BUILDINGENERGY BOSTON

Advancing All-Wood Design and Carbon Storage in the Built Environment

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Northeast Sustainable Energy Association (NESEA)
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BuildingEnergy Boston 2022 - NESEA

Addison Godine subbing in for Matt O'Malia
OPAL Build

OPAL
OPAL / BUILD
TIMBERHP

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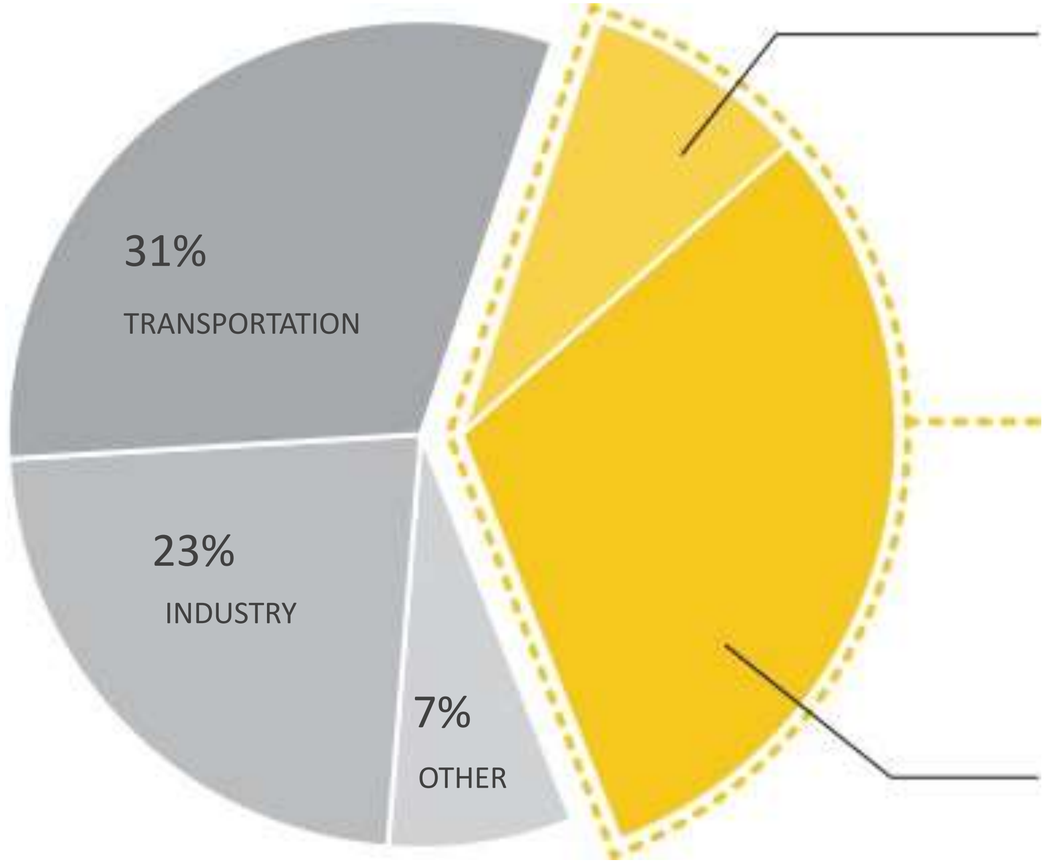
1. The problem:

Embodied Carbon

Built Environment and Energy Consumption

(CO_2e emissions)



8.2%
THE IMPACT FROM MATERIALS & CONSTRUCTION
(EMBODIED ENERGY)

39%
BUILDINGS

30.8%
THE IMPACT OF BUILDING OPERATIONS
(OPERATIONAL ENERGY)

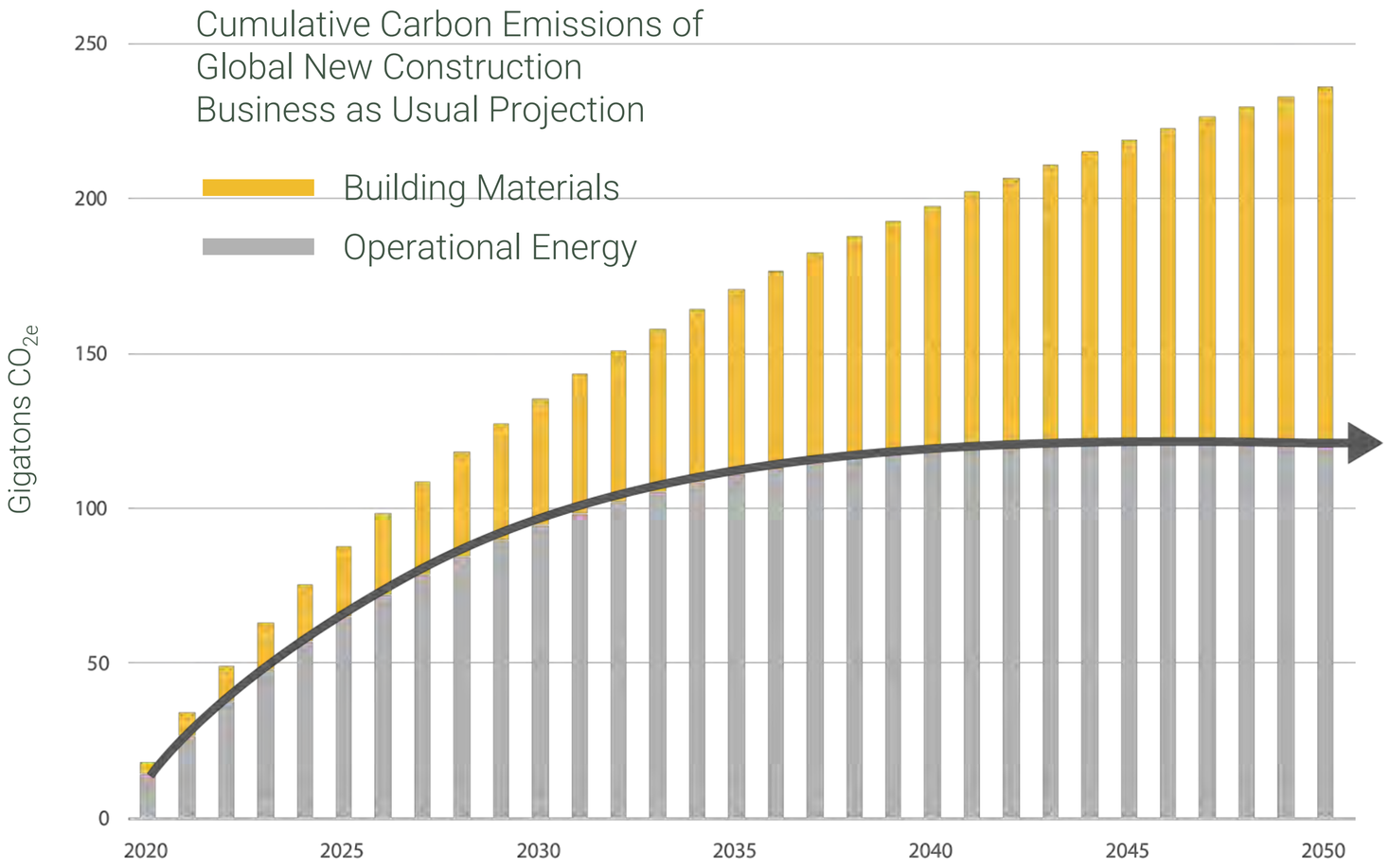
The construction and operation of buildings in the United States alone is responsible for almost

2 Gigatons CO_2e emissions annually.

The prescription for dramatically reducing that impact is well understood and immediately technologically achievable.

Source: Global Alliance for Building and Construction, *Global Status Report*, 2019; US EIA, *EIA International Energy Outlook 2017*, 2017.

Embodied Carbon is increasingly significant



Source: AIA 2030

By 2050, it is projected that embodied carbon will take up almost half the total carbon emissions from new construction.

Energy Retrofit Programs

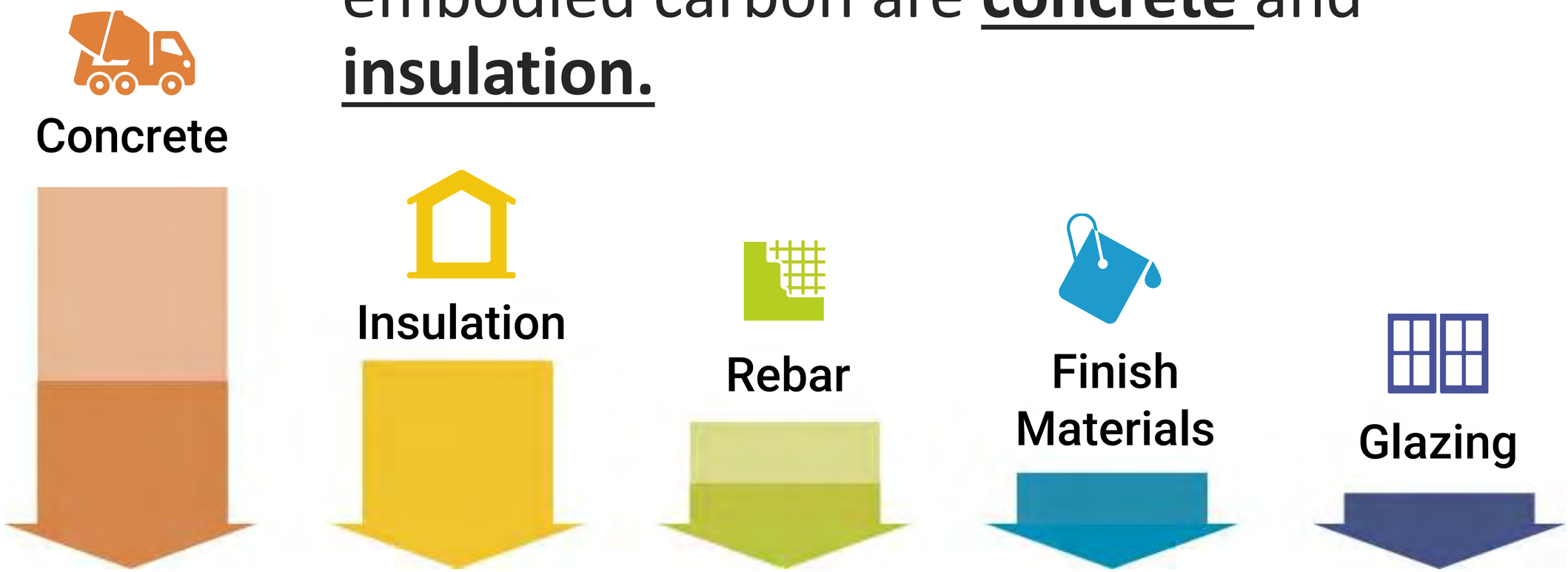
+

Renewable Energy

↓

Reduced Operational CO_{2e}

The greatest opportunities for reducing embodied carbon are **concrete** and **insulation.**



TOP BUILDING MATERIAL CATEGORIES FOR **REDUCING EMBODIED CARBON**

Source: RMI

The insulation market is dominated by fossil-fuel dependent products with devastating environmental impacts

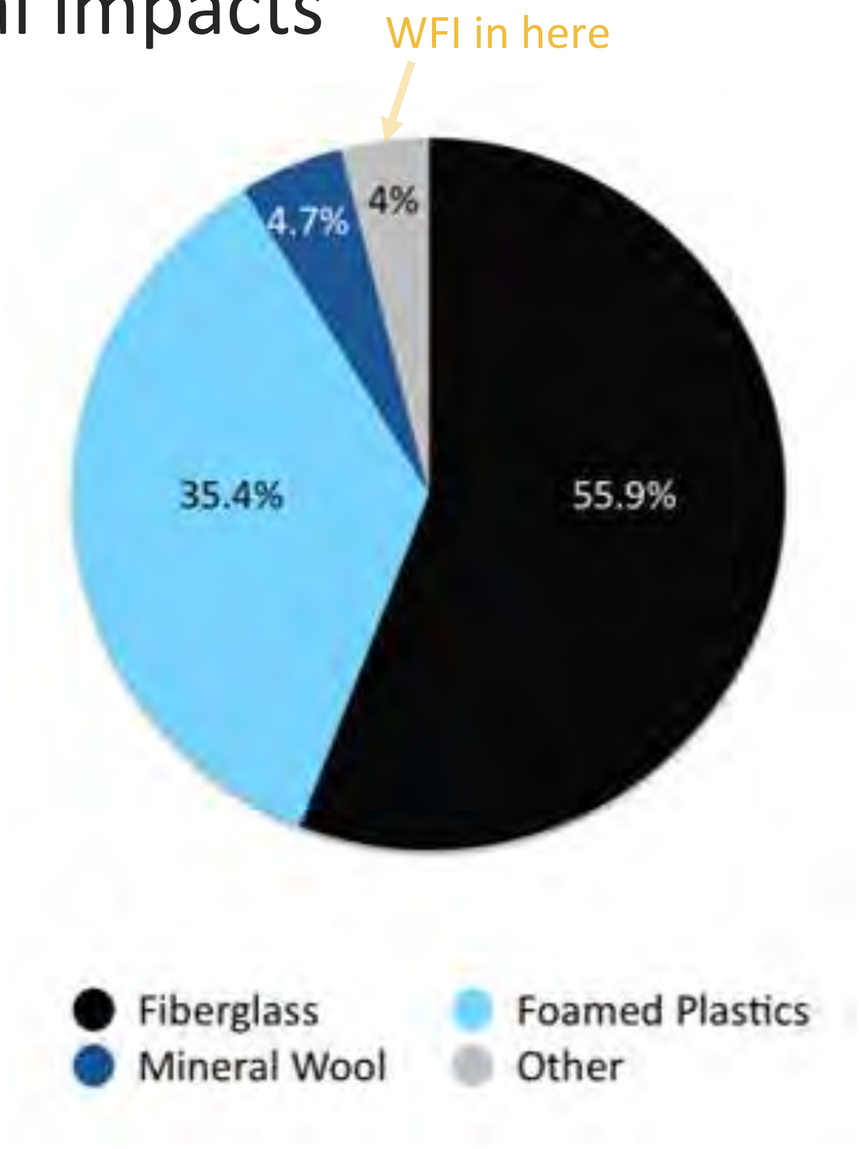
High Embodied Carbon
Global Warming Potential

Vapor closed, traps moisture
Leading to mold and mildew, health risks, and rot

Non-recyclable
Monstrous hybrid / chemistry / cost realities

Off-gassing
Affects indoor air quality

Highly flammable
Fiberglass and foam insulation are fire accelerants

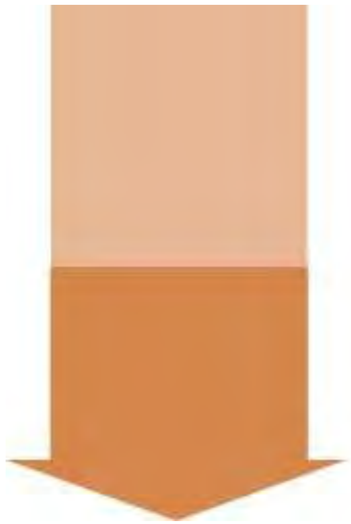


2. A Solution:

Wood-Insulated Panels (WIPs)

