Stor4Build
U.S. DEPARTMENT OF ENERGY

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Panel 4: TES Roles in Building Envelopes: Opportunities and Challenges

Moderator:
Dr. Som Shrestha, *Senior R&D Staff, ORNL*

Panelists:

Dr. Jan Kosny
Research Professor,
University of Massachusetts,
Lowell

Mr. Michael (Mick) Dunn
Technical Sales Manager,
Armstrong Ceilings

Dr. Shantonio Birch
Founder,
ThermoVerse

Ms. Lisa Morey
Founder and Owner,
Colorado Earth

Funded By: U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Co-Directors: BERKELEY LAB | NREL Transforming ENERGY | OAK RIDGE National Laboratory

Supported By: ACEEE American Council for an Energy-Efficient Economy | Pacific Northwest NATIONAL LABORATORY

Unlocking the Potential of TES Technologies in Building Envelopes

Why Don't We Use What Really Works?

Dr. Jan Kośny

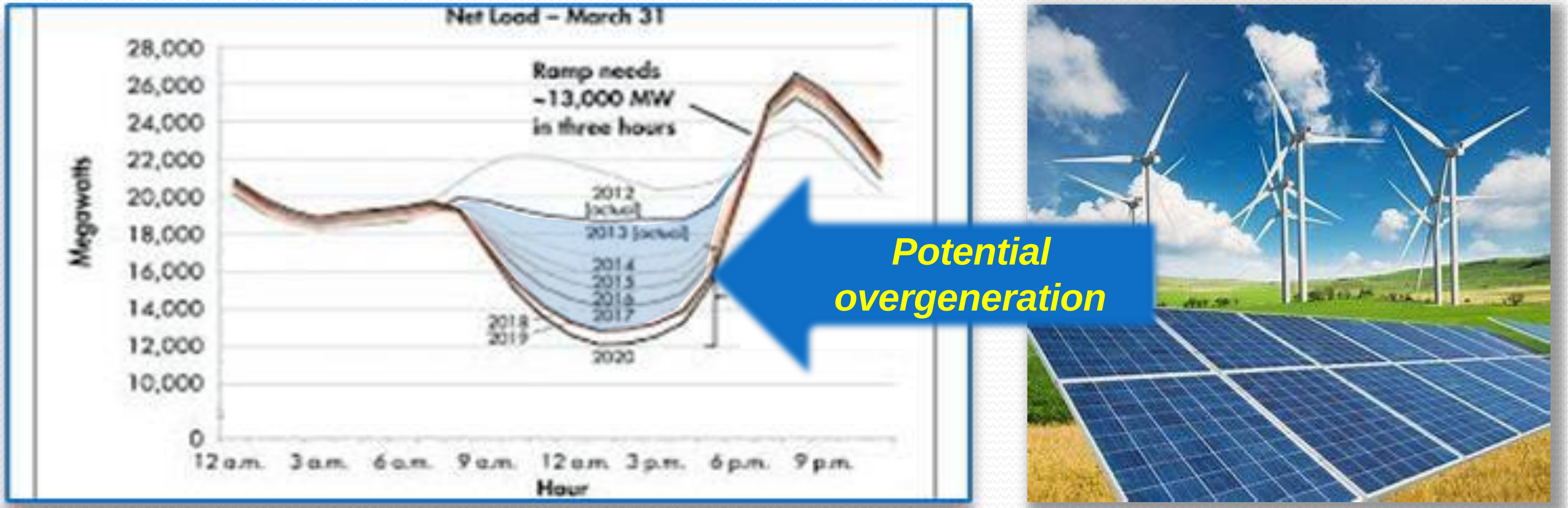
Department of Mechanical Engineering, University of Massachusetts, Lowell, MA, USA
Dipartimento di Ingegneria, Università di Palermo, Palermo, Italy

Director – UML Building Energy Efficiency and Temperature Control Materials Laboratory
Co-Director – UML Photovoltaic Prototyping and Testing Laboratory

Associate Editor - Frontiers, Solar Energy in Urban Development
Editorial Board Member – Buildings Journal, Energy Storage and Applications

Stor4Build 2024 Annual Meeting, ORNL, Oak Ridge TN, Aug. 26-27 , 2024

Great Strategic Needs & Opportunities for PCM Technologies in U.S. Buildings

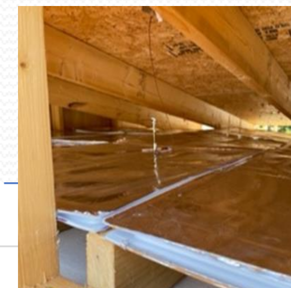


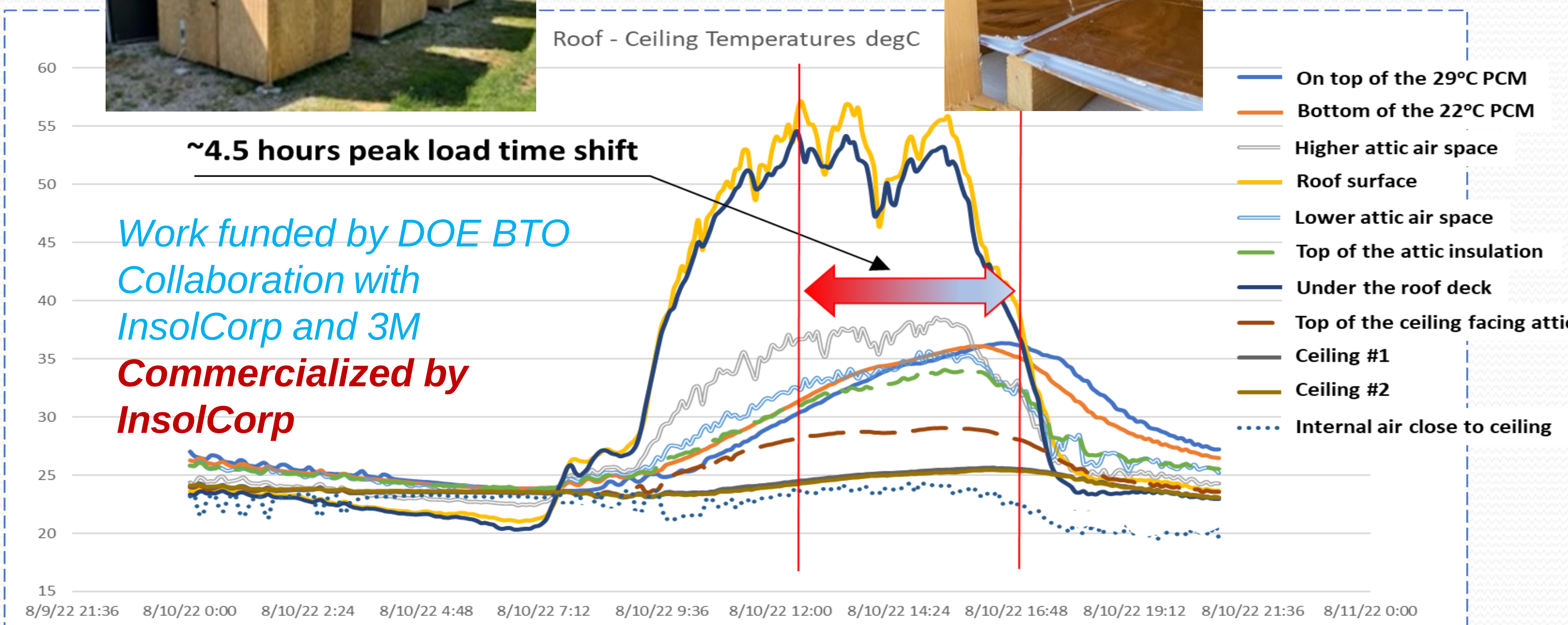
- Demand Peaks with Possible Power Overgeneration
  - Duck curve depicts the time imbalance between peak demand and renewable energy production.
  - For larger-scale PV operations, it highlights a risk of power overgeneration and uncertainty of renewable power availability.
  - **Utilizing EE and transient characteristics of building structures – existing thermal mass, PCMs, dynamic action of fenestration, etc. can help right now and at a low cost.**

