency Energy Generation Target: **89,359 kWh Annually**

Post-contingency Energy Generation Target: **116,167 kWh Annually**

Tracking The Energy Budget



Calculating Predicted Energy Generation

Starts with understanding some basic information about the building AND some assumptions about the PV panels

General Information:

- Building Campus orientation: 12 Degrees East of South
- Building Orientation: Due South and 12 Degrees East of South
- Roof Slope: 18 Degrees
- Calculations assume 340 Watt PV panels dimensions: 77.5” x 39.1”

Calculating Predicted Energy Generation

No Standards – Makes Designing Difficult

Manufacturer	Model	Cell type	Rated power @ STC (W)	Rated power per sq. ft. (W/sf)	Module efficiency (%)	Length (in.)	Width (in.)	Depth (in.)	Weight (lbs.)
Motech	XS72C4-340	mono	340	17.1	17.4	77.4	37	1.6	58.9
Suniva	OPT340-72-4-100	mono	340	16.2	17.43	77.6	39	1.5	50.7
Sunpower	SPR-X21-345	mono	345	19.6	21	61.4	41.2	1.8	41
Candian Solar	CS6U-350P	mono	350	16.9	18	76.9	38.7	1.4	48.5
Solaria	XT-350R-PD	mono	350	18	19.4	63.8	43.9	1.6	46
Solar World	SWA-350	mono	350	16.3	17.54	78.5	39.4	1.3	47.6
Axitec	AC-360M/72S	mono	360	17	18.55	77	39.1	1.6	50.7
Sunpreme	GxB-380	mono	380	18.2	19.4	77.2	38.9	0.1	55.6

Solar Panel Orientation

It is possible to determine the impact at any location. However, the pattern is generally similar. South is best, but some slight deviations have minimal impact.

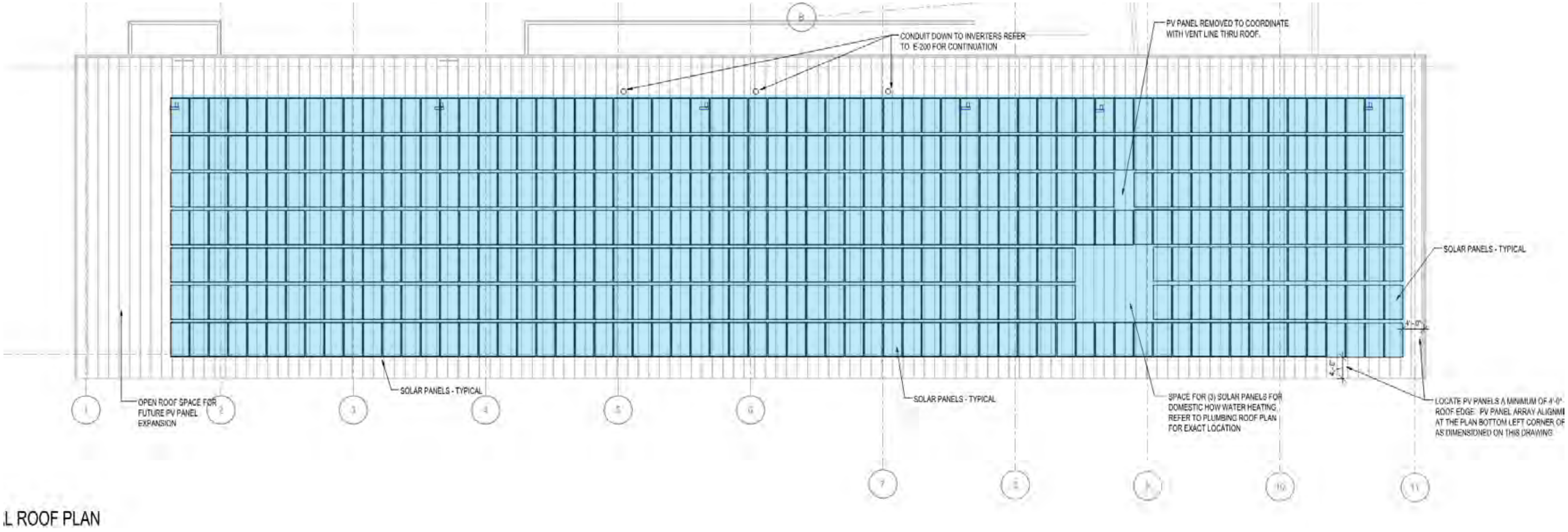
PV production losses by orientation for Cambridge, MA

			West						South						East		
	120	105	90	75	60	45	30	15	0	15	30	45	60	75	90	105	120
90	35%	41%	48%	53%	59%	63%	66%	68%	68%	69%	67%	65%	61%	55%	49%	42%	35%
75	41%	48%	56%	63%	70%	75%	80%	82%	84%	84%	81%	77%	72%	66%	58%	50%	42%
60	48%	56%	64%	72%	79%	85%	90%	93%	94%	94%	91%	87%	81%	74%	66%	58%	49%
45	56%	63%	71%	78%	85%	91%	96%	99%	100%	99%	97%	93%	87%	81%	73%	65%	57%
30	65%	71%	77%	83%	88%	93%	97%	99%	100%	100%	97%	94%	90%	85%	79%	73%	66%
15	75%	78%	82%	85%	88%	91%	93%	94%	95%	94%	93%	91%	89%	86%	82%	79%	76%
0	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%

in:posse

Running Test Fits

Do we need access ways? Perimeter Space?