A structural / thermal / moisture enclosure solution system

Concrete



14%-33% reduction
None to low cost premium

Replace w/CLT

Insulation

16% reduction
No cost premium

Replace w/WFI

Wood fiber insulation made in America

Carbon Storing
Made from carbon-storing softwood

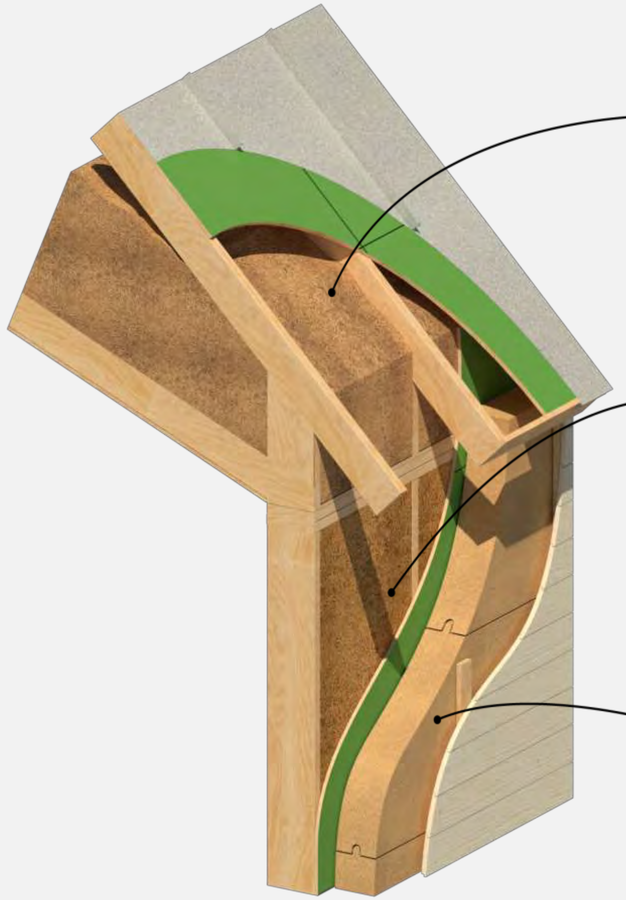
High Performance
Manages air, moisture, conductivity, and sound

Highly Recyclable
In-factory offcuts go back in the “hopper”

Nontoxic, Safe
Sawdust when you cut it; healthy indoors

Class A/B Flame Spread
Offers a high degree of fire protection

TIMBERHP



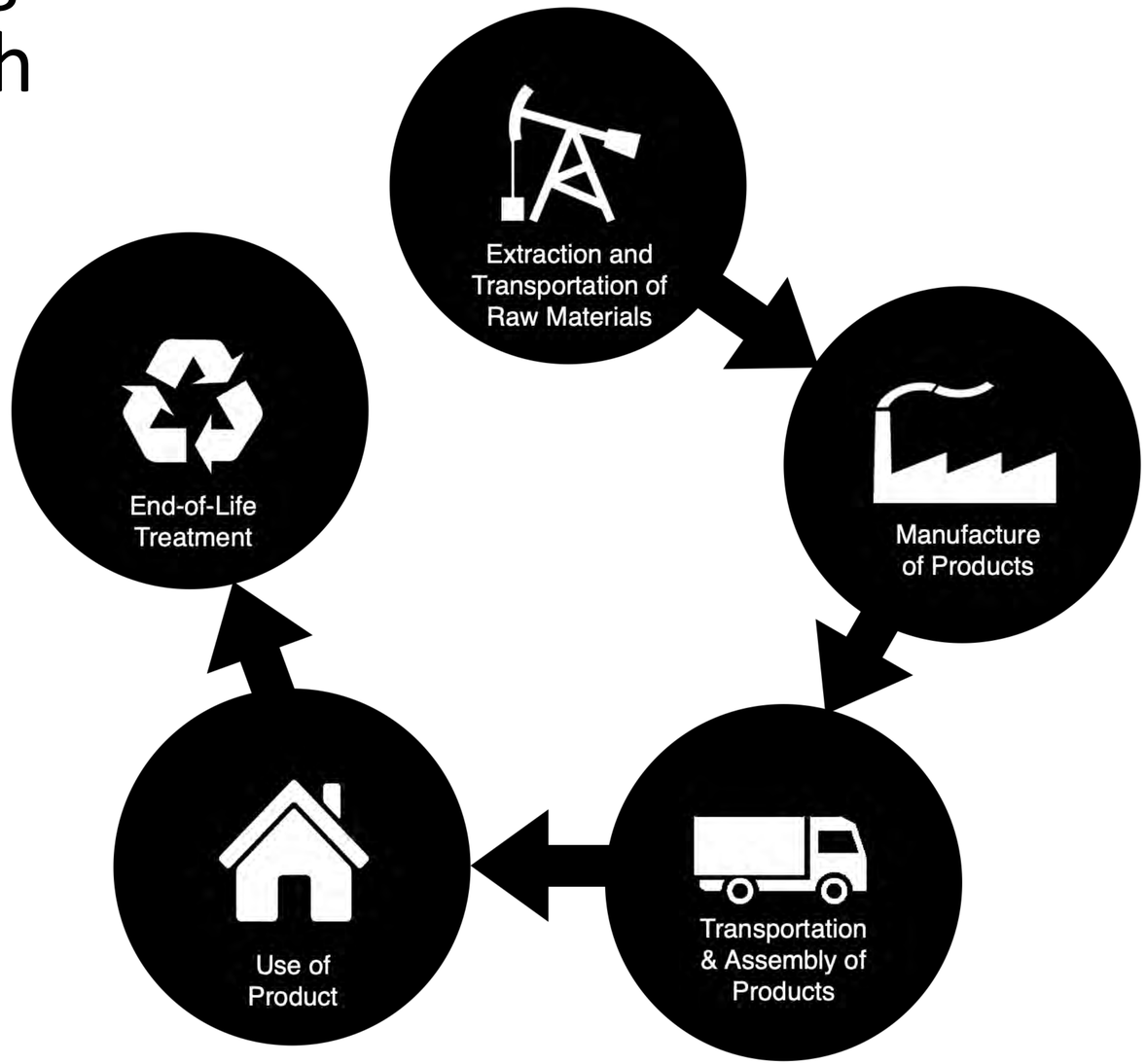
TimberFill
loose fill and dense pack insulation for attics and stud cavities

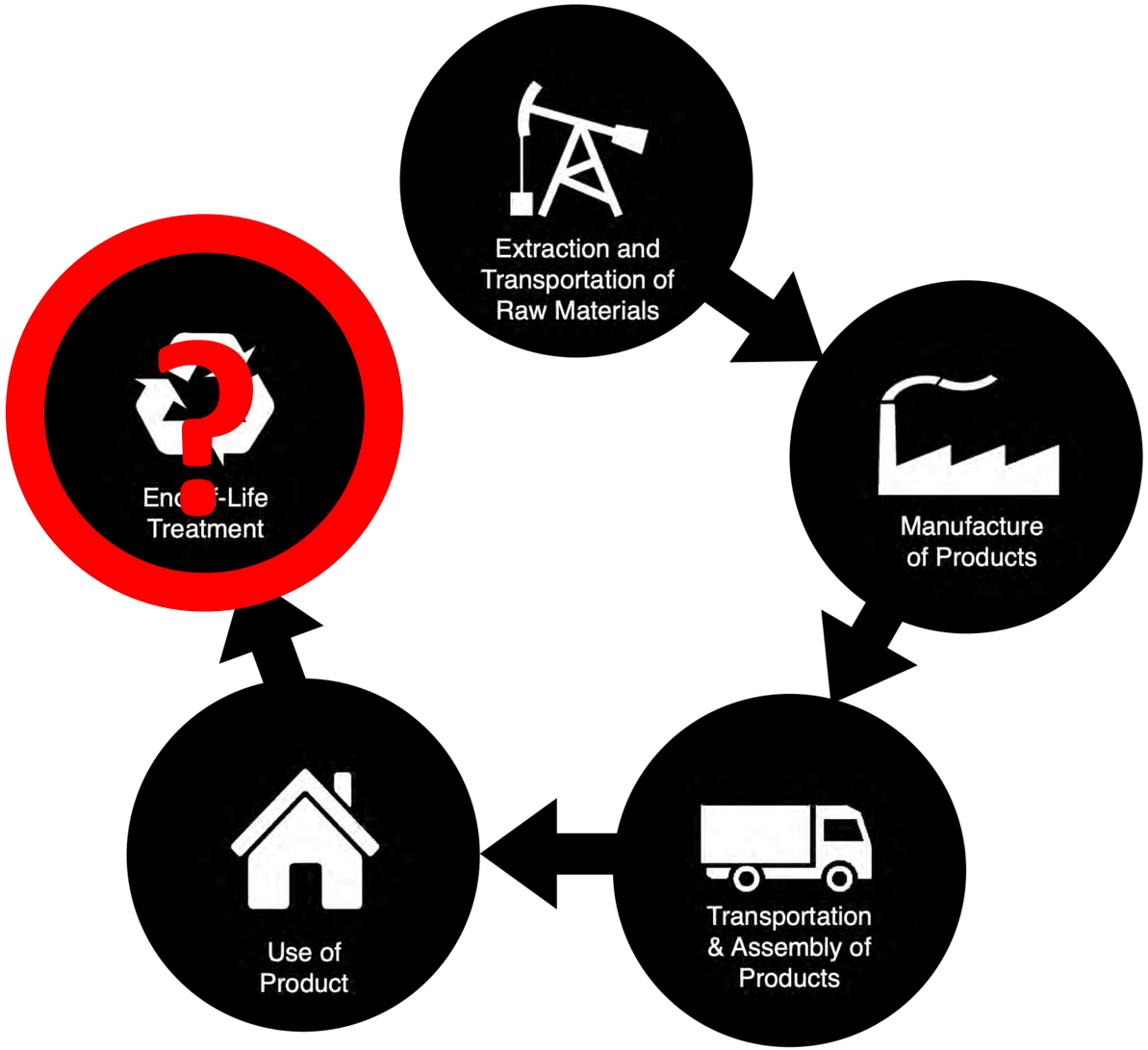
TimberBatt
wall cavities, ceiling joists, rafters, attics, demising walls

TimberBoard
continuous interior and exterior, above-grade insulation

Embodied Carbon from Building Materials are measured through a scientific modeling tool called Life Cycle Assessment (LCA)

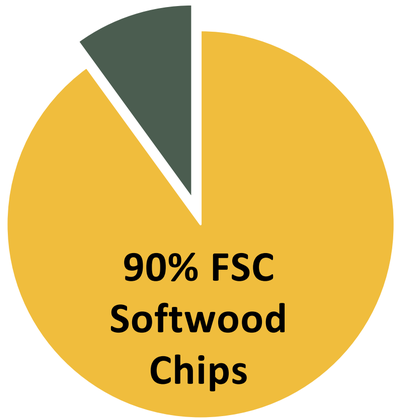
The Cradle-to-Grave LCA technique quantifies a building material's carbon footprint through the following life stages:




Extraction and
Transportation of
Raw Materials
Manufacture
of Products
Transportation
& Assembly of
Products
Use of
Product
End-of-Life
Treatment

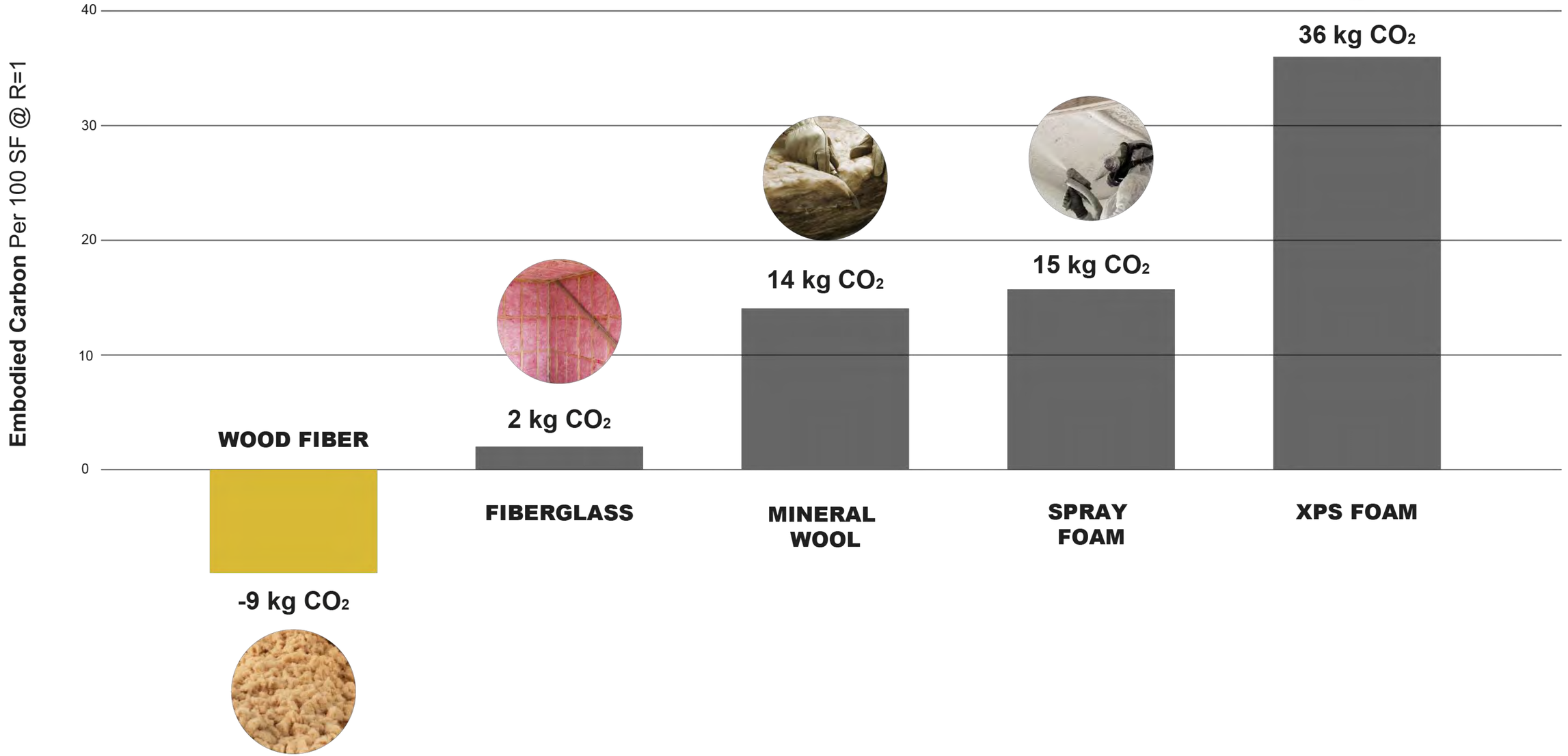
Insulation products made from wood fiber are a superior climate-friendly alternative to conventional insulation.