DTD – Dynamic Thermal Disconnect in Slope Roof with Attic

A Combination of **Radiant Barriers** with **Thermal Insulation, Air Cavities,** and **Two PCMs** Yields over **80% of Peak Load Reduction** with Significant **Peak Load Time Shifting** of 4.5-5.5 hours

- recorded 2022-23

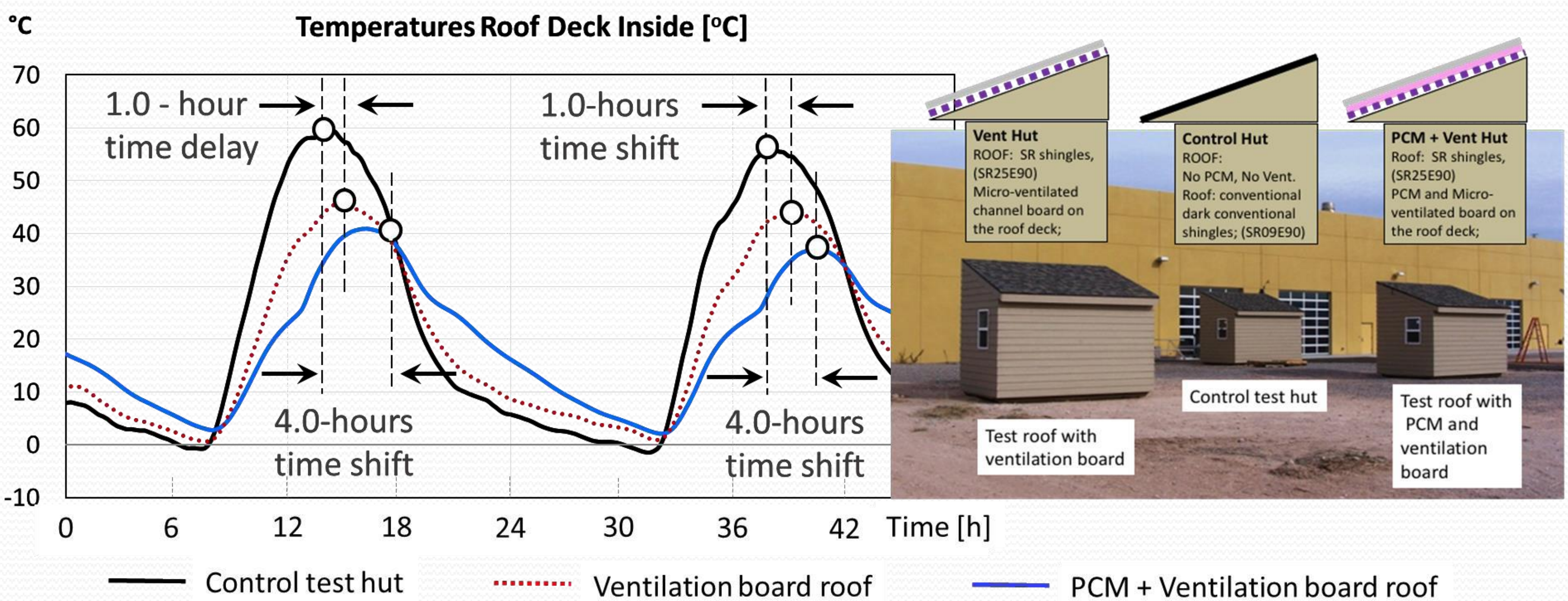




DTD – Dynamic Thermal Disconnect in Cathedralized Roof

A Combination of **Radiant Barriers** with **Thermal Insulation, Vented Air Cavities,** and **PCMs** Yields over **80% of Peak Load Reduction** with Significant **Peak Load Time Shifting** of ~4.0 hours

Work funded by DoD, collaboration with CertainTeed and Microtek Labs - recorded 2012-14



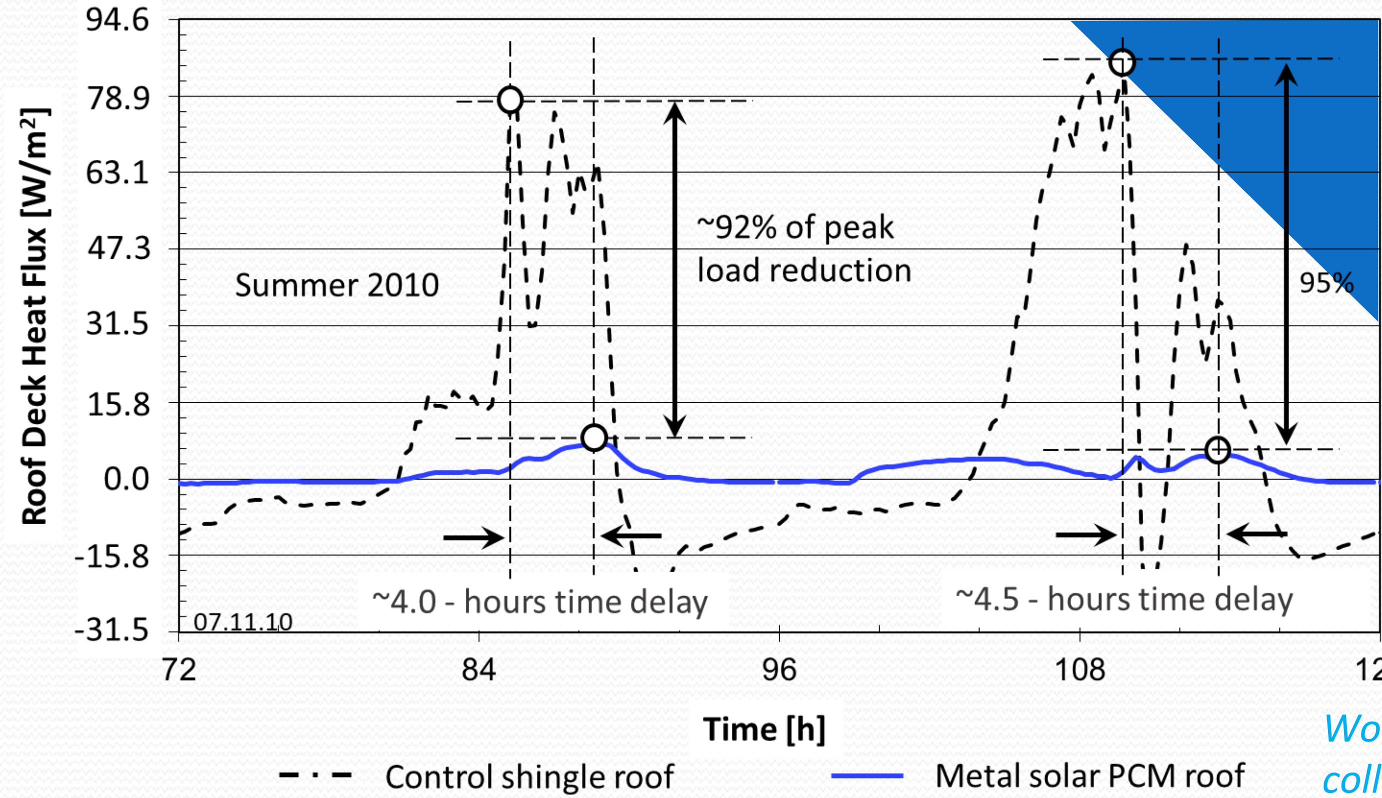
Kosny et al. (2021) Applied Sciences, MDPI - **Application of Phase Change Materials and Conventional Thermal Mass for Control of Roof Generated Cooling Loads**

DTD – Dynamic Thermal Disconnect in Roof with integrated PV

A Combination of **Radiant Barriers** with **Thermal Insulation, Air Cavities,** and **Thermal Mass** Yields over **90% of Peak Load Reduction** with Large **Peak Load Time Shifting** of 4.0-4.5 hours