Budget Reconciliation

- Using Design/Build to manage costs
- Premiums for Net-Zero
- Premiums for demonstrating technology

Cost Breakdown

Description	**50% DD Design**	**100% CD Bid**
General Conditions	321,100	321,000
Foundations	535,851	316,800
Structure	483,500	463,000
Horizontal Envelope	592,389	156,000
Vertical Envelope	1,331,810	965,629
Finishes	337,939	430,165
Plumbing	158,000	131,000
HVAC & Controls	439,698	386,000
Electrical & Solar	783,800	673,600
Subtotal	**4,984,087**	**3,843,194**
Permit	15,000	10,000
PreConstruction	23,500	20,500
Contingency	200,891	0
Contractor's Fee, Insurance	288,019	293,583
TOTAL	**5,511,497**	**4,167,277**

Summary of Net Zero Strategies

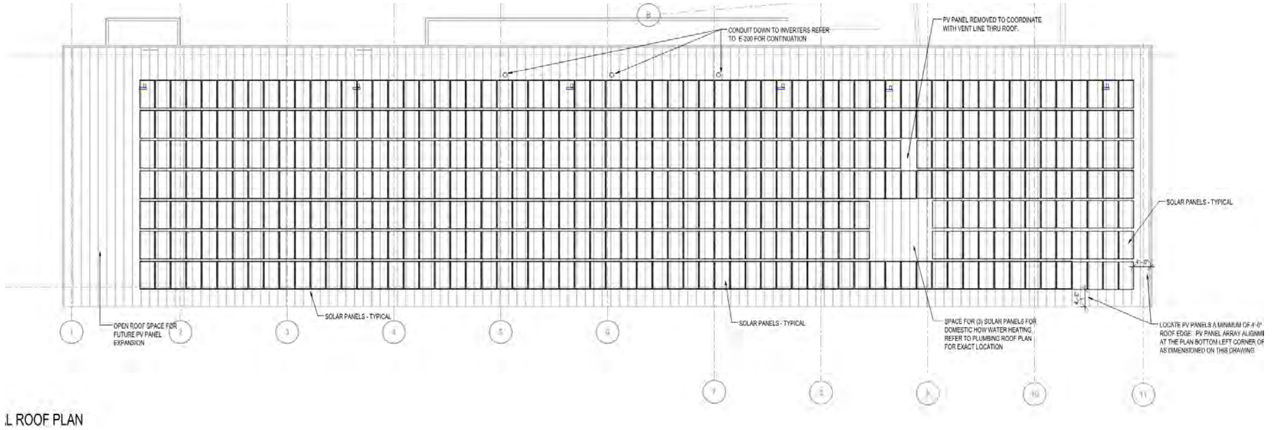
- Solar/PV
- Insulation at Roof and Slab
- Reduced Air Leakage
- Fiberglass Windows
- Roof Slope
- Roof Eave Overhangs
- VRF System

NZE Cost: $395,000
9% of building cost

Solar/PV System

Goal: Produce more energy than building consumes with 30% contingency

Strategy: Use roof mounted PV array



Premium Cost: $277,000

Cost/SF: $18.47

% Cost: 6.65%

Insulation - Roof

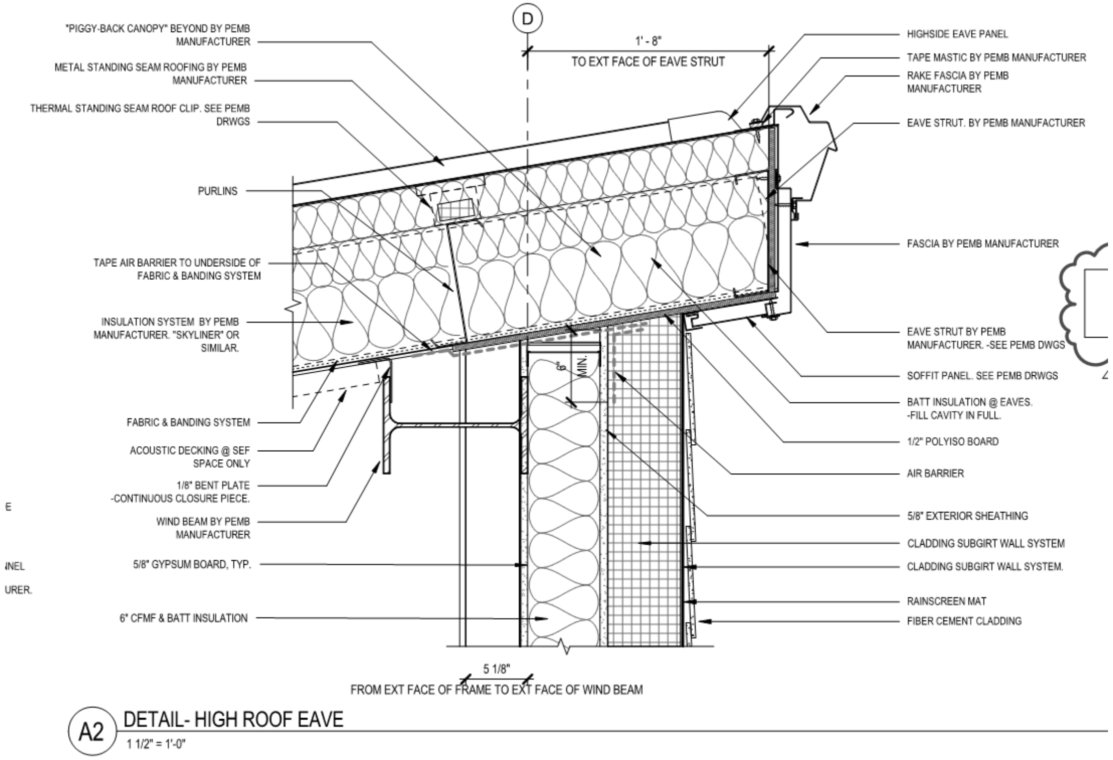
Goal: Increase insulation in roof over code