- **Carbon Sequestering — only scalable construction insulation with the potential to address both operational and embodied carbon**
- **Renewable/ Sustainable — All products made from >90% Forest Stewardship Council softwood chips**
- **Recyclable — Post construction and demolition waste can be fed back into the process to make new product**
- **Nontoxic — Urea formaldehyde free**

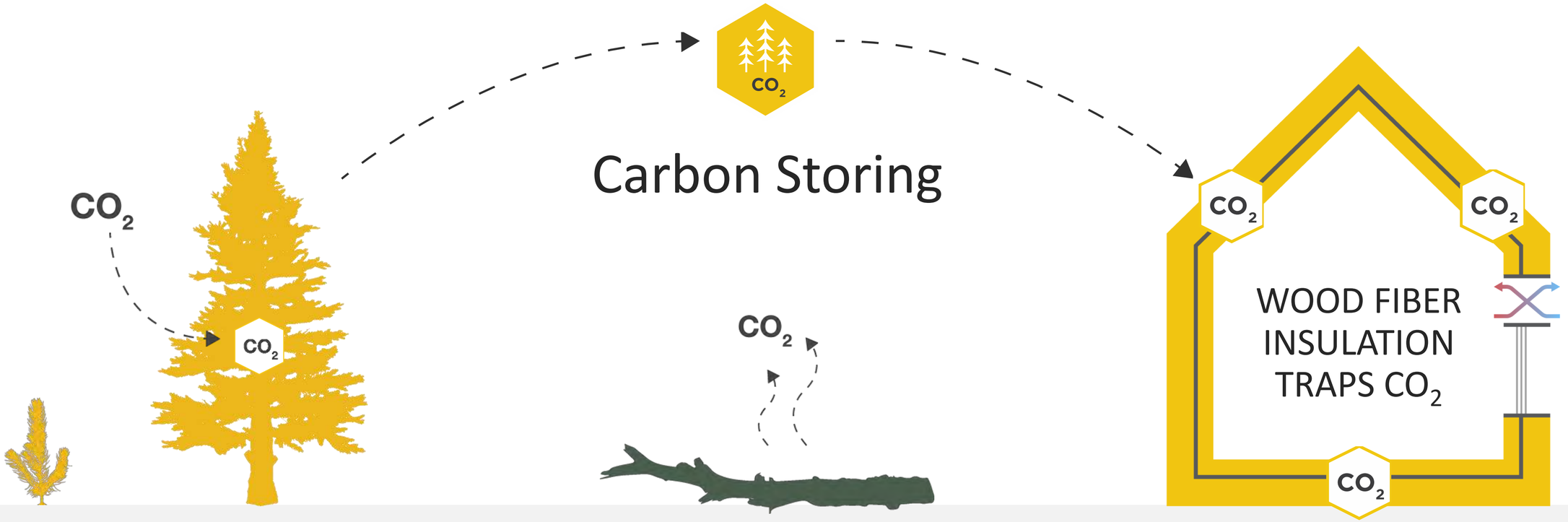


Source: IAL Consultants, Gupta-Verlag

Comparison to other insulation products:



Solution : Carbon storing wood products used in construction yield a net benefit to the atmosphere



Atmospheric carbon dioxide is taken up by trees and, through photosynthesis, stored as carbon in biomass

At the end of the tree's life, when left to decay, this stored carbon returns to the atmosphere slowly

Harvesting trees as the source material for building products can delay the release of that carbon for the life of the building and potentially far longer

Wood Fiber Insulation utilizes an existing waste stream as its primary feedstock

Made from clean, species-agnostic, softwood residuals; insulating wood fiber composites are a perfect fit for the United States' wood products manufacturing sector

LUMBER IS MILLED FROM LOGS

THE WASTE CHIPS ARE RECOVERED

FINELY GROUND

AND FORMED INTO INSULATION

European wood fiber insulation market shows product potential in North America

- 15 manufacturing facilities in Europe
- Estimated $700 million (~5% of total insulation market) for all three products (board, batt and loose fill)
- Currently, European market is oversold and cannot meet demand
- All manufacturers have projects underway to increase production to meet European demand.
- Gutex, Steico, and Schneider are all building additional facilities to meet European demand

EUROPEAN SUPPLIERS OF WOOD FIBER INSULATION:

STEICO natürlich besser dämmen

GUTEX® DÄMMPLATTEN AUS SCHWARZWALDHOLZ

pavatex by SOPREMA

best wood® SCHNEIDER

UNGER DIFFUTHERM® Umweltfreundliche innovative Dämmsysteme

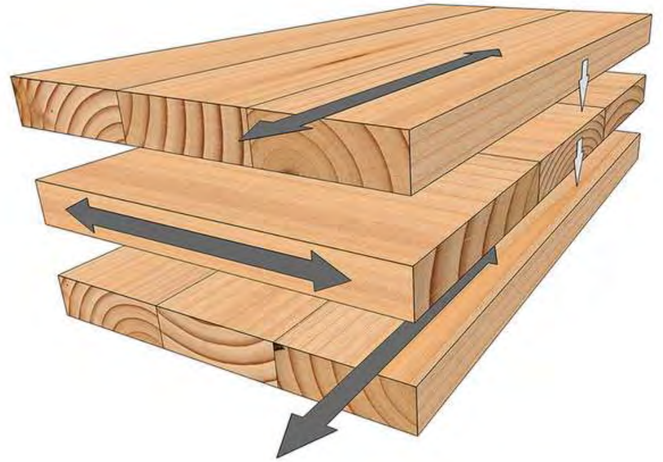
INTHERMO Meine natürliche Dämmung!

AGEPAN® SYSTEM

Freight costs combined with high production costs limit the sale of European wood fiber insulation in North America to select projects only where price is not a factor.

+ CLT

- IBC-approved up to 18 stories
- NYC-approved up to 6 stories / 85ft
- Stores 590.97 kg CO_2 eg/ 1 m^3
- 130 kg CO_2 eg / 100 board feet
- 1.3 kg CO_2 eg/ board foot
- Made from southern yellow pine, black spruce, doug fir, and other softwoods
- Able to be made from young, small-diameter trees
- Trees store most of their carbon in the first 5-10 years