- recorded 2008-10

Technology Commercialized by Phase Change Energy Solutions

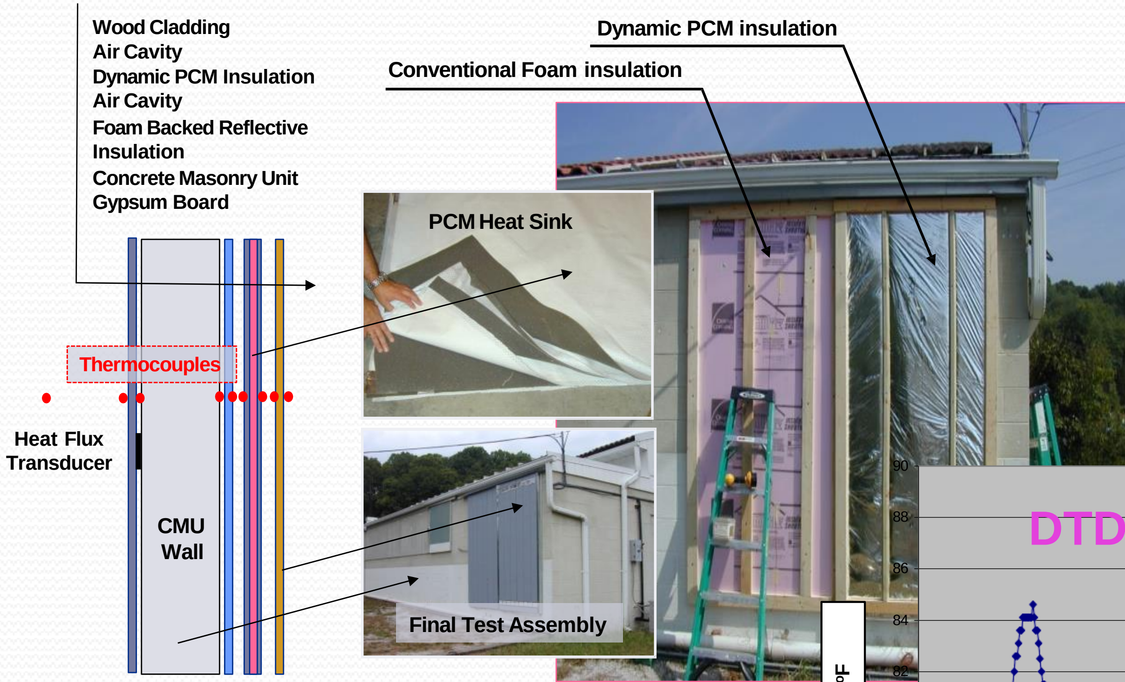


Data recorded in ORNL test attic – Kosny et al. 2012 Solar Energy

Work funded by DOE BTO, collaboration with MCA, and Phase Change Energy Solutions

DTD System used in Masonry Wall Retrofit for U.S. Southern Locations – Comparison with conventional foam wall retrofit

- recorded 2007-08

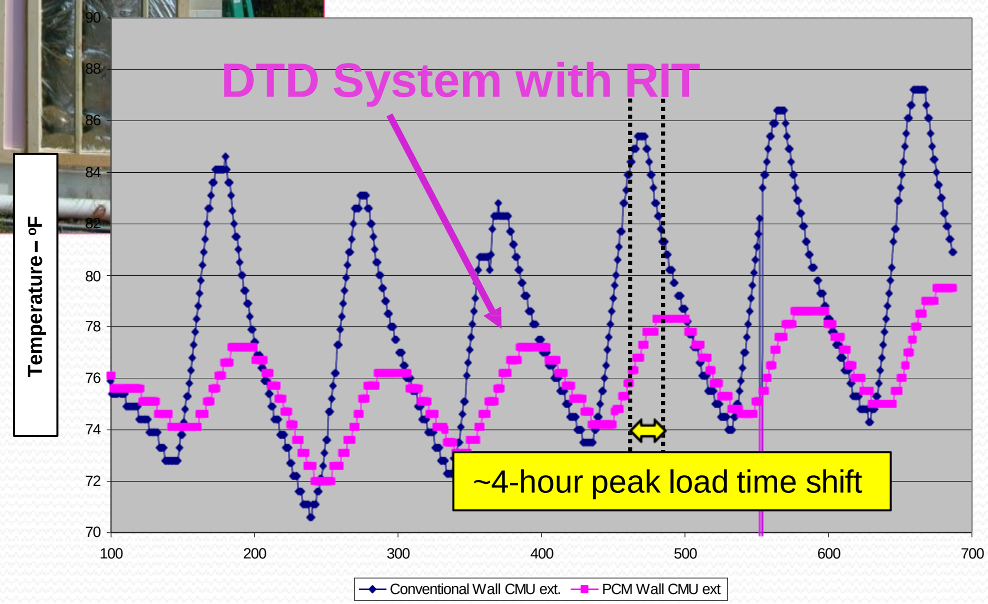


*Retrofit strategy for low R-value CMU wall with use of **CONVENTIONAL INSULATION** and **DYNAMIC PCM-ENHANCED INSULATION** of the same R-value*
source: J. Kosny experiment at ORNL facility

Two wall retrofit strategies of the same nominal R-values

On the right test wall, it was used a combination of radiant barrier, thermal Insulation, and PCM

Measured temperatures on top of the CMU wall

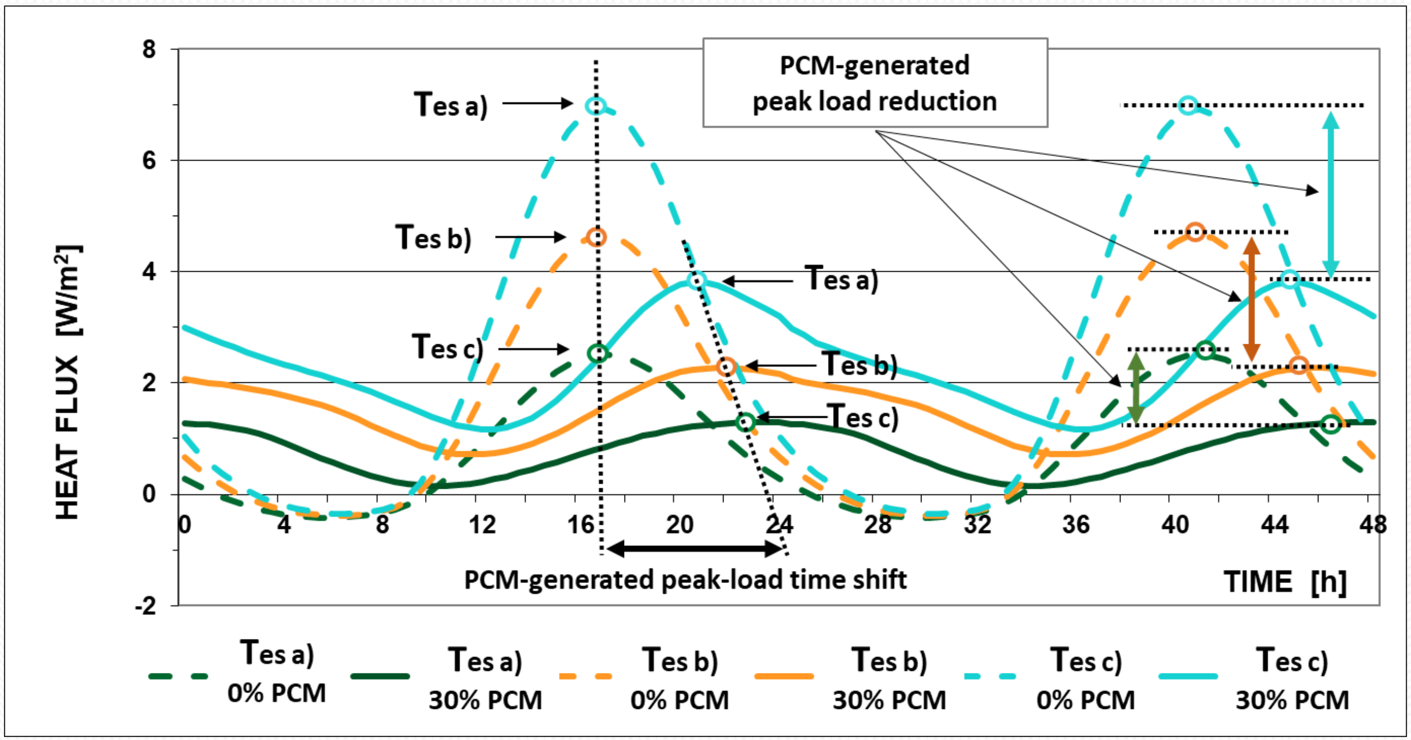


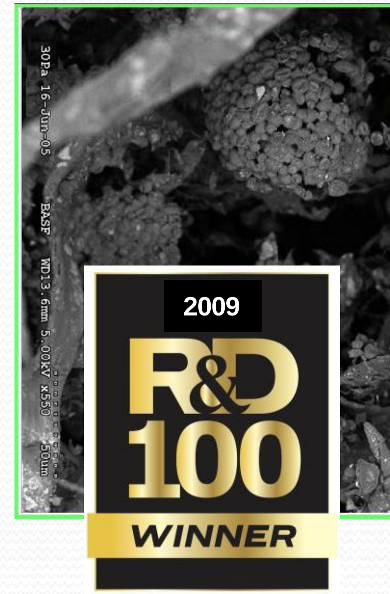
Work funded internally by ORNL, collaboration with Outlast, and RIMA