Strategy: Use a 3 layer, R-49 system by PEMB

Premium Cost: $11,900

Cost/SF: $0.80/SF

% Cost: .29%



Insulation – Floors

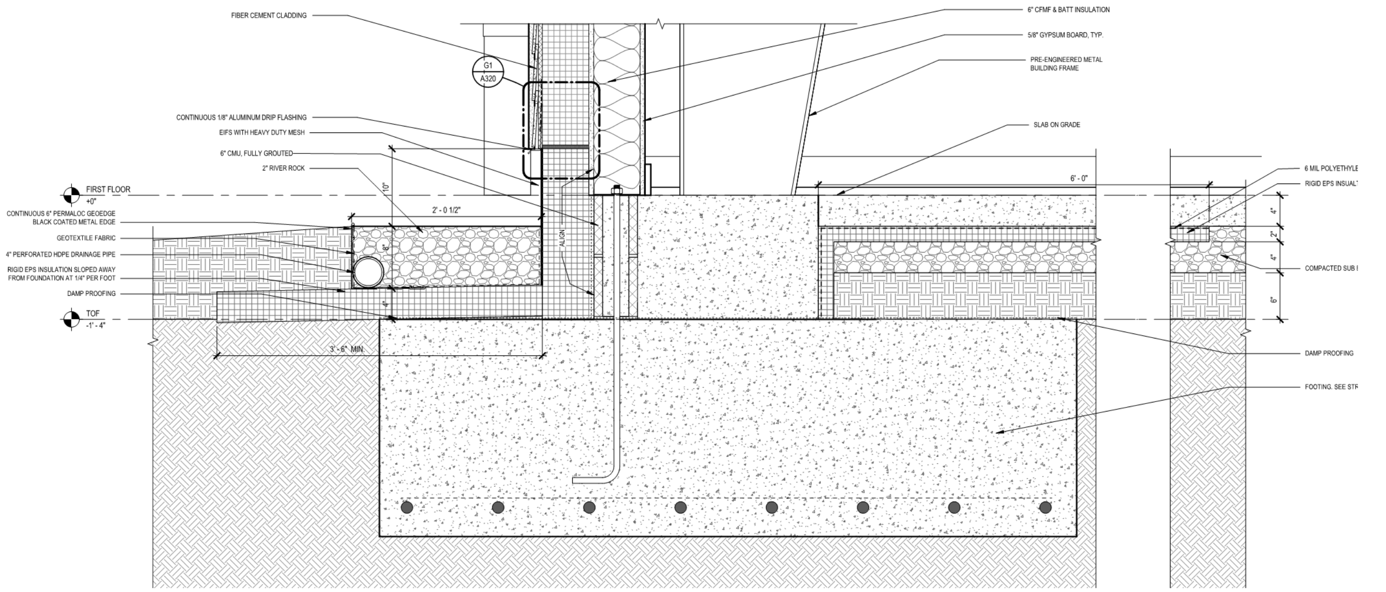
Goal: Increase insulation in floor

Strategy: Floors – Used 2” rigid insulation at 6’ around perimeter as well as a skirt of 6” vertical and 4” horizontal

Premium Cost: $10,000

Cost/SF: $0.67/SF

% Cost: .25%



A5 FOUNDATION PIER SECTION
1 1/2" = 1'-0"