+ High-performance windows & doors

UPVC Windows

Aluminum Windows

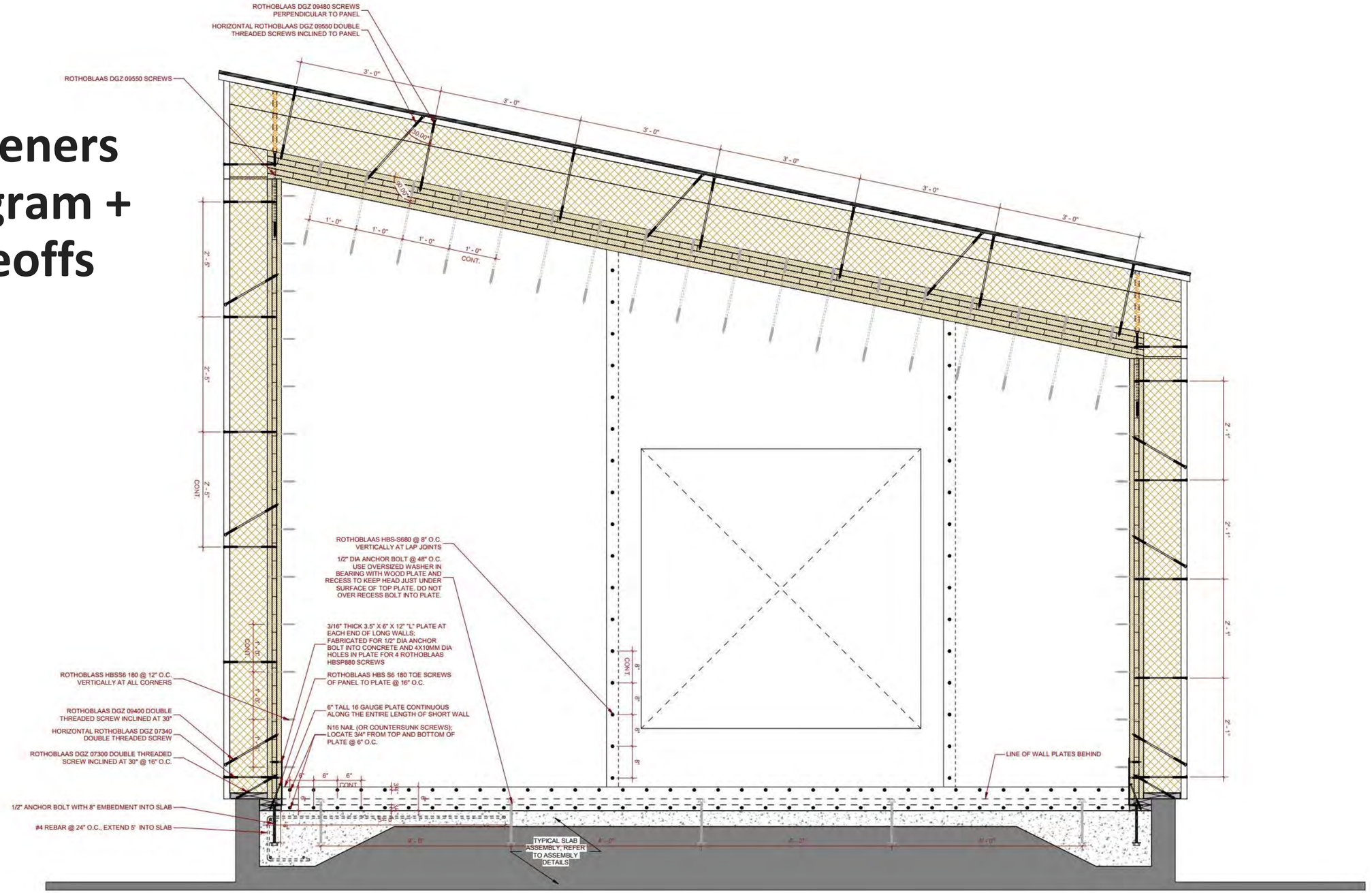
Aluminum swing door

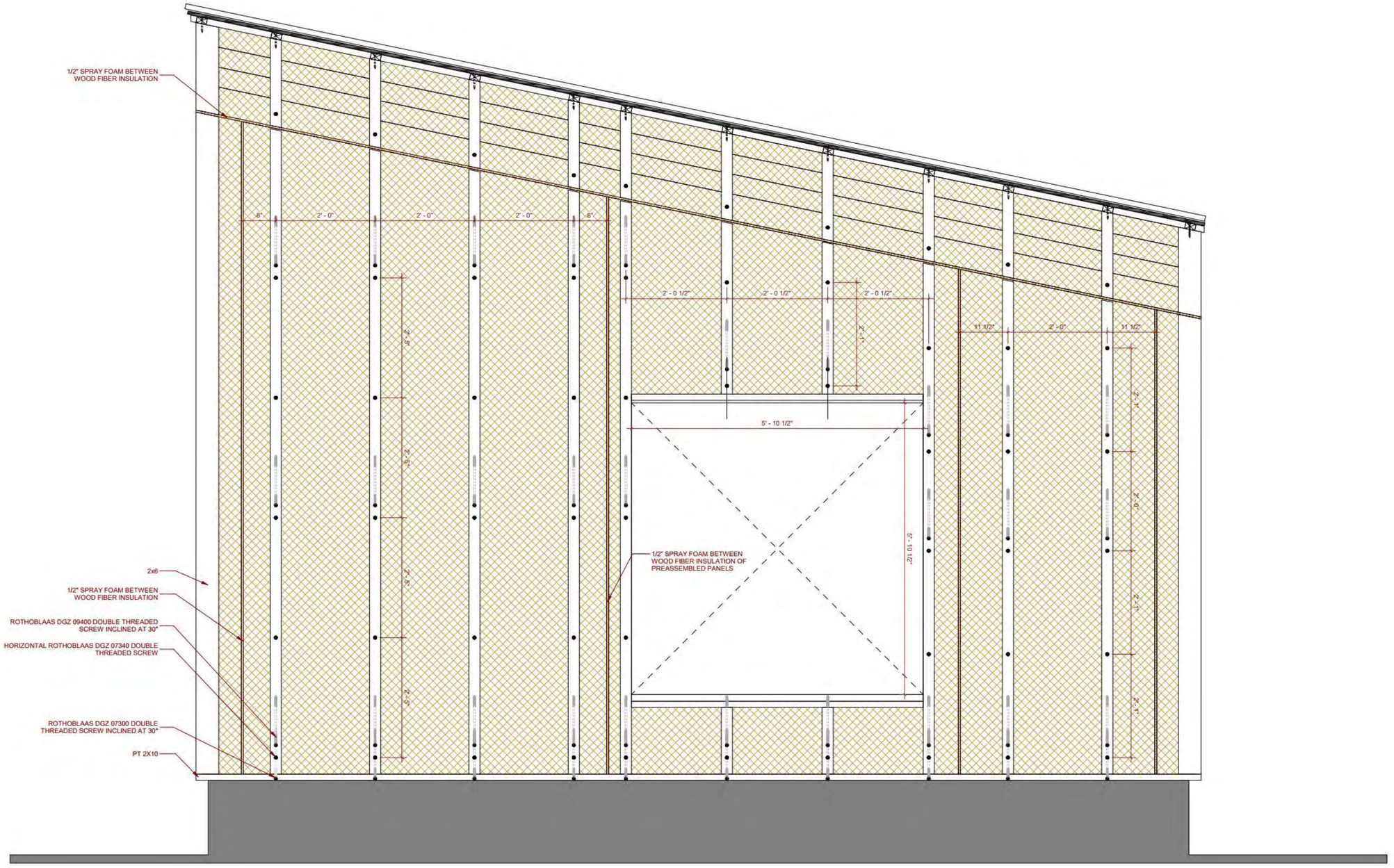
Aluminum sliding door

3. Pilot Project:

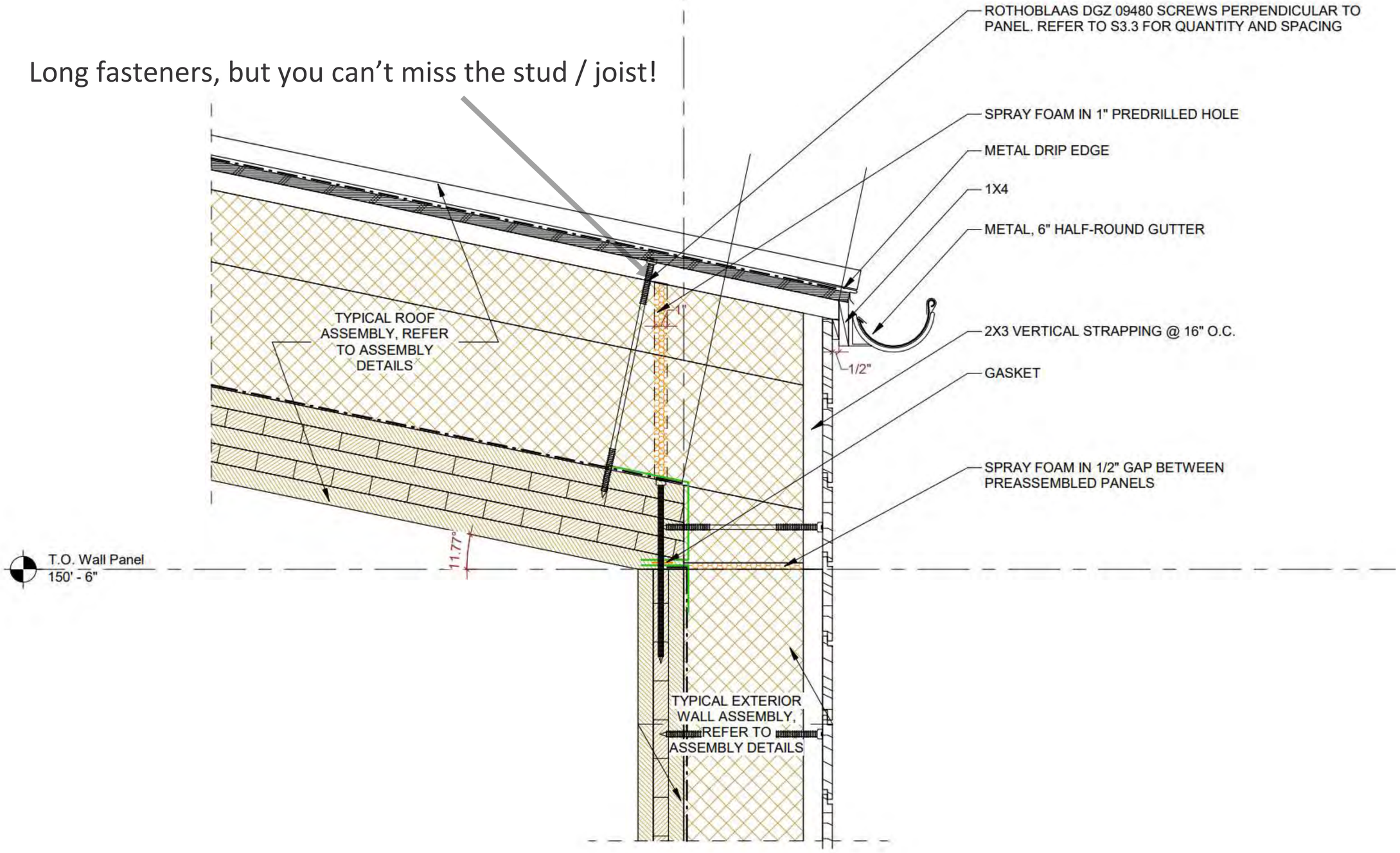
A School Building in Maine

Fasteners Diagram + Takeoffs



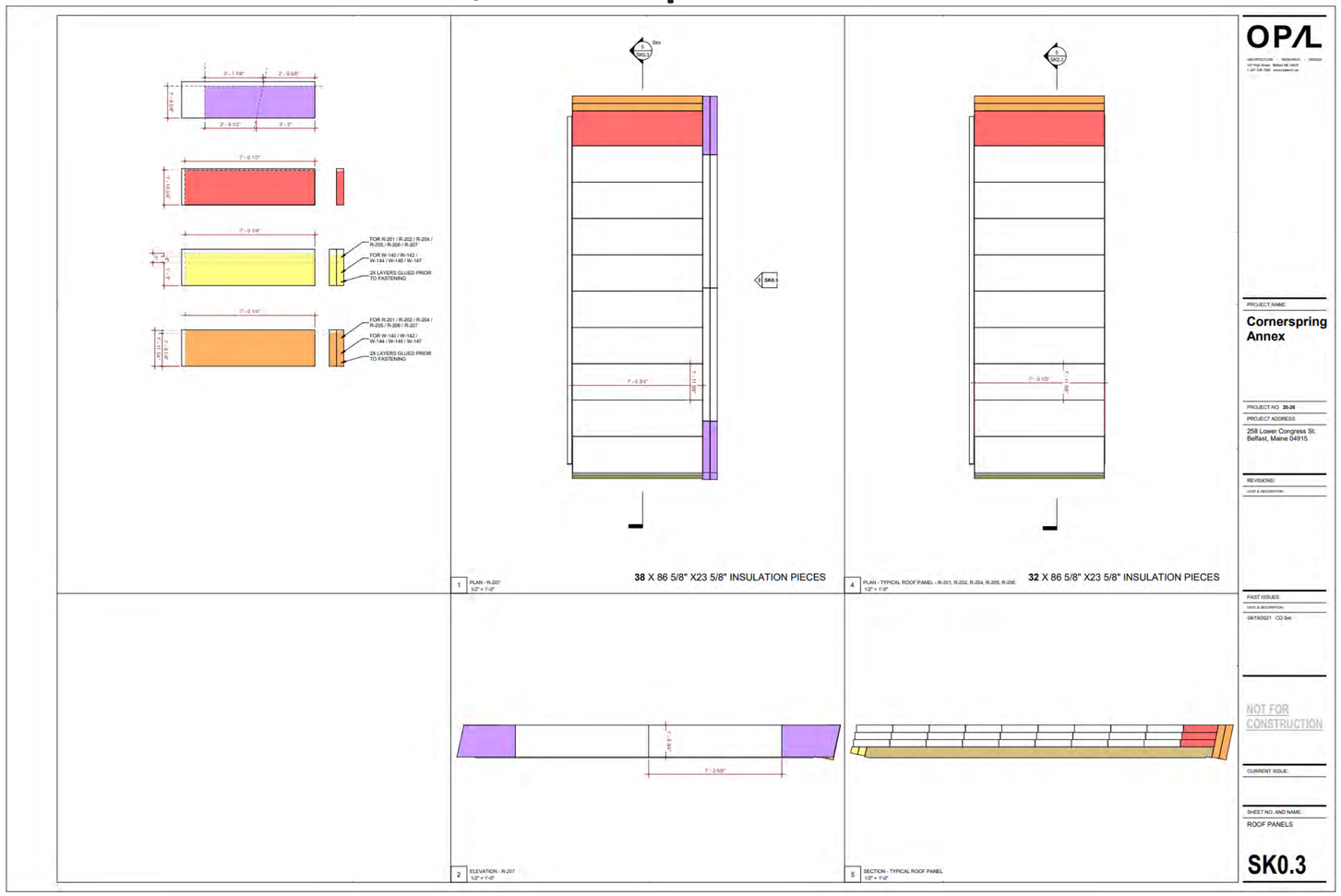

1/2" SPRAY FOAM BETWEEN WOOD FIBER INSULATION
8"
2' - 0"
2' - 0"
2' - 0"
8"
2' - 0 1/2"
2' - 0 1/2"
2' - 0 1/2"
11 1/2"
2' - 0"
11 1/2"
5' - 10 1/2"
9' - 10 1/2"
1/2" SPRAY FOAM BETWEEN WOOD FIBER INSULATION OF PREASSEMBLED PANELS
2x6
1/2" SPRAY FOAM BETWEEN WOOD FIBER INSULATION
ROTHOBLAAS DGZ 09400 DOUBLE THREADED SCREW INCLINED AT 30°
HORIZONTAL ROTHOBLAAS DGZ 07340 DOUBLE THREADED SCREW
ROTHOBLAAS DGZ 07300 DOUBLE THREADED SCREW INCLINED AT 30°
PT 2X10

Long fasteners, but you can’t miss the stud / joist!



Insulation cut & Fastener Lists

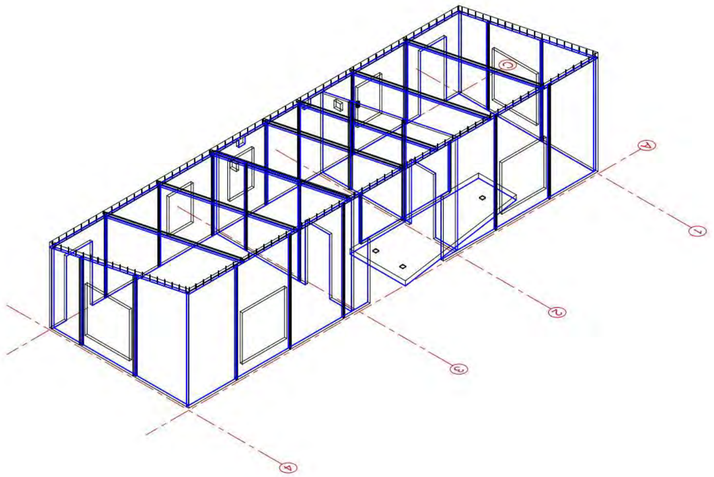
- In-housed
- Automation / CNC-potential

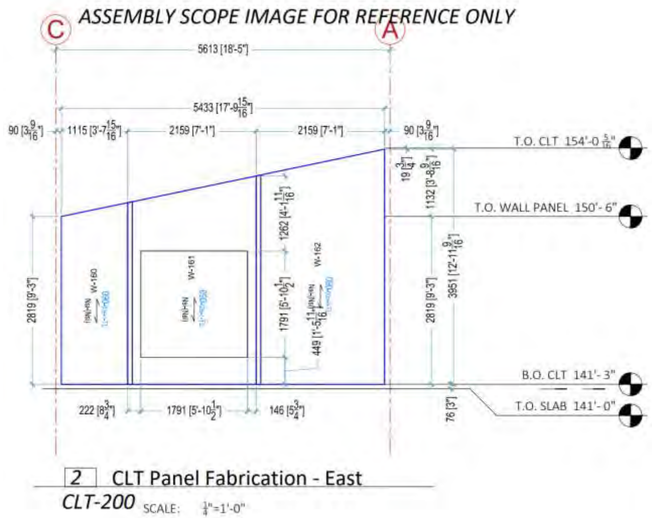


MODEL	MANUF	Q	USED FOR
HBS1080	Rothoblaas	150	Lifting uninsulated wall panels tabletop
HBS10100	Rothoblaas	150	Lifting uninsulated wall panels tabletop
HBS10360	Rothoblaas	100	Lifting insulated wall panels in tabletop
VGS11375	Rothoblaas	100	Lifting insulated wall panels in tabletop
VGS11275	Rothoblaas	75	Lifting insulated wall panels vertical
Assy Kombi 12x160	MTC Solutions	100	Lifting uninsulated roof panels
VGS11600	Rothoblaas	50	Lifting insulated roof panels
GRK R4 12 x 5 5/8"	GRK	100	Fastening CLT to PT shelves
VGZ9360	Rothoblaas	200	Roof to wall
TBS8360	Rothoblaas	50	Roof to wall for pulling connection tight
VGZ9400	Rothoblaas	25	Canopy Roof
VGZ11550	Rothoblaas	25	Canopy Roof
VGZ9260	Rothoblaas	15	Canopy Roof
HBS6180	Rothoblaas	350	Wall to wall (corners) + Int. wall to roof
HBS6160	Rothoblaas	200	Roof lap joint
HBS680	Rothoblaas	350	Wall lap joint
HBSP880	Rothoblaas	200	connecting bent plates + Hold down plate

CLT Shops

- Manuf-provided
- Data-rich
- 2 week process min.





2 CLT Panel Fabrication - East
CLT-200 SCALE: 1/4"=1'-0"

KLH USA Element List

Client Label *Label-Number KLH	Panel Type	Quantity [Panel]	Thickness [mm]	Length/Grain Direction [cm]	Width [cm]	Nett Weight [kg]	[Delivery]	Lifting Type
W-100	090-03s-1-TL-NSI-(NSI)	1	90	395.1	215.9	243	-	
W-101	090-03s-1-TL-NSI-(NSI)	1	90	397	221.1	342	-	
W-102	090-03s-1-TL-NSI-(NSI)	1	90	395.1	215.9	243	-	
W-103	090-03s-1-TL-NSI-(NSI)	1	90	397	105.6	148	-	
W-104	090-03s-1-TT-NSI-(NSI)	1	90	172.9	366.7	263	-	
W-105	090-03s-1-TL-NSI-(NSI)	1	90	351.7	223.5	300	-	
W-106	090-03s-1-TL-NSI-(NSI)	1	90	306.8	119.1	141	-	
W-107	090-03s-1-TL-NSI-(NSI)	1	90	351.7	223.5	300	-	
W-108	090-03s-1-TL-NSI-(NSI)	1	90	306.8	119.1	141	-	
W-109	090-03s-1-TL-NSI-(NSI)	1	90	397	223.5	227	-	
W-110	090-03s-1-TL-NSI-(NSI)	1	90	397	194.5	321	-	
W-120	090-03s-1-TL-NSI-(NSI)	1	90	395.1	215.9	335	-	
W-121	090-03s-1-TL-NSI-(NSI)	1	90	351.7	223.5	164	-	
W-122	090-03s-1-TL-NSI-(NSI)	1	90	306.8	119.1	144	-	
W-140	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	163	-	
W-141	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	200	-	
W-142	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	255	-	
W-143	090-03s-1-TL-NSI-(NSI)	1	90	281.9	139.7	158	-	
W-144	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	197	-	
W-145	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	200	-	
W-146	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	258	-	
W-147	090-03s-1-TL-NSI-(NSI)	1	90	281.9	223.5	163	-	
W-160	090-03s-1-TL-NSI-(NSI)	1	90	306.8	119.1	144	-	
W-161	090-03s-1-TL-NSI-(NSI)	1	90	351.7	223.5	164	-	
W-162	090-03s-1-TL-NSI-(NSI)	1	90	395.1	215.9	335	-	
W-180	090-03s-1-TL-NSI-(NSI)	1	90	397	202.1	333	-	
W-181	090-03s-1-TL-NSI-(NSI)	1	90	397	223.5	227	-	
W-182	090-03s-1-TL-NSI-(NSI)	1	90	397	223.5	363	-	
		28				6473		

2 CLT Wall Panel Schedule
CLT-300


WFI cut with Cable Saw
Future: CNC


WFI precut, labeled,
bundled by panel
FIRE EXTINGUISHER
C8
C11A
C11B
C11


60-ton bridge crane


20-ton load


CLT
SLED
40k lbs


Move pieces using
Rothoblaas Wasps


Padded Sawhorses

Lift roof panels from the top

U-Maine Installs Sensors in Roof + Wall Assemblies


Great Dane FREEDOM
Atlantic Great Dane


GROVE


VELOCITY

WRB shouldn’t be strictly necessary, but ***supply chain issues*** forced the purchase of a zero-paraffin WFI for this project, thereby necessitating WRB


ZIPsystem
STRUCTURAL 1
5/8" ROOF AND WALL SHEATHING
MENTO 1000
www.procilma.com

U-Maine finishes up sensor installation


MENTO 1000

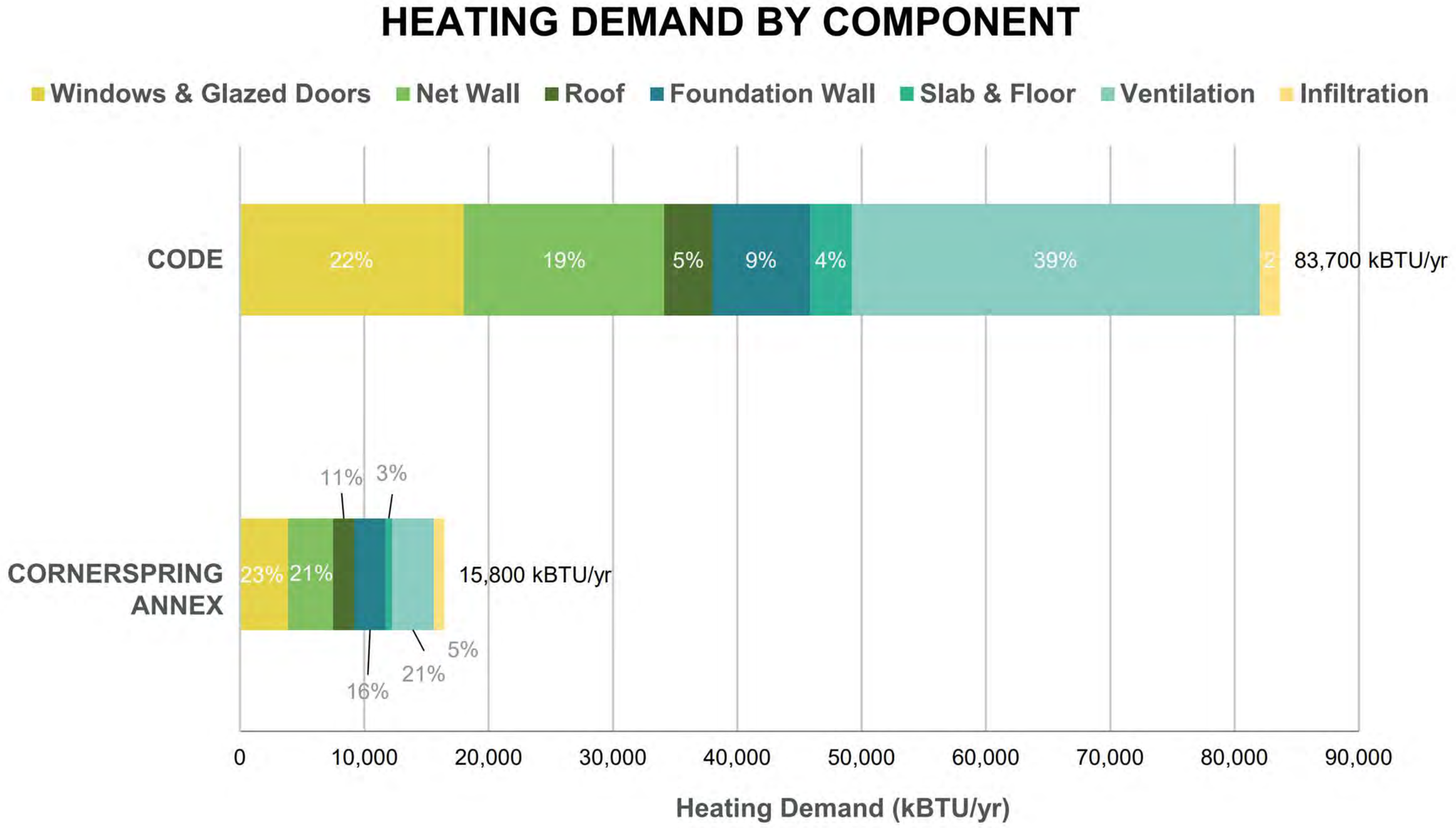

TURTLE
TURTLE
DUNE

Costs

35% of this is insulation fasteners!
Adhesives have potential to be a game-changing solution here: eliminate thermal bridging, dramatically reduce cost. U-Maine is working on this!