PCM-foam Commercialized by Outlast

Thick Layers of Insulation-PCM Blends Work Very Well in the Case of **Reduction of Peak Thermal Loads** and **Peak Load Time Shifting**

Simulated diurnal heat flux values for 30-cm. thick assemblies containing insulation with 30wt% PCM.





These theoretical performance predictions were confirmed with series of both Hot-Box and Field Testis of Roofs and Walls Cellulose and Fiberglass based PCM Blends

Kosny et al. (2021) Applied Sciences, MDPI - **Application of Phase Change Materials and Conventional Thermal Mass for Control of Roof Generated Cooling Loads**

2.5 to 6.5-hour Peak Load Time Shifting and **Peak Load Value Reduction for up to 80%**

Parametric analysis of building envelopes containing PCM-enhanced insulation

Assembly thickness [m]	Internal temp. [°C]	Sol-air ext. temp. schedule T_{es}	Night ext. temp. min. [°C]	Total cooling load reduction [%]	Peak load reduction [%]	Peak load time delay [h]
0.14	20	T_{es} c)	15	2.5	4.0	1.0
0.14	20	T_{es} b)	15	2.8	8.0	2.0
0.14	20	T_{es} a)	15	10.8	18.0	2.5
0.14	25	T_{es} c)	15	7.7	3.0	0.5
0.14	25	T_{es} b)	15	10.8	6.0	1.0
0.14	25	T_{es} a)	15	22.0	25.0	2.5
0.30	20	T_{es} c)	15	0,5	45.0	3.5
0.30	20	T_{es} b)	15	7.5	51.0	4.5
0.30	20	T_{es} a)	15	13.6	48.0	6.5
0.30	25	T_{es} c)	15	17.3	40.0	3.0
0.30	25	T_{es} b)	15	35.0	65.0	5.5
0.30	25	T_{es} a)	15	72.0	82.0	6.5

Kosny et al. (2021) Applied Sciences - **Application of Phase Change Materials and Conventional Thermal Mass for Control of Roof Generated Cooling Loads**

Work funded by DOE BTO, collaboration with AFT, John's Manville, and Microtek Labs.

Lab and field test performed during 2005-2008, ***Technology Commercialized by AFT***

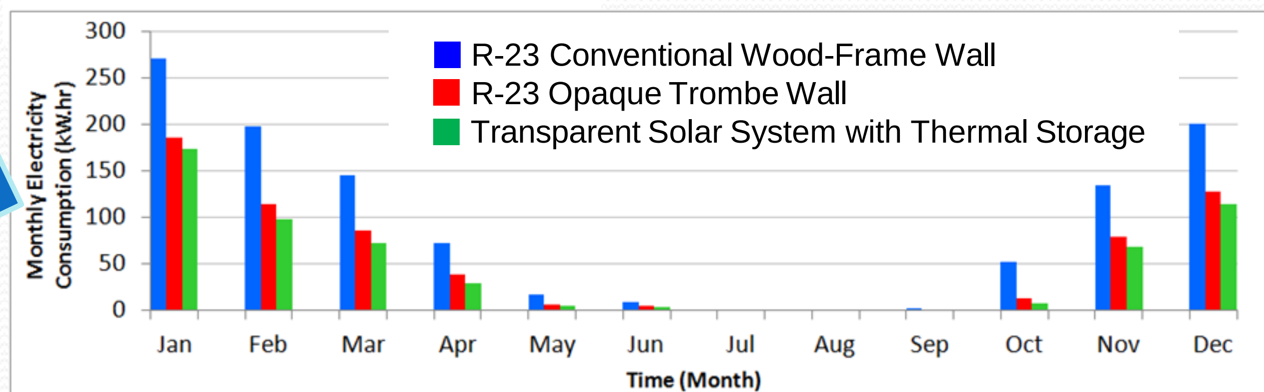
Both, **Opaque and Transparent Trombe Walls Containing PCM** Work Excellent as Building Integrated **Solar Heating Systems**

Transparent Solar Heating system with integrated Thermal Storage.

2013-14 field testing in MA climate conditions. Work sponsored by Hunter Douglass

Vented Trombe Wall and Solar Air Collector with Bee's Wax based Heat Sink – tested in 1989. Bio-PCM was placed in 2-in. thick metal container, behind the glazing – Univ. of Techn, Rzeszow, Poland.

Transparent Trombe wall using Transparent Aerogel and PCM TES can generate during winter in MA 140^{o}F to 180^{o}F. Technology developed by UML - 2021, based on the results of the ARPA-E funded work in collaboration with VCU.



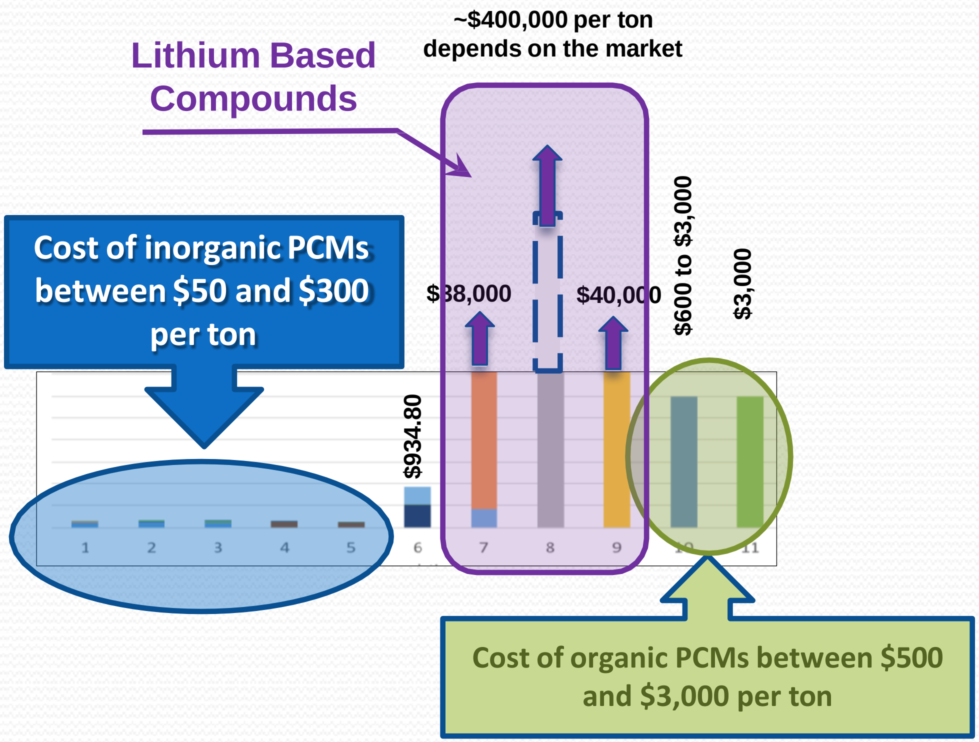
PCMs are Several Orders of Magnitude Less Expensive

when comparing to other types of energy storage materials

Quick Cost Comparisons:

$15 per kWh - commonly used by U.S. DOE EERE price ceiling for PCMs

- **Lithium based inorganic compounds are several orders of magnitude more expensive than both inorganic and organic PCMs**



$273 per kWh - Lithium-ion batteries

According to Blumberg a **cost of source Lithium used in 2017 in Li-ion batteries was about $273 per kWh**

https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf

THANK YOU!