Reduced Air Leakage

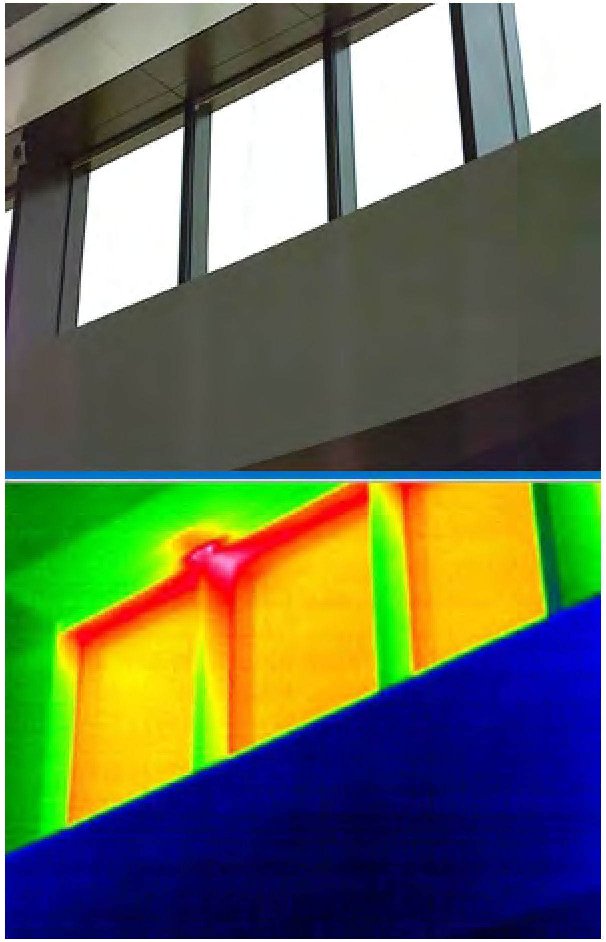
Goal: Decrease air leakage

Strategy: Establish and test for air leakage rate of .08 cfm/sf

Premium Cost: $25,000 (TBD)

Cost/SF: $1.67/SF

% Cost: .60%



Fiberglass Windows

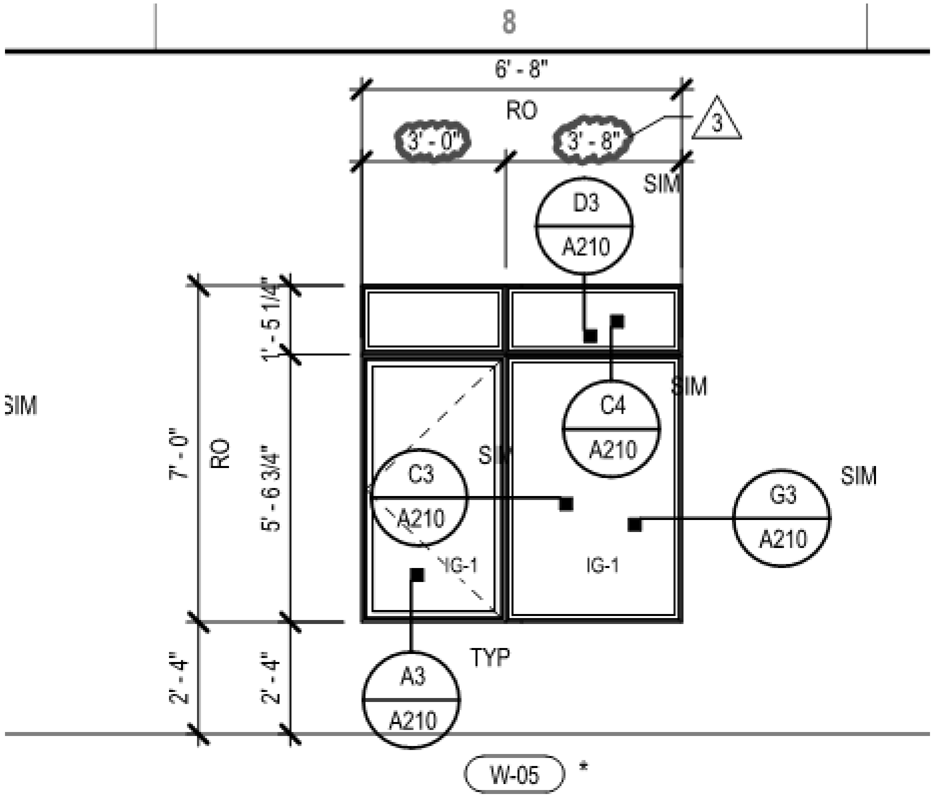
Goal: Combine economy with thermal break properties; ability to provide fresh air in swing seasons

Strategy: Use economical, commercially available fiberglass frames with double pane, operable windows