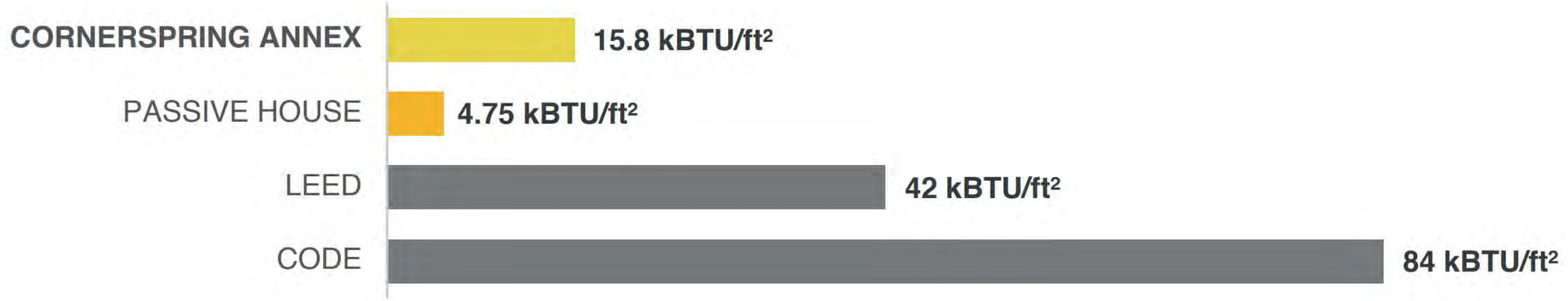
	Actual / Factor	/GSF to FO CLT	/GSF to FO WFI	/Total SA to FO WFI w/out ROs	/Total SA to FO WFI w/ROs	
CMS		*998*	*1056*	*2579*	*2876*	*%*
CLT	$52,550.00	$52.66	$49.76	$20.38	$18.27	29%
WFI	$22,707.38	$22.75	$21.50	$8.80	$7.90	12%
Windows / Doors	$16,940.99	$16.97	$16.04	$6.57	$5.89	9%
Lumber Fasteners Moisture	$26,780.16	$26.83	$25.36	$10.38	$9.31	15%
Labor	$41,498.75	$41.58	$39.30	$16.09	$14.43	23%
Gen. Con.	$22,198.39	$22.24	$21.02	$8.61	$7.72	12%
Total Cost	**$182,675.67**	**$183.04**	**$172.99**	**$70.83**	**$63.52**	

Model


HEATING DEMAND BY COMPONENT
Windows & Glazed Doors
Net Wall
Roof
Foundation Wall
Slab & Floor
Ventilation
Infiltration
CODE
22%
19%
5%
9%
4%
39%
2
83,700 kBTU/yr
CORNERSPRING ANNEX
11%
3%
23%
21%
15,800 kBTU/yr
5%
21%
16%
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
Heating Demand (kBTU/yr)

Model

ANNUAL HEATING DEMAND (kBTU/ft²)



ANNUAL SITE ENERGY USE INTENSITY (kBTU/ft²)

National average obtained through EIA CBECS database.

Model

OTHERS

WOOD FIBER INSULATION

CLT

-11.8 tCO_{2e}

WOOD PRODUCTS IN THE ANNEX

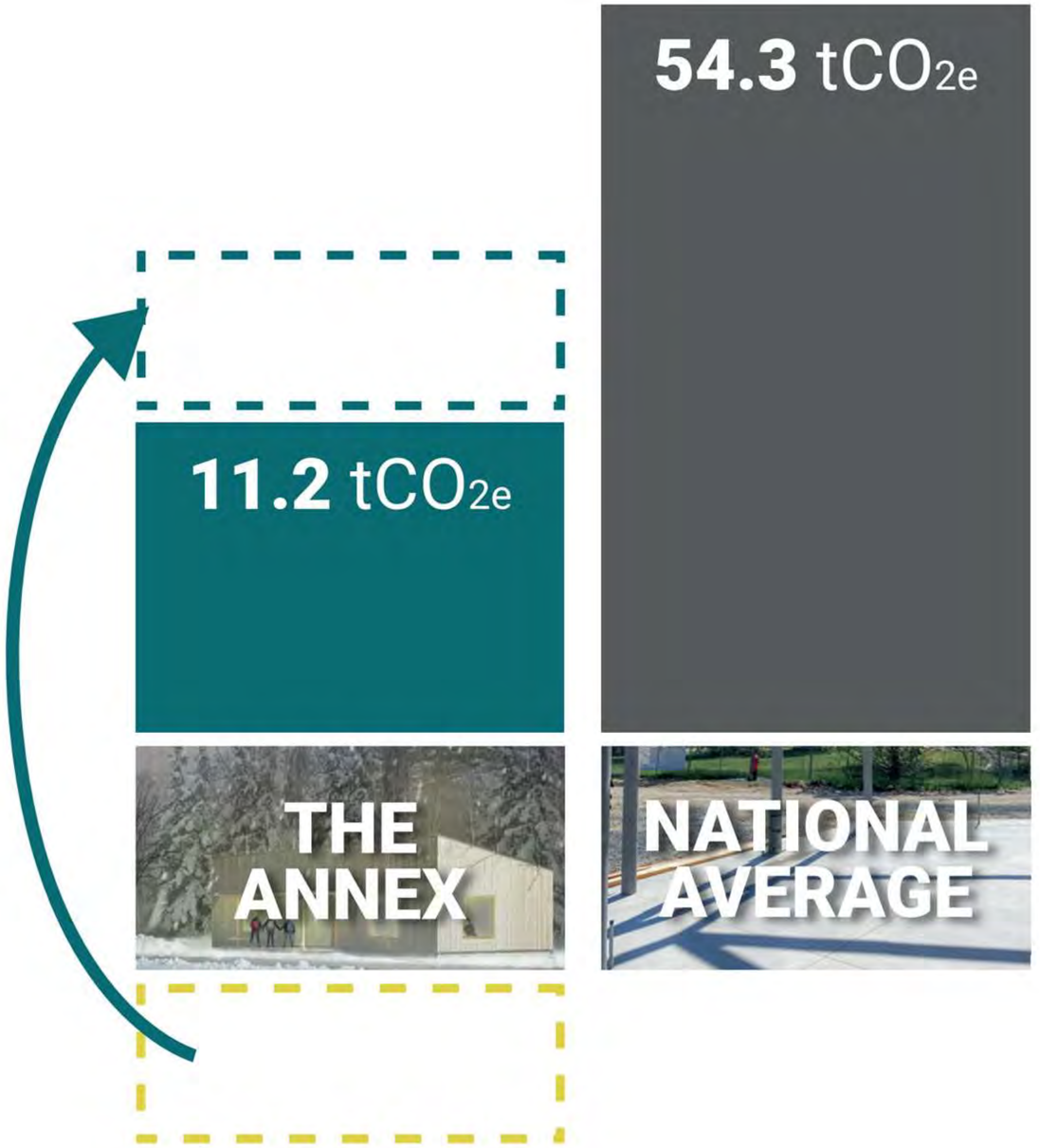
Data inclusive of biogenic carbon. Wood fiber insulation cradle-to-grave data obtained through Sphera; assumed landfill as end-of-life treatment. Cradle-to-grave results of CLT and other wood products generated through Tally. CLT LCI Source - “RNA: Glue laminated timbers CORRIM (2011)”.

Model

23 tCO_{2e}
GWP IN OTHER BUILDING MATERIALS

-11.8 tCO_{2e}
GWP IN WOOD PRODUCTS

11.2 tCO_{2e}
GWP EMBODIED IN THE ANNEX



Data inclusive of biogenic carbon. Full building envelope cradle-to-grave (excluding wood fiber insulation) results generated through Tally. CLT LCI Source - "RNA: Glue laminated timbers CORRIM (2011)". Wood fiber insulation cradle-to-grave data obtained through Sphera; assumed landfill as end-of-life treatment. National average obtained through AIA2030 database.

Model

WOOD PRODUCTS

THE ANNEX

CONCRETE

OPENINGS

THERMAL & MOISTURE CONTROL

OTHERS

THE ANNEX

11.2 tCO_{2e}

NATIONAL AVERAGE

54.3

Data inclusive of biogenic carbon. Full building envelope cradle-to-grave (excluding wood fiber insulation) results generated through Tally. CLT LCI Source - "
Glue laminated timbers CORRIM (2011)". ned landfill as end-of-life treatment.
National average obtained through AIA20

4. Results:

U-Maine Presents Sensor Data

BUILDINGENERGY BOSTON
FEBRUARY 28–MARCH 1 • WESTIN BOSTON SEAPORT DISTRICT • NESEA.ORG/BE22
Conference + Trade Show of the Northeast Sustainable Energy Association (NESEA)

MAINE R1 DEFINES TOMORROW

Advancing All-Wood Design and Carbon Storage in the Build Environment

Real-time monitoring of the hygrothermal performance and energy consumption of the CLT School Building

Jake Snow
School of Forest Resources
Advanced Structures & Composites Center
University of Maine
Feb. 28, 2022

ADVANCED STRUCTURES & composites center

SCHOOL OF FOREST RESOURCES forest.umaine.edu

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& Technologies

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Wood, Engineered
Wood Products, &
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Graduate Student
Wood-based building products

Marilia Hellmeister
Graduate Student
LCA, Building Energy

Outline

- Goals and Objectives
- Hygrothermal monitoring
  - Sensors
  - Locations
  - Data collection & analysis
- Energy use monitoring
- Future work

Goals and Objectives

Goals:

- Evaluate the long-term durability and energy consumption of the CLT building.

Objectives:

- Collect minimum one-year data of T, RH, MC, and electricity use.
- Risk evaluation in terms of moisture condensation and mold growth.
- Comparison of energy use measured and simulated by software.

Hygrothermal monitoring: What is measured?

CLT panels:

- Moisture content (MC) through the depth of the 3-layer and 5-layer panels

WFI boards:

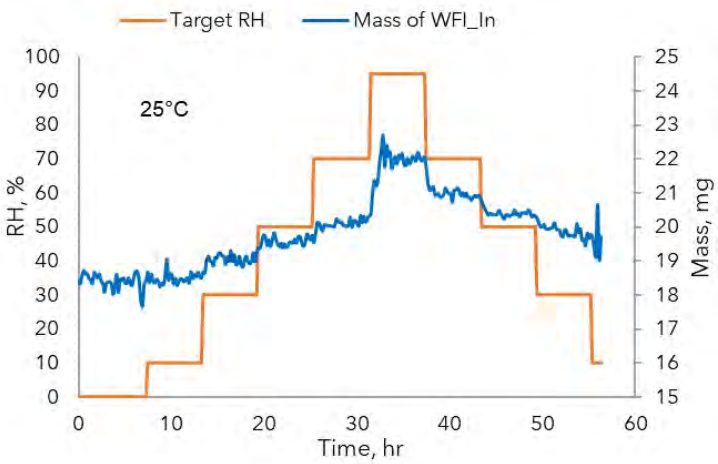
- Temperature (T) and relative humidity (RH) of air in the WFI through the depth of the boards

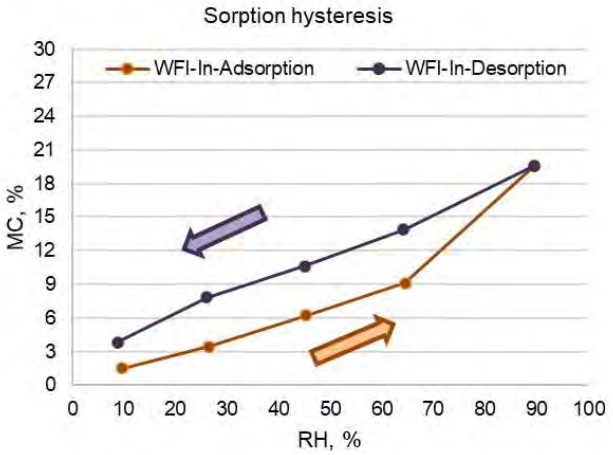
- Dewpoint temperature of the air at a given T. and RH level

Determination of MC of WFI (Interior Use)

WFI board: Equilibrium Moisture content (EMC) at different T and RH levels during adsorption and desorption.