Stor4Build 2024 Annual Meeting, ORNL, Oak Ridge TN
Aug. 26-27 , 2024

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University of Massachusetts, Lowell

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Email: JAN_KOSNY at UML.EDU

Templok®

PCM Integrated Ceilings

What is Templok®

Drop-In Thermal Storage/Mass

- Drop-In Solution – Easy Retrofit
- Ceilings = Large surface area.
- Predominant envelope issues have limited options/expense (eg. High rise).
- Accessible & Low Risk
- Re-Usable & Relocatable if needed
- +4 CAC (sound blocking)
- Typical 50-70% Coverage

FRONT of Ultima® Templok® panel

BACK of Ultima® Templok® panel

Why PCM Ceilings?

Simplicity & Control

Why PCM in Ceilings and Not Exterior Envelope?

- **VERSATILE:** There is no one-size fits all solution, important to start with versatility.
- **RISK/COST:** Envelope may be higher performance, but not without higher risk, cost & technical hurdles.
- **LABOR:** Leveraging existing labor of ceiling subcontractor or maintenance. Does not require separate trades.
- **1 BOX AT A TIME:** Can be incrementally added to spaces over time (patch and match upgrades).

CONTROL & DEMAND BENEFIT:

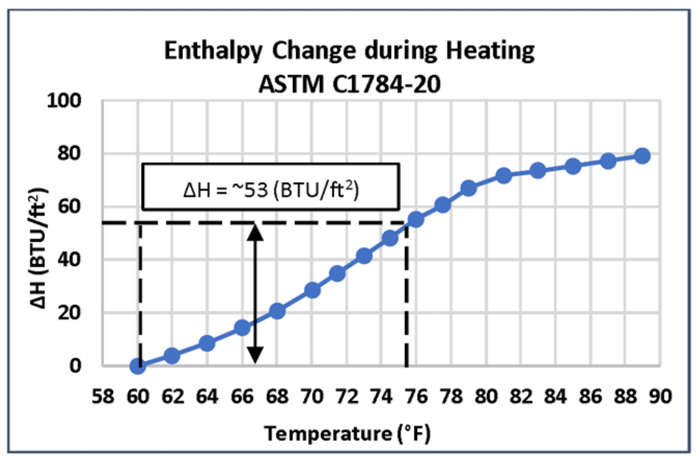
- Return plenum makes the storage part of HVAC loop with minimal invasiveness.
- PCM has ability to absorb excess or waste heat inside buildings from solar gain, internal gains, etc.
- Possibility of year round performance in many climates.
- Can be charged with economizer or high COP cooling overnight, with more predictable demand benefits during day using setpoint control.

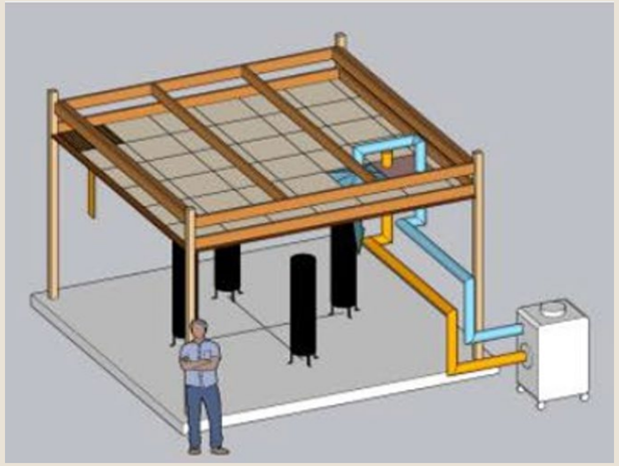
Validation work

Lab & Field Validation

LAB / CONTROLLED VALIDATION & TESTING

- Benchtop -> Room Scale Validation





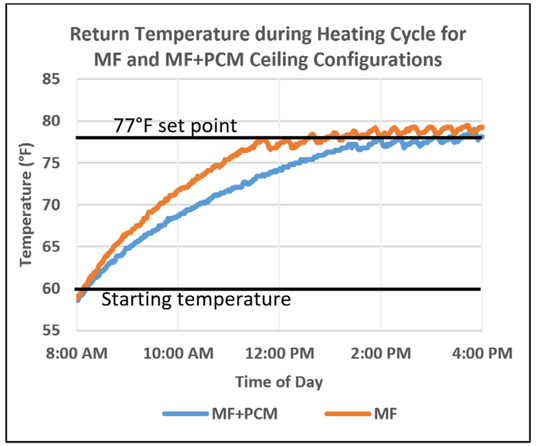
See full report: 2024 ASHRAE conference paper CH-24-C109

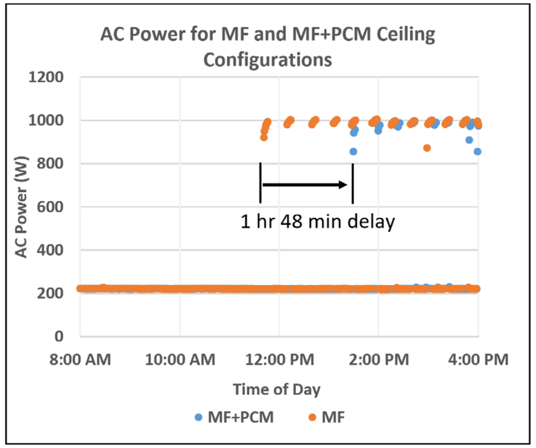
- **3 points of agreement:**

Reduced Cooling Load on AC* By air enthalpy difference across AC	4,080 btu's
Increased Heat Absorbed in Ceiling By heat flux measurements on ceiling surface	3,815 btu's
PCM Storage via Temp & Enthalpy Theoretical estimate by known temperature range and enthalpy curve of PCM	3,935 btu's

*During daytime hours after morning pre-cool in 13’x13’ chamber with 800W internal load

- Passive temperature moderation with PCM:





FIELD VALIDATION & TESTING

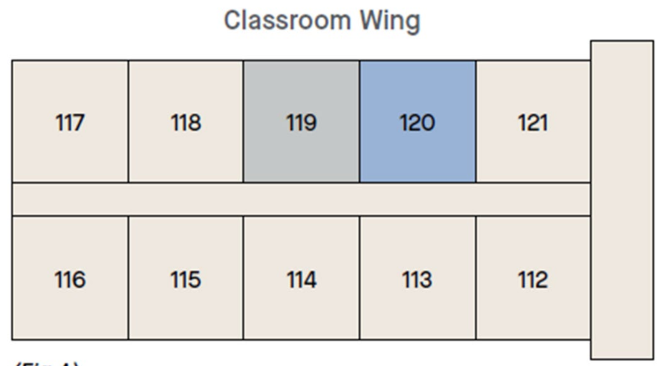
- Energy Modeling
- Field M&V within AWI network
- GSA Green Proving Grounds (GPG) / DOE
- NYSERDA – Heat Recovery Program
- Studies on support of electrification, peak demand reduction, HVAC sizing reduction

Applications:

Field Studies To Date

- Monitored power usage of x14 Classrooms with ASHP's
- Found strong correlation between adjacent rooms in baseline.
- Treated x2 Rooms with PCM – 1 Upstairs, 1 Downstairs
- Multi-variate analysis demonstrated 6% to 9% reductions in heating use overnight in Winter & Spring.
- NO changes to thermostatic setpoint were used.
- Potential to support electrification in cool climates