Premium Cost: 0

Cost/SF: $0/SF

% Cost: 0%



Roof Slope

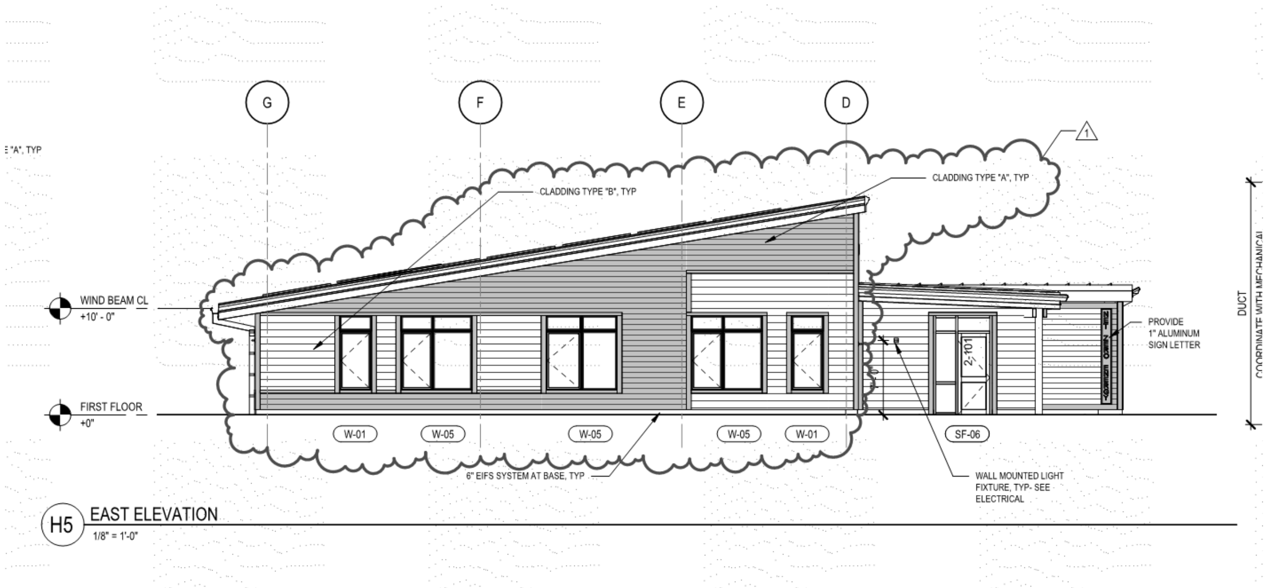
Goal: Provide south facing sloped roof for PV array

Strategy: Used roof slope of 2:12

Premium Cost: $72,300/inch of roof slope

Cost/SF: $4.82/SF/inch of roof slope

% Cost: 1.74%/inch of roof slope



Roof Eave Overhangs

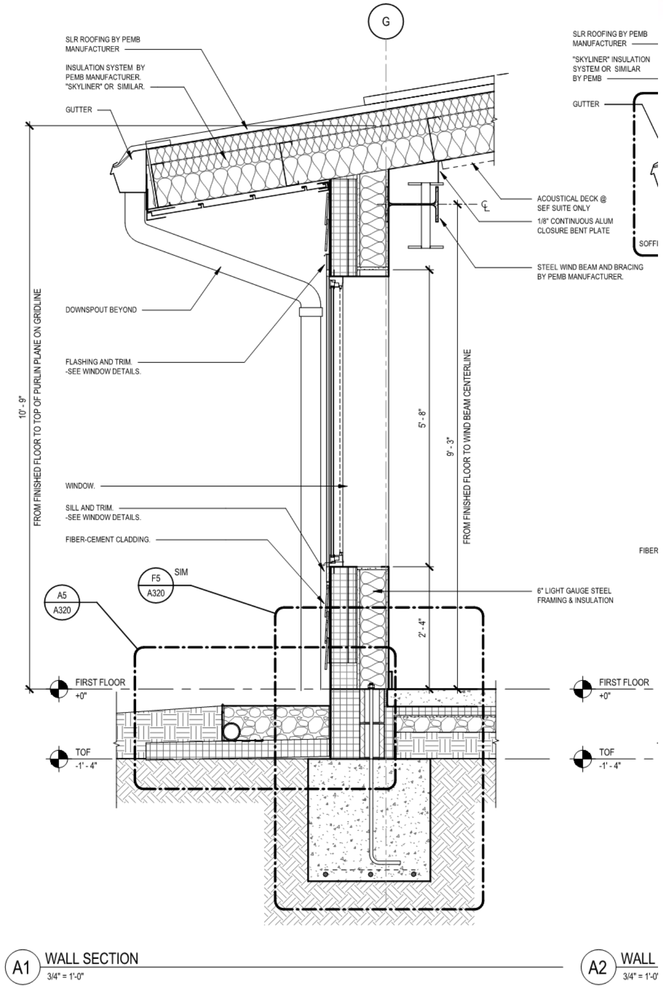
Goal: Minimize overhangs while protecting south facing openings from solar heat gain

Strategy: Use 3’ overhangs on south facing windows

Premium Cost: $14,125 ($28.25/SF of overhang)