Surface Measurement Systems
World Leader in Sorption Science





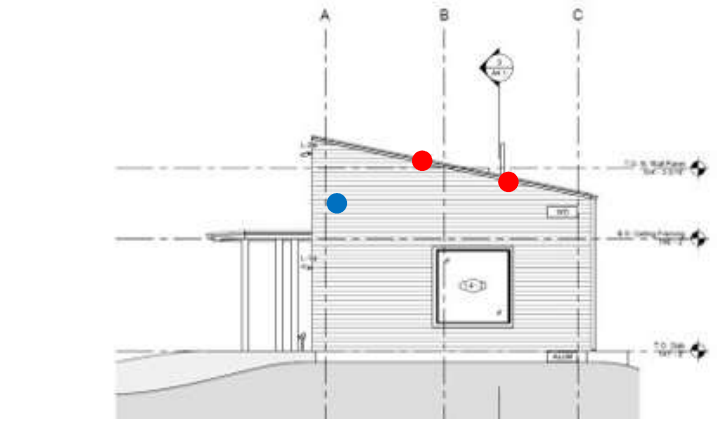
Sensor Specs

- A-1-40 HumiSense temperature and humidity probe
  - ±.3°C/ ±2.0%RH typical
  - 0-100% RH Range
- A-2 resistance moisture probe
- S-2 wireless data logger
  - 2 RH/T ports
  - 1 MC% port
  - 64K reading memory
  - Adjustable reading intervals
- G-4 Gateway with Verizon Cellular

OmniSense

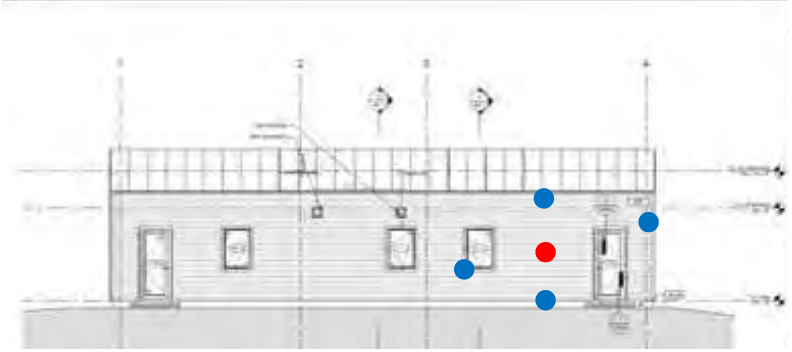
Sensor Location

- Red dots ● indicate primary sensor clusters with a higher density of sensors
- Blue dots ● indicate secondary sensor clusters with a lower density of sensors
- Two different wall locations for Northern and Southern aspect
- Four roof locations at different points on the slope and different panels
- One window and two corners



West

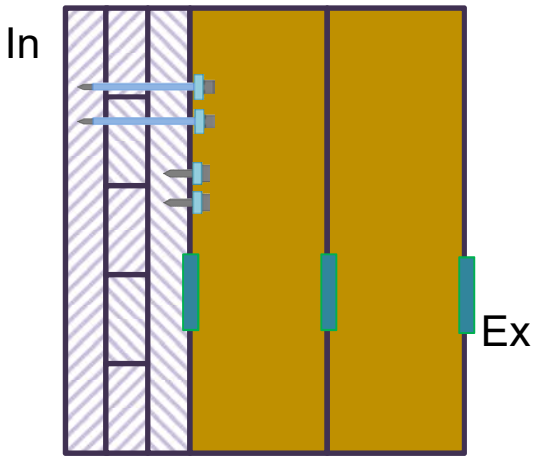
North



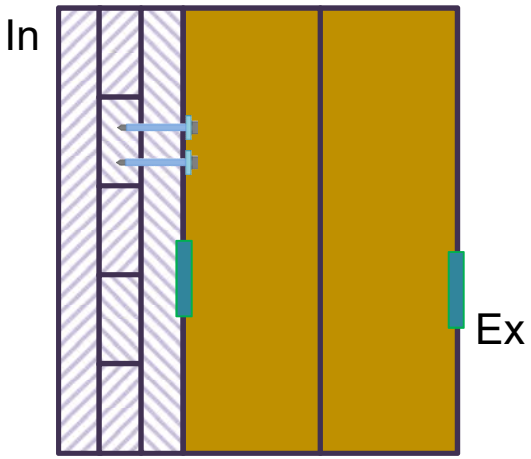
South

Position of sensors across the depth of wall and roof assemblies

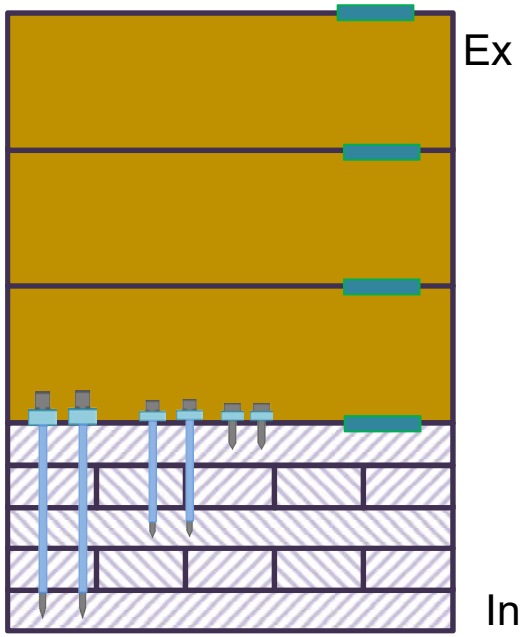
Primary monitoring locations on walls (South and north face walls)



Secondary monitoring locations (window, wall-to-roof connection, wall-to-floor connection, etc.)



Primary monitoring locations on roof panels

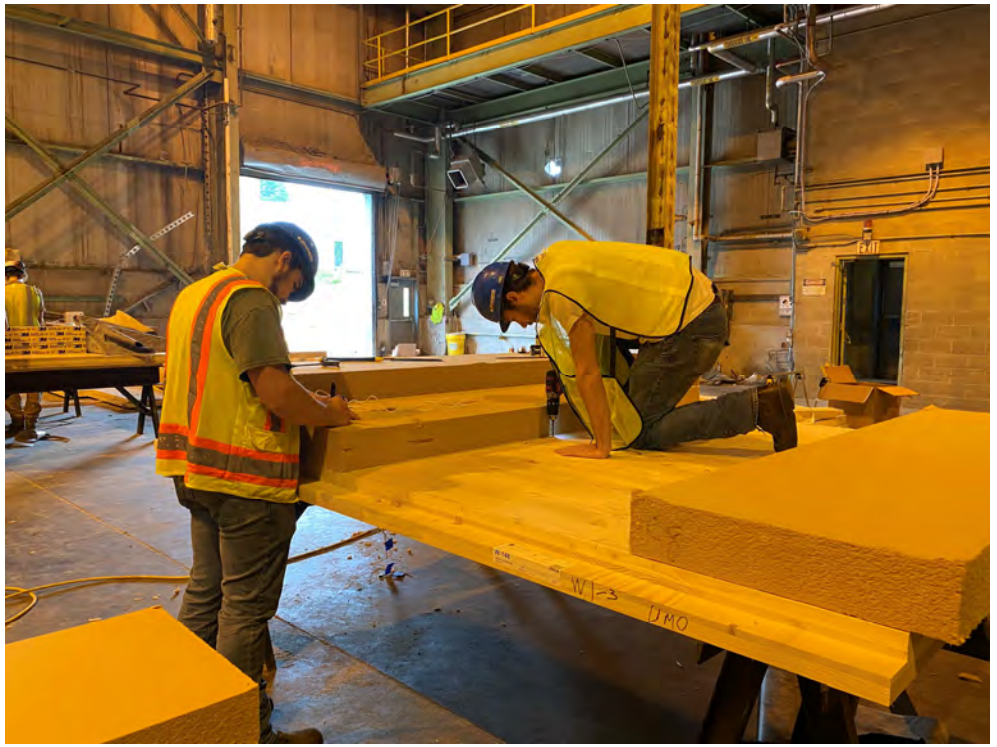


MC% Pins

T&RH sensor

Sensor Installation in manufacturing site (Madison, ME)

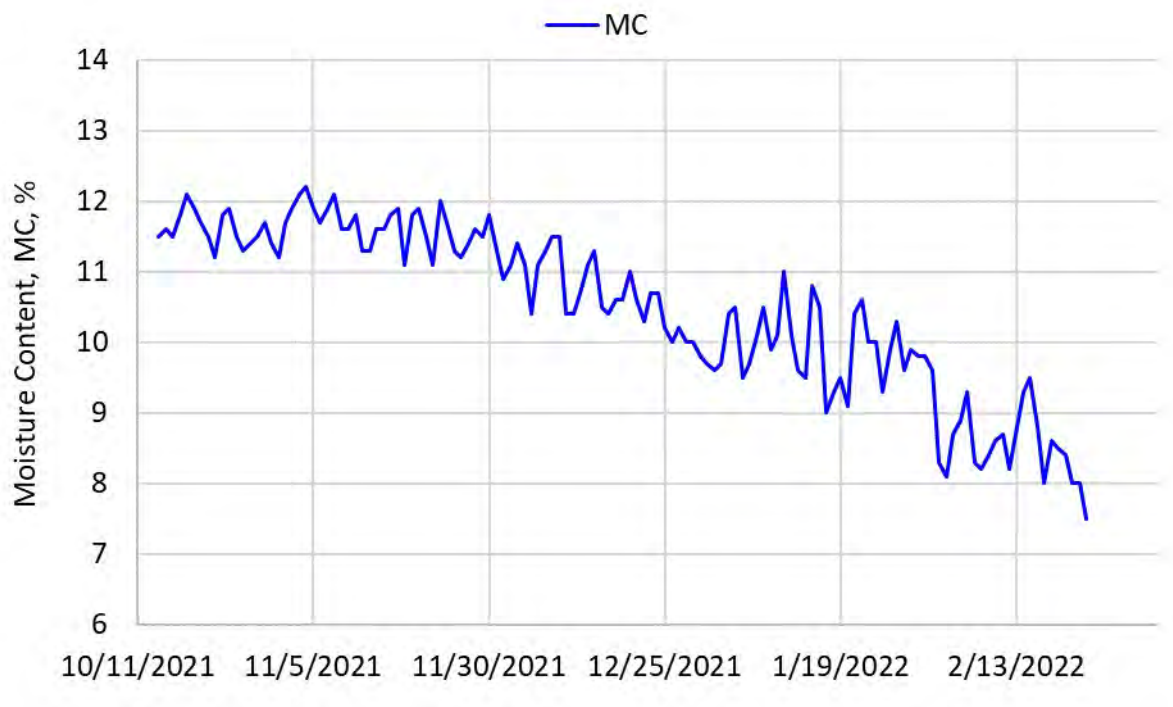
- A total of 18 Moisture sensors
- A total of 36 T & RH sensors
- Intact WFI boards
- All wires running along the seams between panels



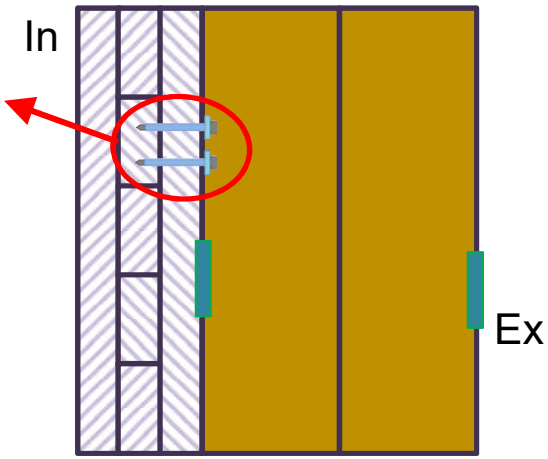
Distribution of wires and junction box in CLT building + weather station

Preliminary data analysis

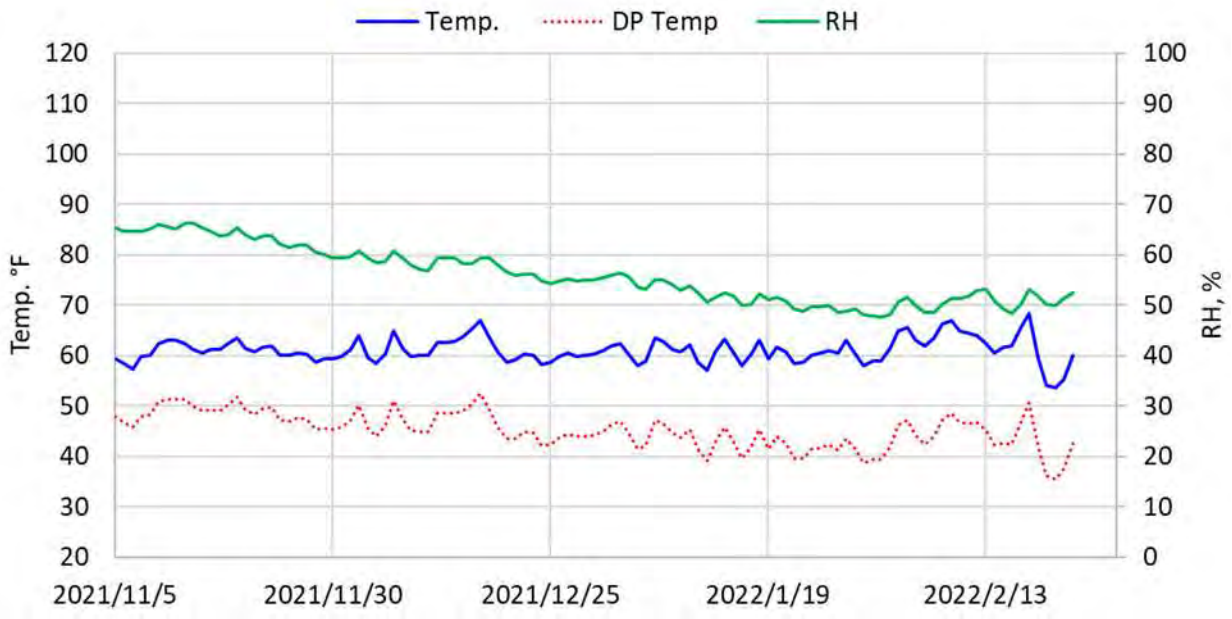
MC reading based on daily values



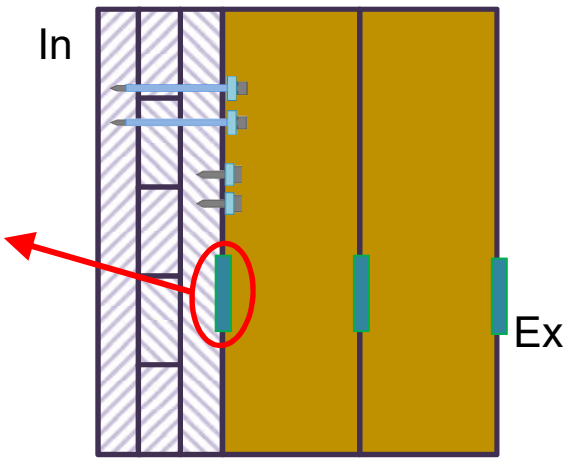
Secondary location:
Top corner wall



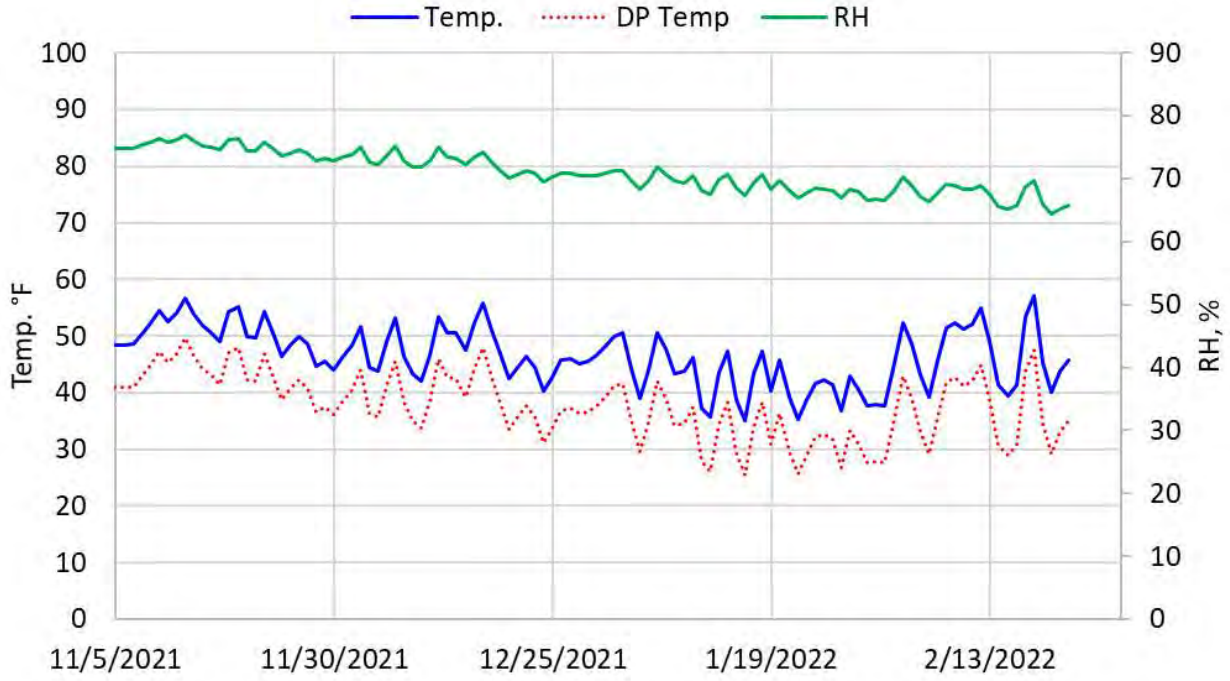
T, RH, & dewpoint T reading based on daily values