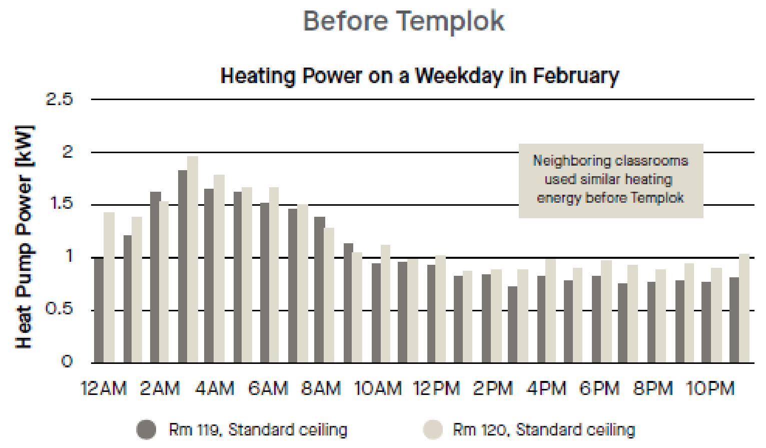
Regulating Indoor Temperature



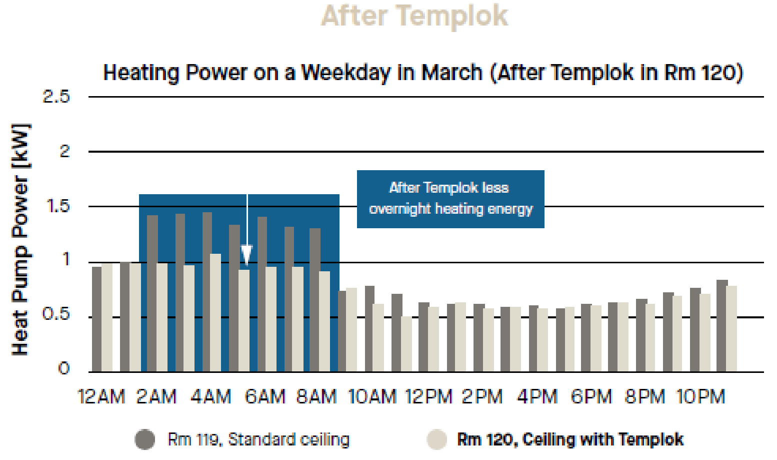
(Fig A)

Table 2: Estimated reduction in heating power due to the PCM variable (Second floor, Winter and Spring)

Condition	Estimate	P-value	Adjusted R^2	% Reduction
Winter (3/13-4/4) - Day Hours (8 a.m. - 8 p.m.)	-0.001 (P < C)	> 0.05	0.72	--
Winter (3/13-4/4) - Night Hours (9 p.m. - 7 a.m.)	-0.032 (P < C)	< 0.05	0.71	7%
Spring (4/5-5/5) - Day Hours (8 a.m. - 8 p.m.)	-0.001 (P<C)	> 0.05	0.59	--
Spring (4/5-5/5) - Night Hours (9 p.m. - 7 a.m.)	-0.018 (P<C)	< 0.05	0.78	9%



(Fig B)



(Fig C)

Applications:

Field Studies Under Way

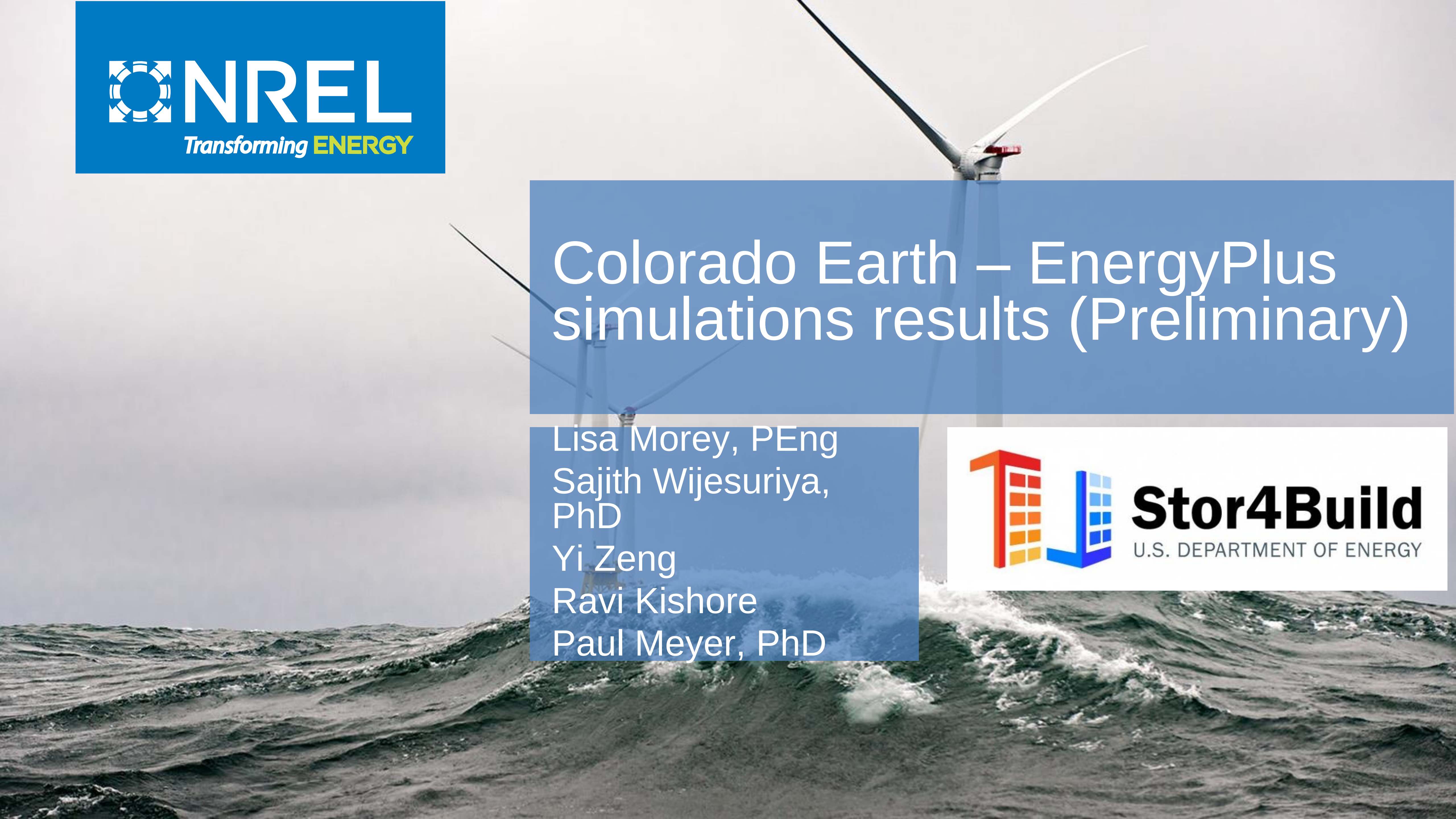
New York Public Library Branch

- 5,000 SF building
- Heating + cooling from two RTUs
- No BMS – local thermostat control
- High energy use intensity
- Poor thermal comfort in winter
- Existing 2x4 tiles in poor condition

Manhatten Office Building – Temperature Management

- Commercial office building
- Pilot to be perimeter 15th floor offices
- Poor temperature control throughout building due to solar gains.
- Focus of pilot is thermal comfort improvements





NREL Transforming ENERGY

Colorado Earth – EnergyPlus simulations results (Preliminary)

Lisa Morey, PEng
Sajith Wijesuriya, PhD
Yi Zeng
Ravi Kishore
Paul Meyer, PhD

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WEST GATE

U.S. DEPARTMENT OF ENERGY | LEEP

Lab-Embedded Entrepreneurship Program

ENERGY I-CORPS

OTT Office of Technology Transitions

COLORADO SCHOOL OF MINES @150 | 1874-2024

CAPSTONE DESIGN

Our Goals

1. **Reduce overall energy consumption**
2. **Shift peak demand**
3. **Reduce Delta T**
4. **Improve Thermal Comfort for occupants**
5. **Reduce the need for new energy generation**

The EcoBlox

ECOBLOX CONSTRUCTION

DOUBLE WALL SYSTEM

Double wall construction with a 3" gap for loose-fill insulation. Electrical fixtures are placed in the wall during construction, and the two layers of block are tied together with Durawall.