Cost/SF: $.94/SF

% Cost: .34%



VRF System

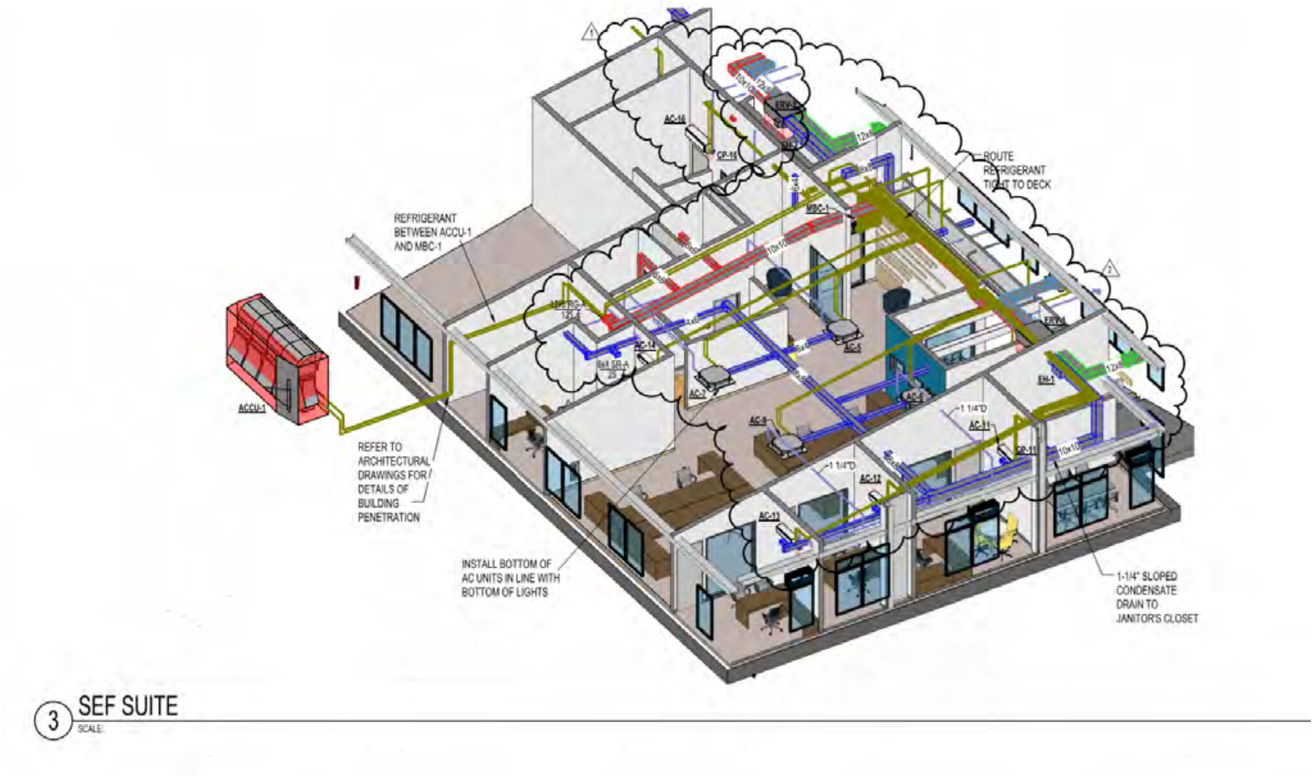
Goal: Minimize energy use

Strategy: Use VRF system

Premium Cost: $56,500

Cost/SF: $3.77

% Cost: 1.36%



Demonstrating Sustainable Tech

- Super-Insulated Walls
- Clerestory
- Solar Hot Water
- Control System
- Window Contacts
- Lighting Controls

Demonstration Cost: $395,000
11.3% of building cost

Insulation - Walls

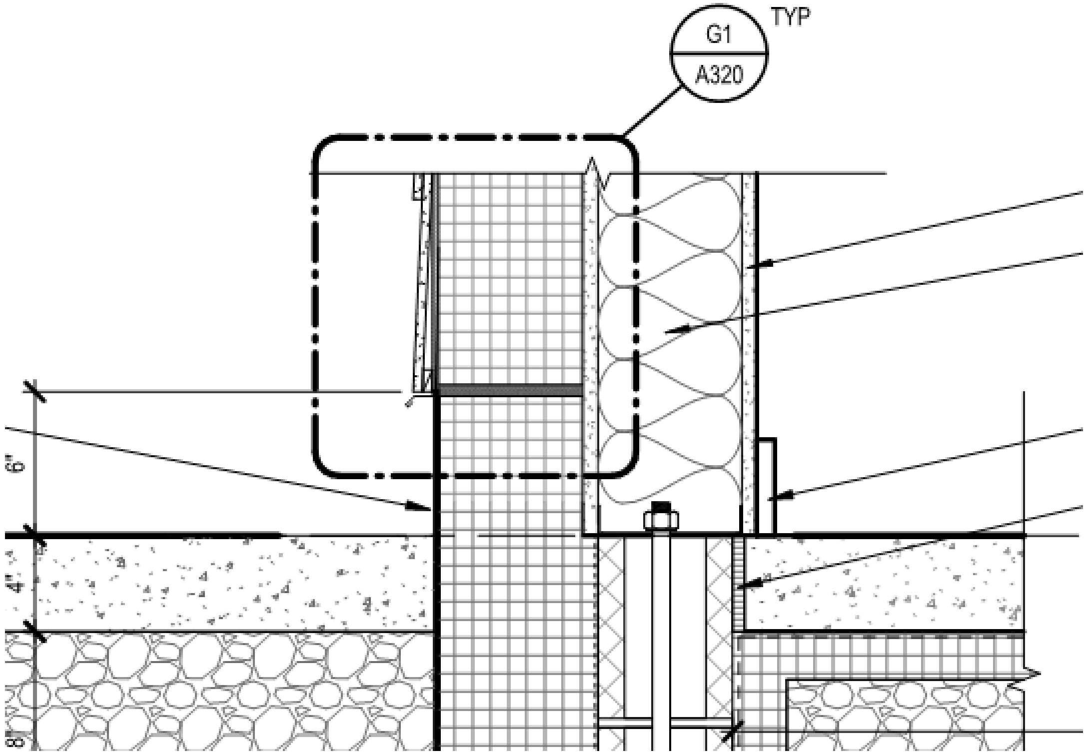
Goal: Increase insulation in walls over code