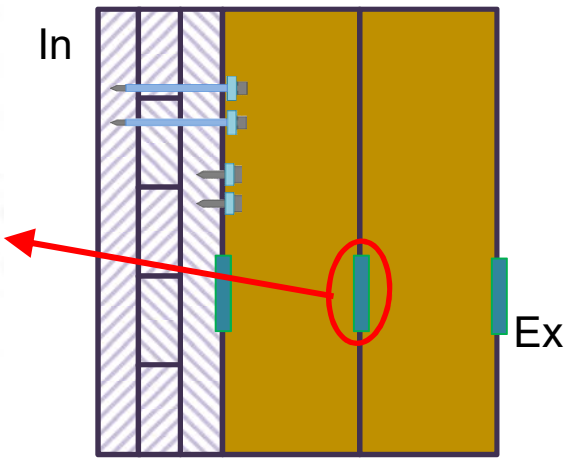
Primary location:
Mid-height of the wall



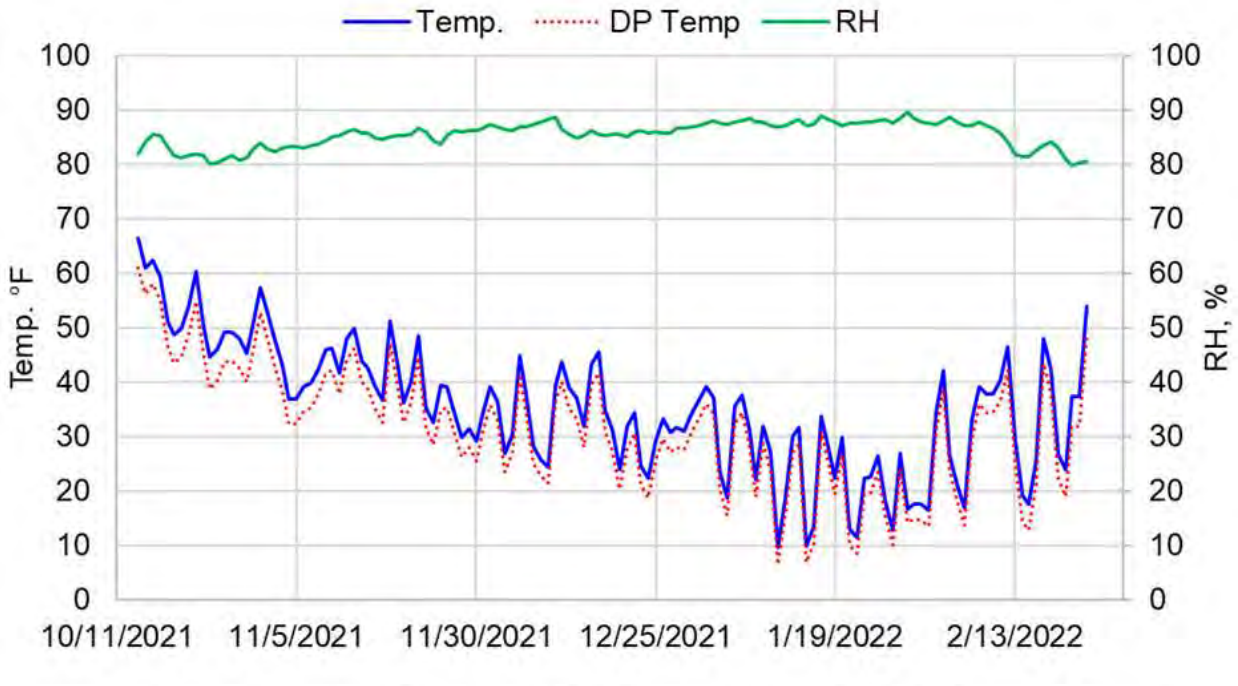
T, RH, & dewpoint T reading based on daily values



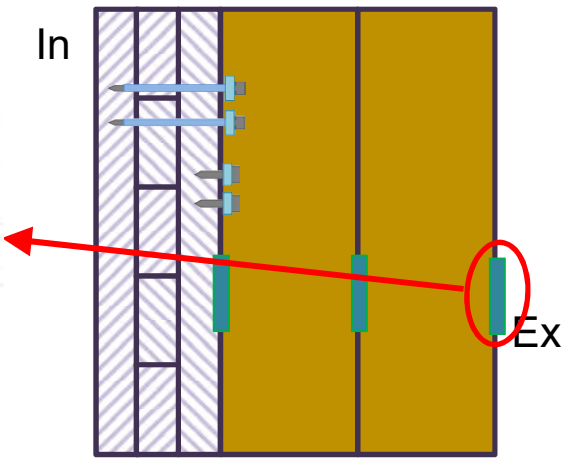
Primary location:
Mid-height of the wall



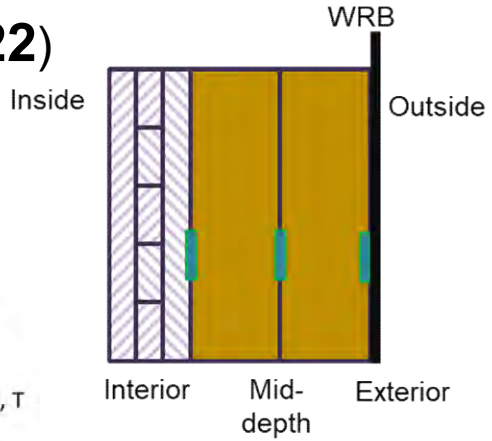
T, RH, & dewpoint T reading based on daily values



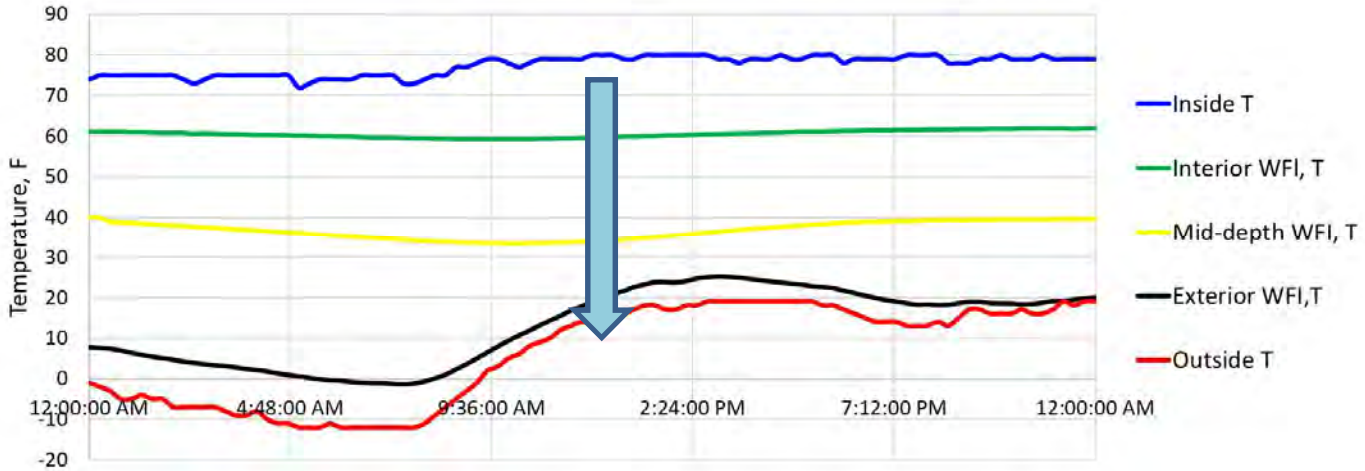
Primary location:
Mid-height of the wall



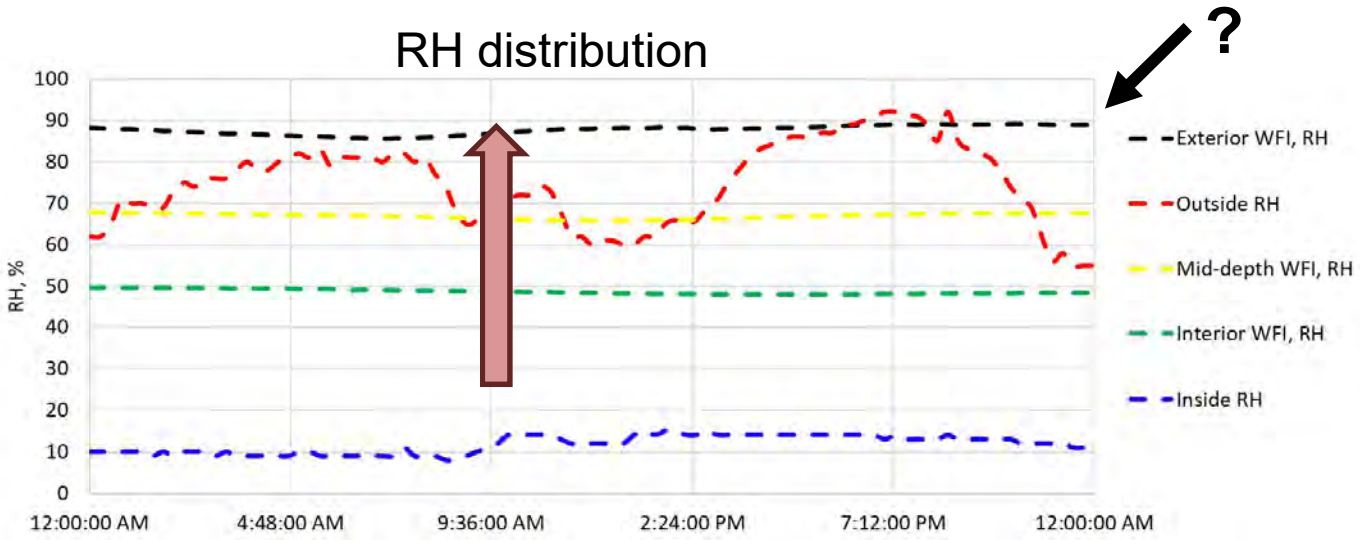
Overall T. and RH distribution (**24-hour data on Jan 27, 2022**)



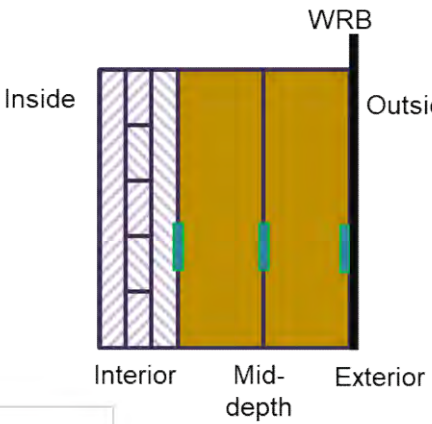
Temperature distribution

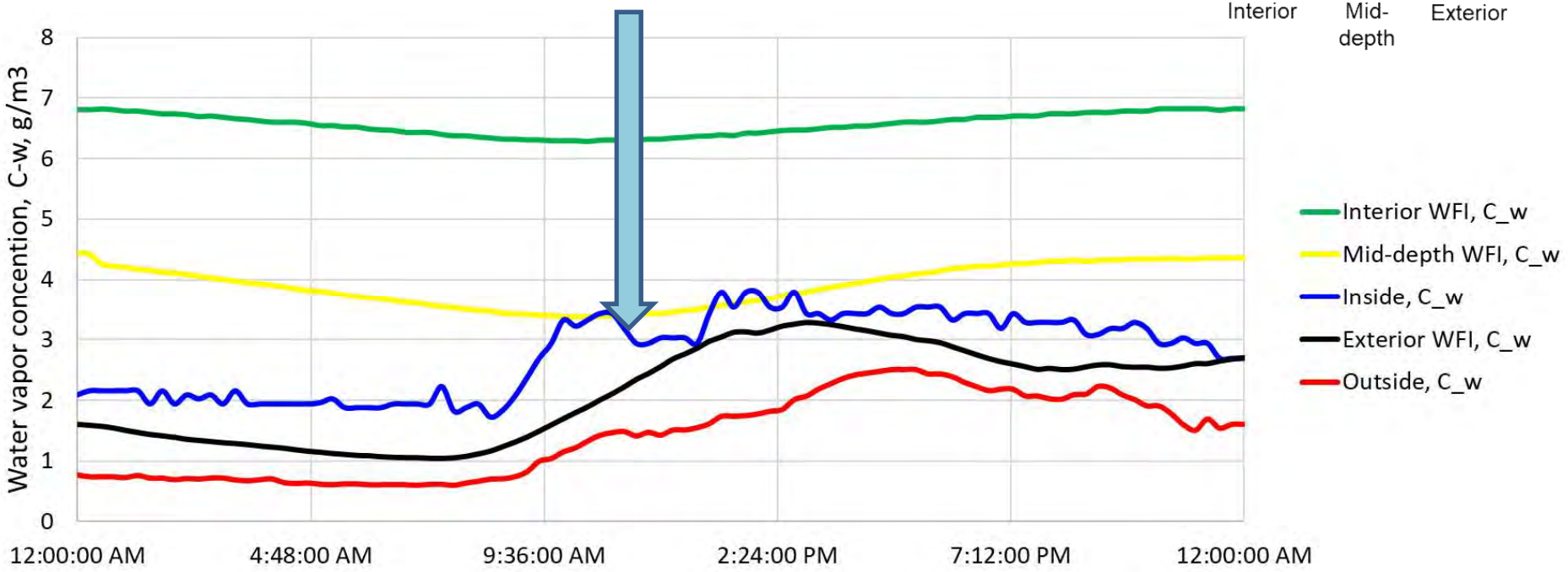


RH distribution



Overall water vapor concentration (absolute humidity) distribution (**24-hour data on Jan 27, 2022**)





What information can we obtain?