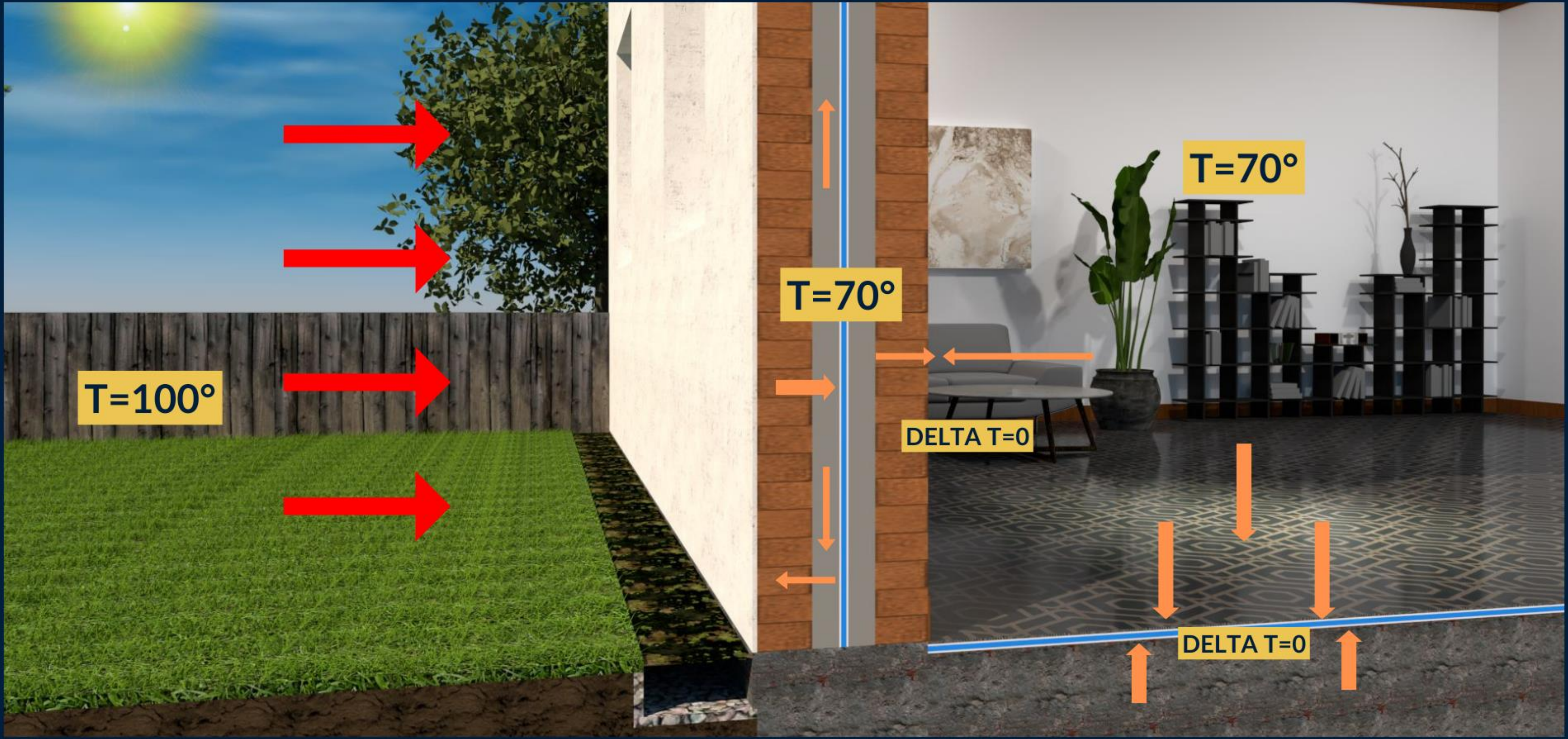
NEXT GENERATION BUILDING STRATEGIES

Thermal Mass
And Low-Embodied Carbon
Materials

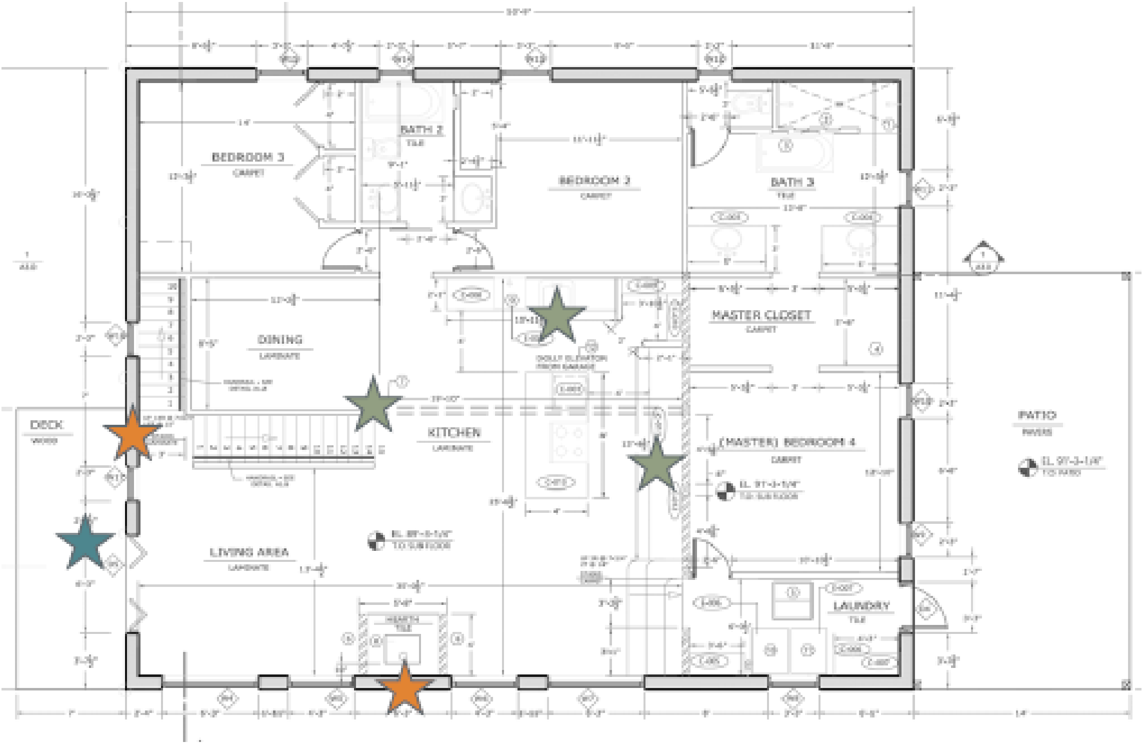
Phase Change Materials

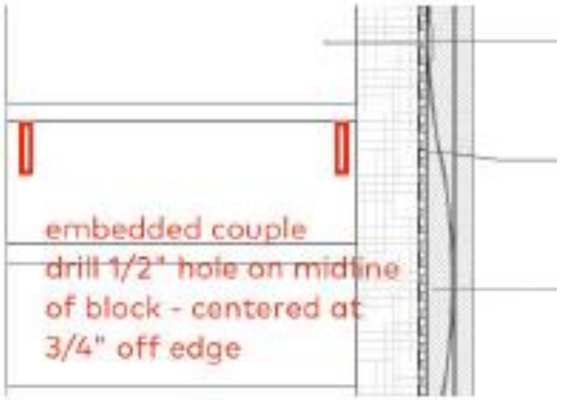
Reflectivity

PASSIVE DESIGN



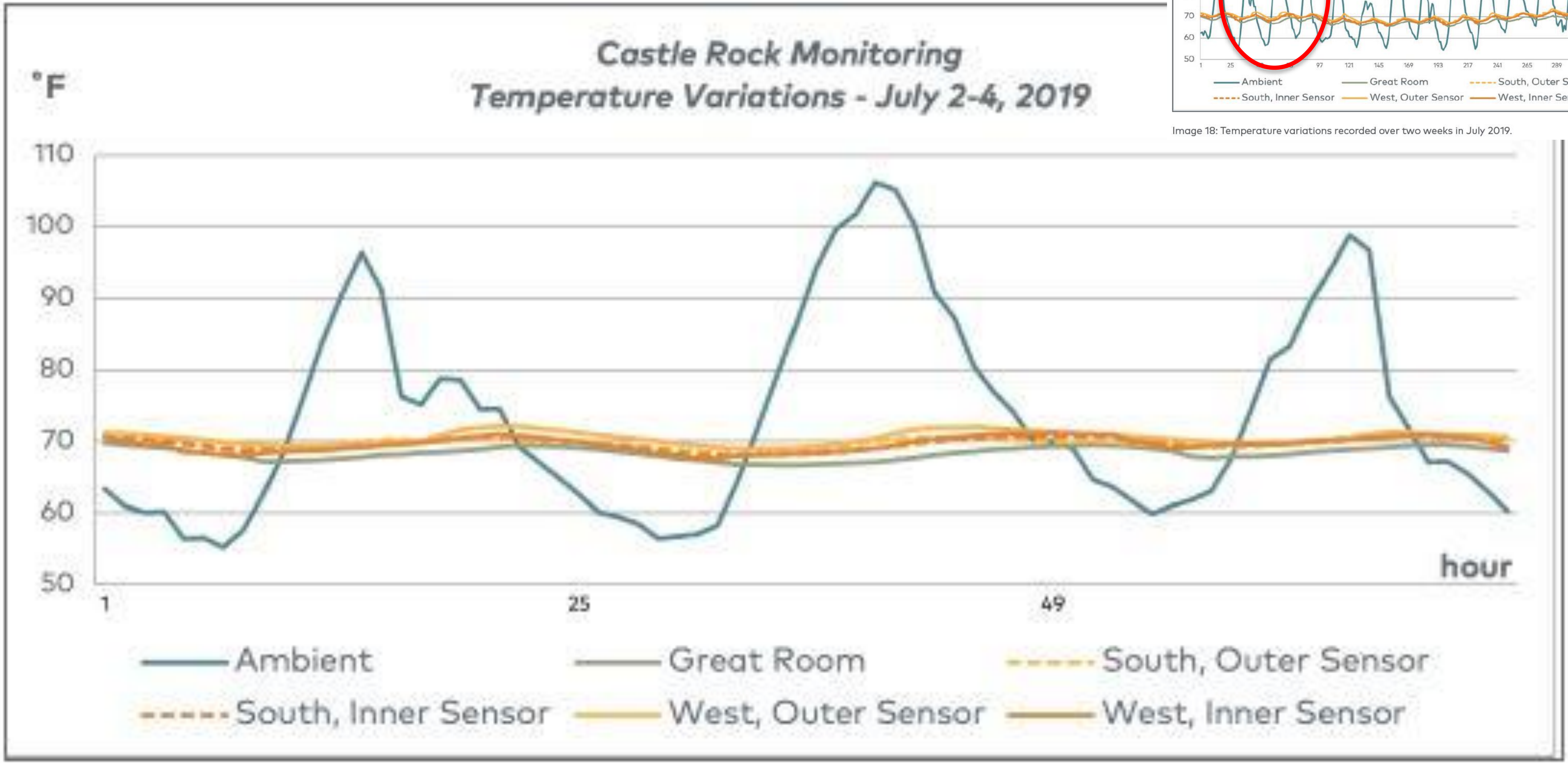