Strategy: Use 6” batt insulation plus 6” continuous rigid insulation on green girt system

Premium Cost: $26,500

Cost/SF: $1.76/SF

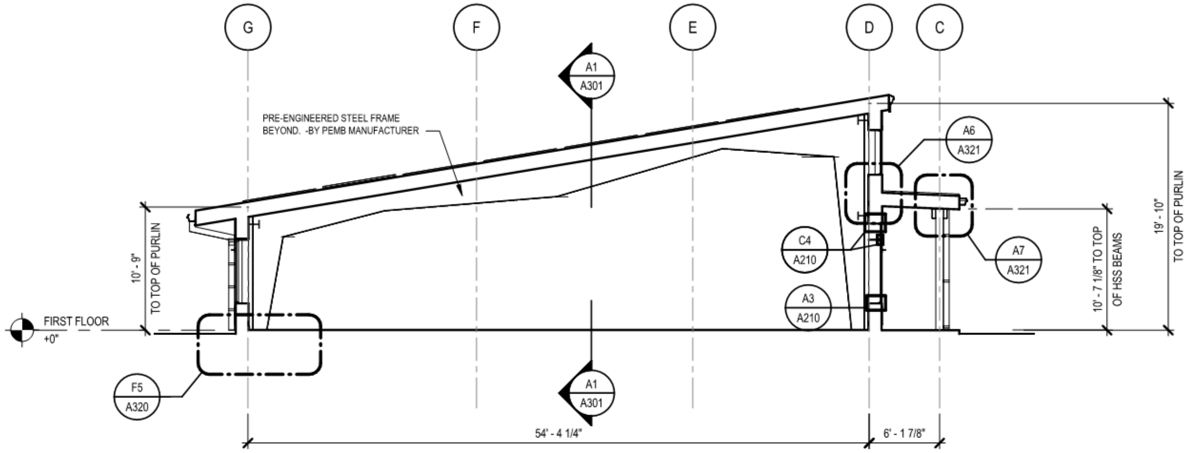
% Cost: .64%



Clerestory

Goal: Introduce natural light into space and create more pleasant work environment

Strategy: Design a single sloping roof with upper level windows on north side of building



D6 BUILDING SECTION THRU TENANT SPACE
1/8" = 1'-0"