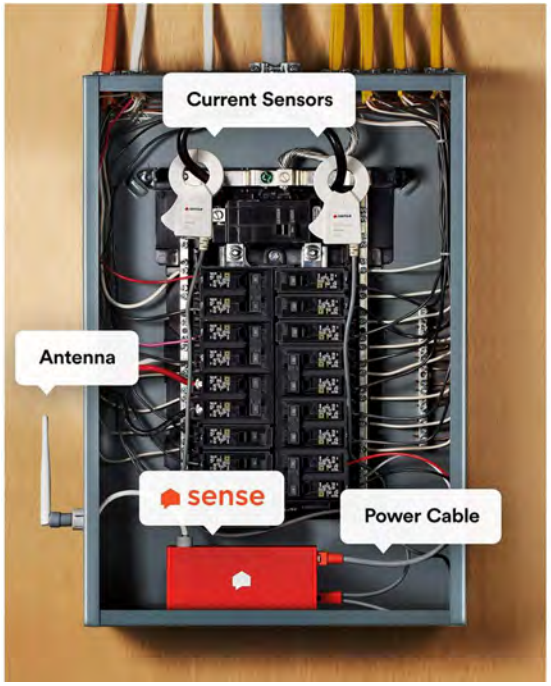
Category	Thresholds	Measurements
Fungal growth	MC>FSP, 41°F <T<104°F	RH>80%, 41°F <T for 20 days (WFI) 9.4%<MC<13.6% (wood) 16.5%<MC<19.5% (WFI)
Mold growth	RH>80% over one month, 41°F <T<104°F	
Corrosion of metal fasteners	MC >18%	
Increase of thermal conductivity (λ)	0.09<λ< 0.115 at 0% <MC<20% (Wood)	
Reduction of material strength	MC>19% (lumber), 16% for engineered wood products	

Ref: https://www.fpl.fs.fed.us/documnts/fplrp/fpl_rp675.pdf

Energy use monitoring

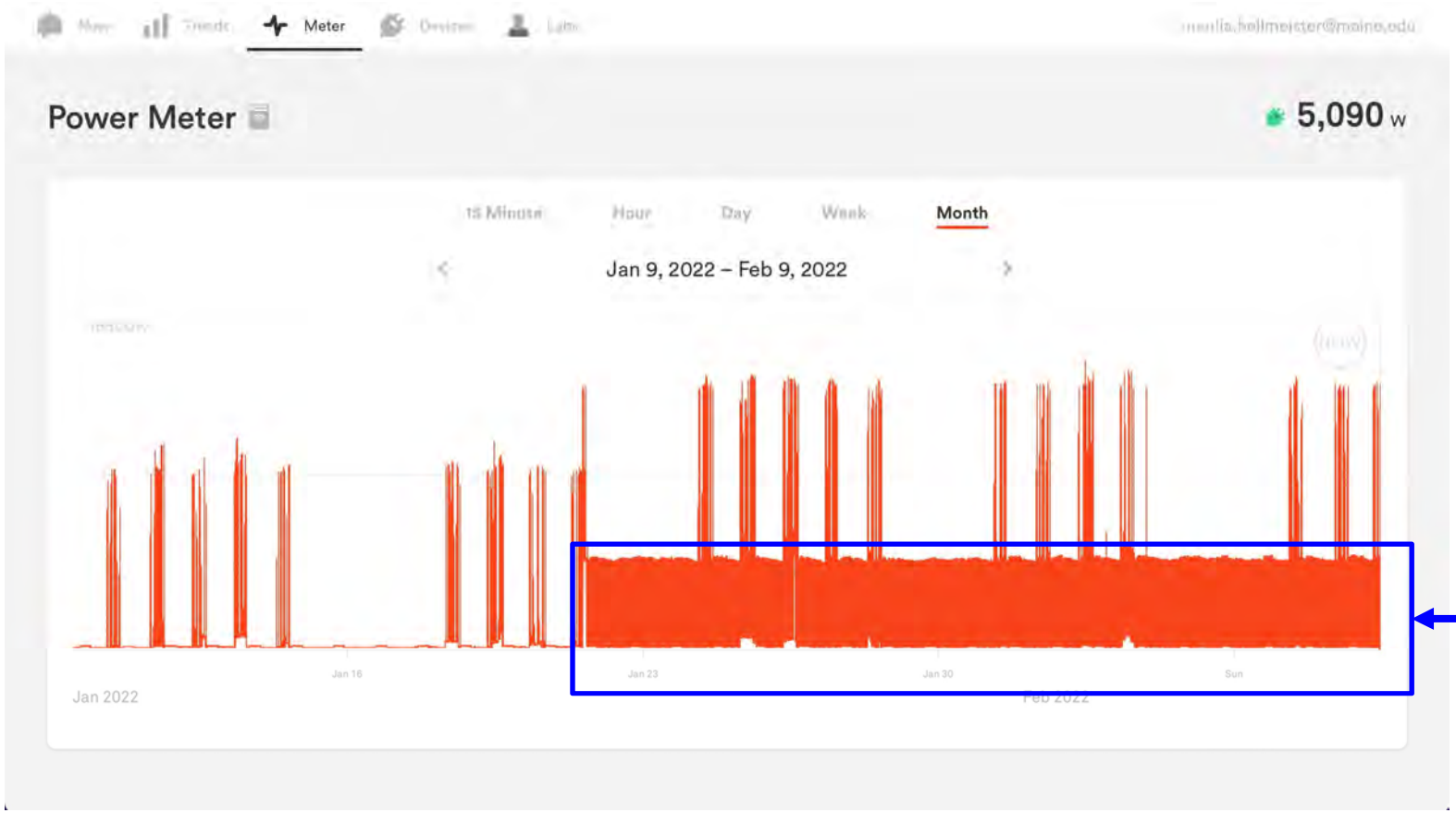
https://sense.com/

Understand how much energy is using by different appliances installed in the building.



Sense device was installed in the electrical breaker box.

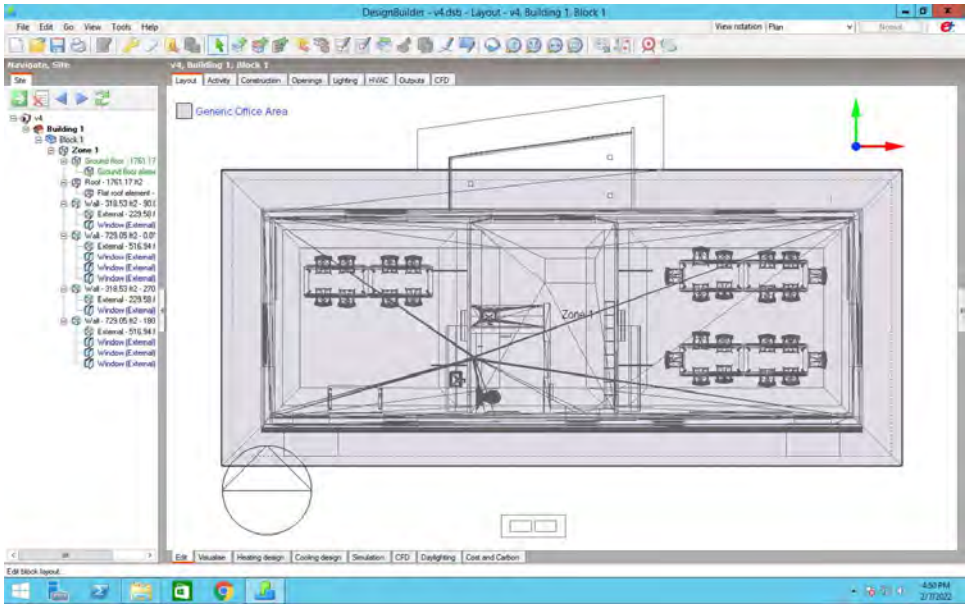
Electricity usage monitoring: Jan 9 to Feb. 9, 2022

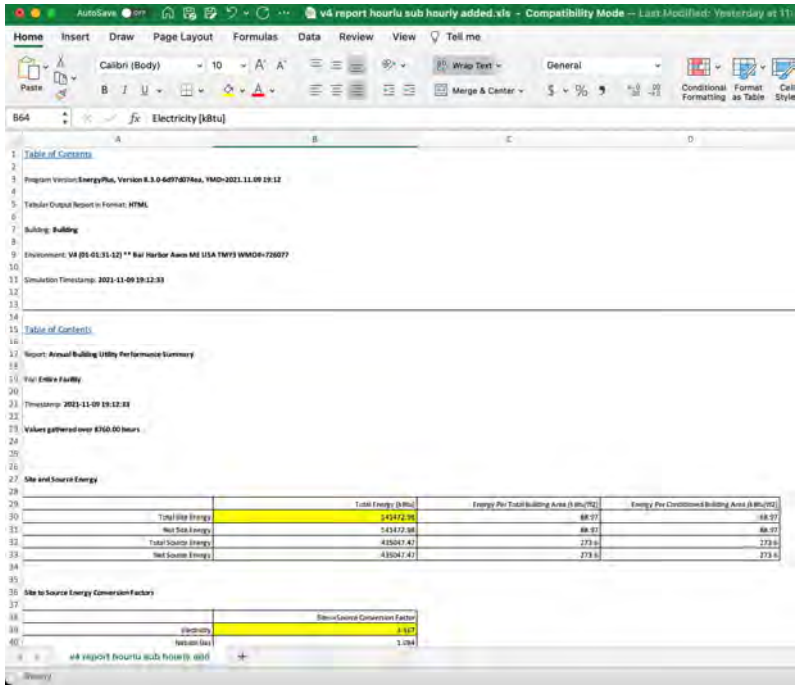


Preheater of ERV is on.

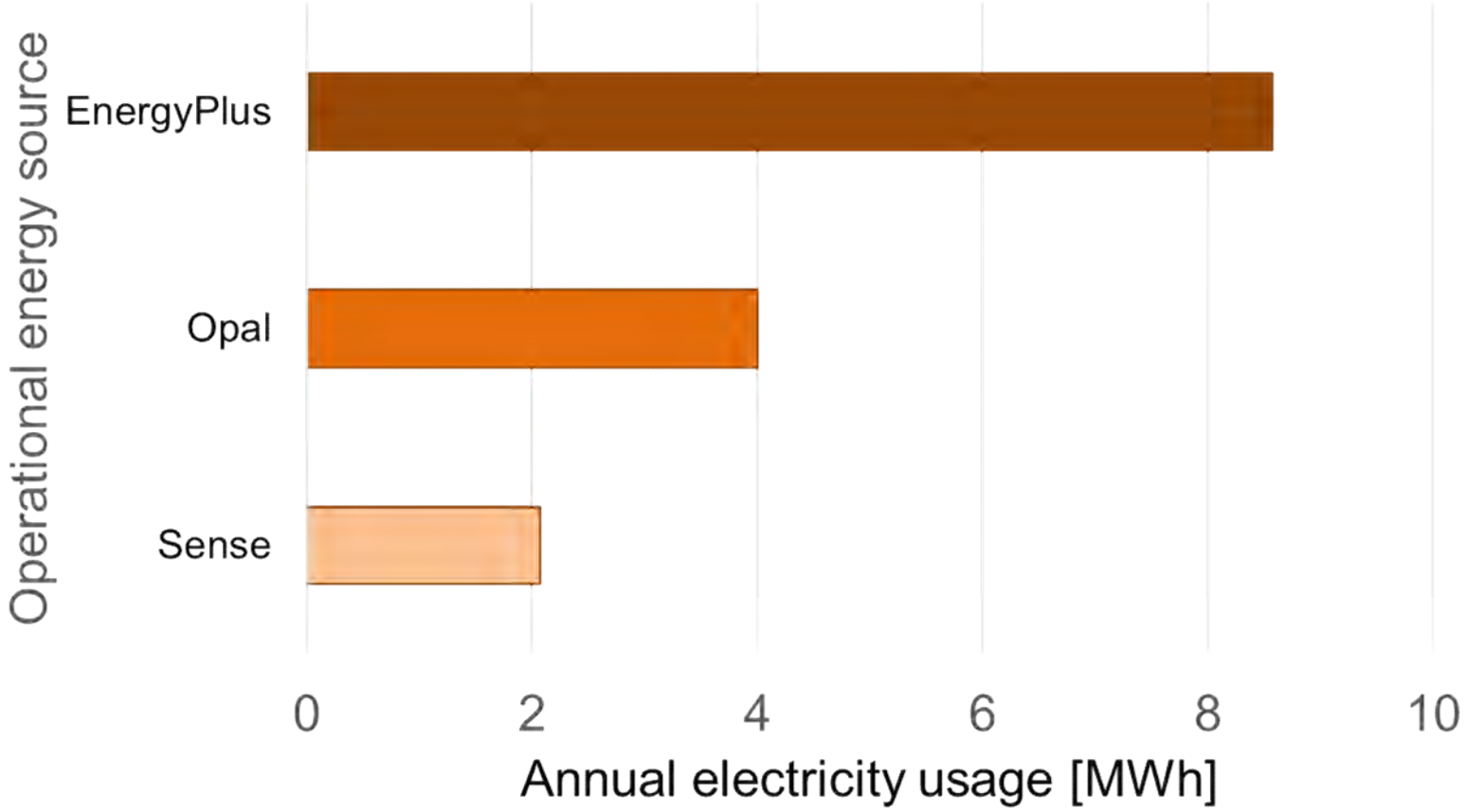
Electricity usage simulation

- EnergyPlus software simulation





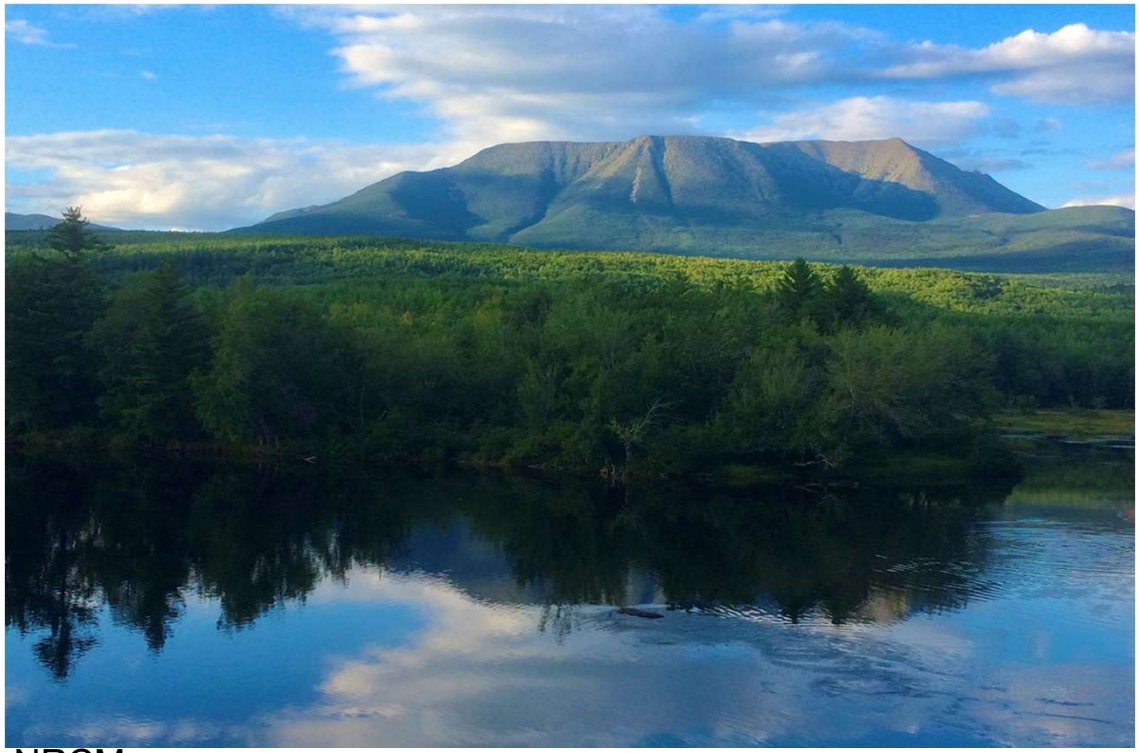
Electricity usage comparison



How will we use these data?

Future work:

- Comparison of similar building projects or lab data
- Validation of building design practices & modeling results
- Evaluation of long-term structural health and energy consumption



NRCM.org

Thank you

Questions?

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