Premium Cost: $375,000

Cost/SF: $25/SF

% Cost: 9%

Solar Hot Water Heating System

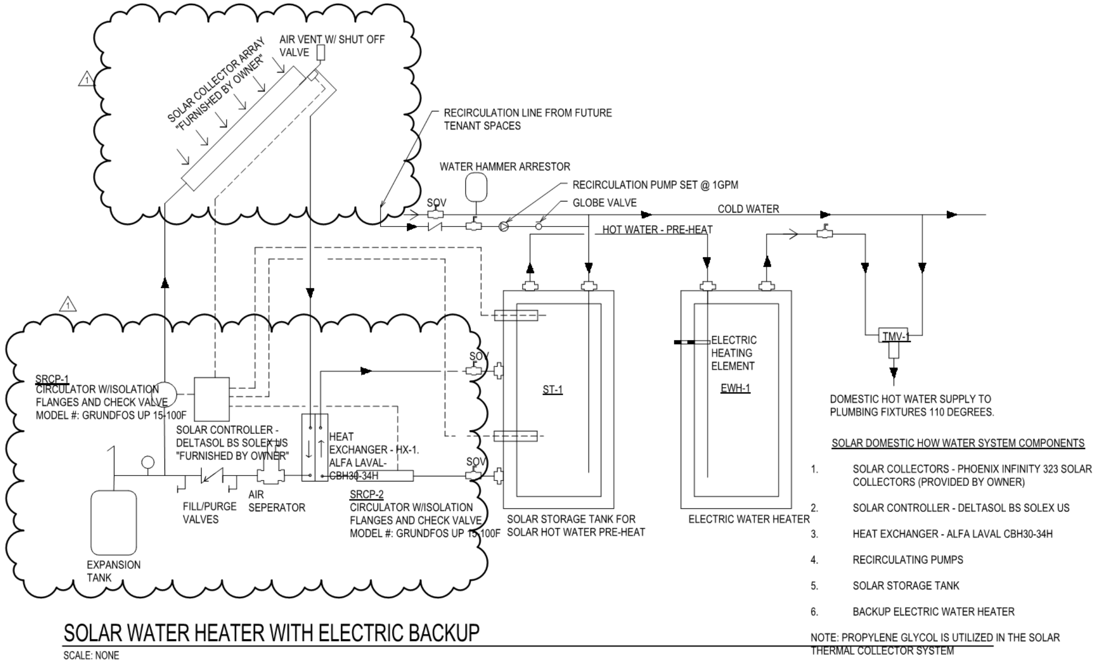
Goal: Minimize energy use

Strategy: Use solar hot water heating system

Premium Cost: $10,700 + owner supplied panels

Cost/SF: $.71/SF+

% Cost: .26%+



Building Controls

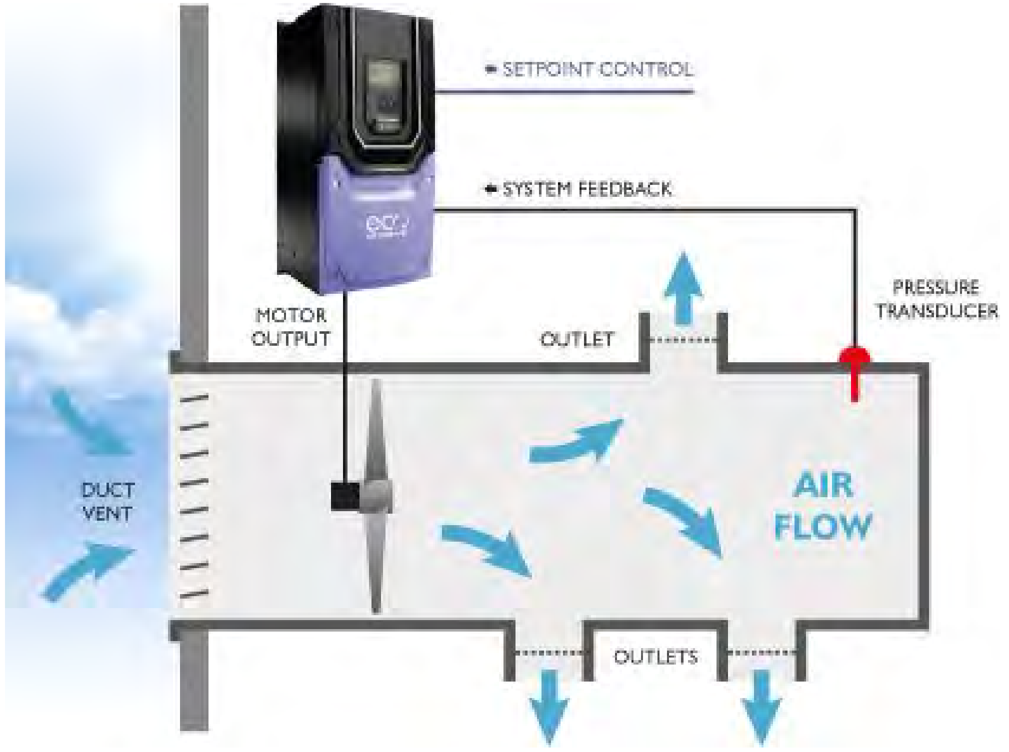
Goal: Minimize energy use

Strategy: Use building automated controls system

Premium Cost: $40,000

Cost/SF: $2.67/SF

% Cost: 1%



Window Contacts

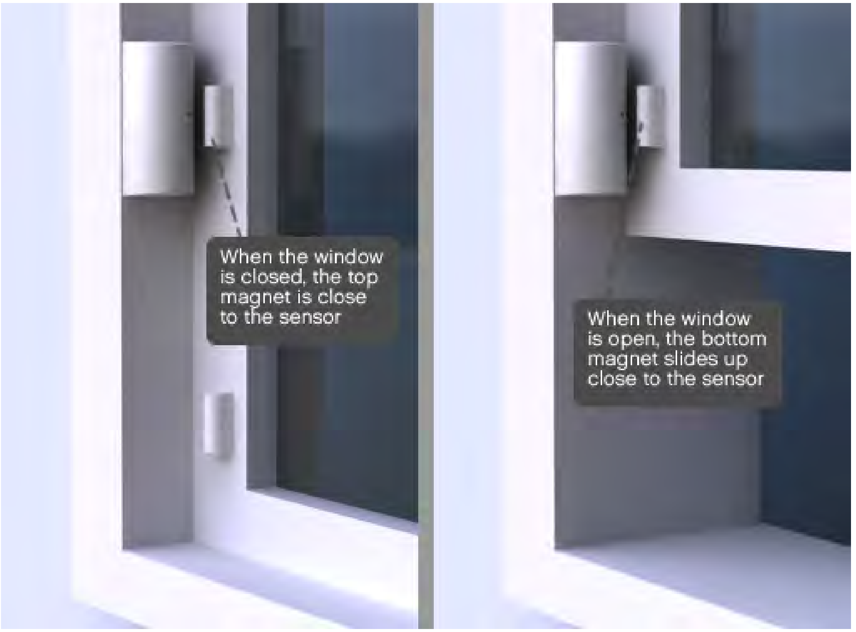
Goal: Minimize energy use when windows are open

Strategy: Provide contacts on each operable window tied to BAS system

Premium Cost: $7,400

Cost/SF: $.49/SF

% Cost: .18%



Lighting Control System

Goal: Minimize energy use

Strategy: Use lighting control system

Premium Cost: $30,000

Cost/SF: $2.00

% Cost: .72%

Does this project prove
the commercial viability of
Net-Zero Energy?

Lessons Learned

What went well?

What could have been done different or better?

SEF NZE
Office Building

Combining Technology, Beauty and Meaning in the New Sustainable Energy Fund

ASHLEY MCGRAW

Sustainable Energy Fund