Colorado Residence
Thermal Study
on EcoBlox





CASTLE ROCK MONITORING

July 30, 2021
prepared by Emu Systems
for Colorado Earth
COE001



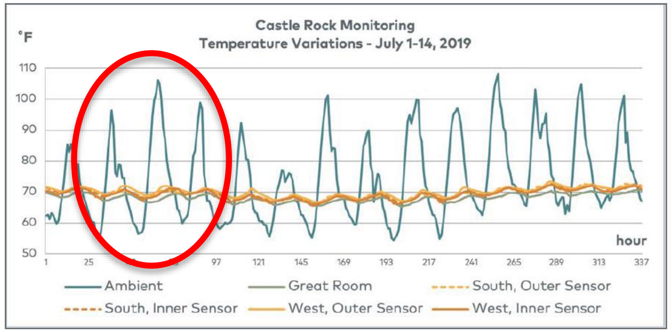


Image 18: Temperature variations recorded over two weeks in July 2019.

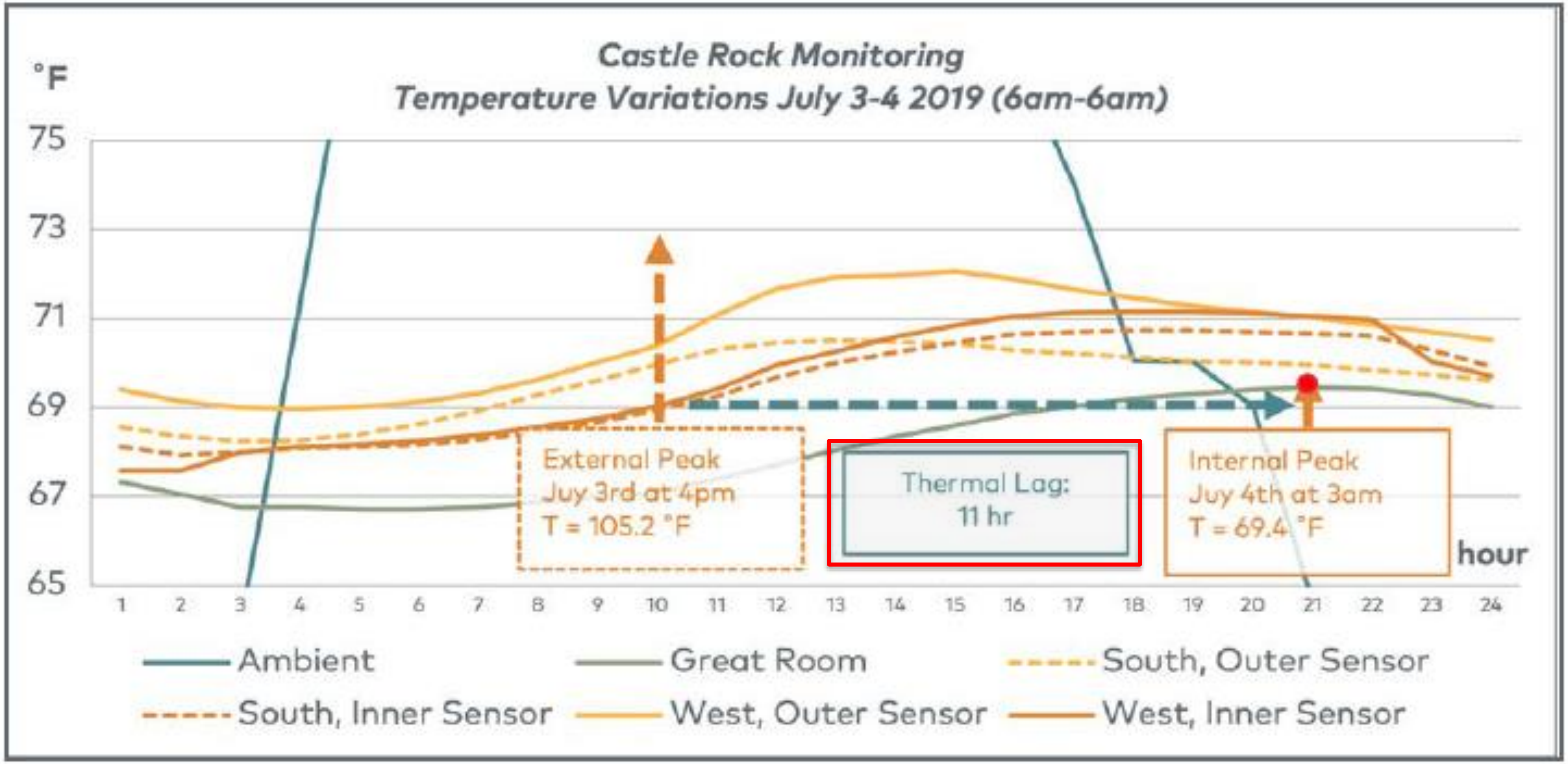
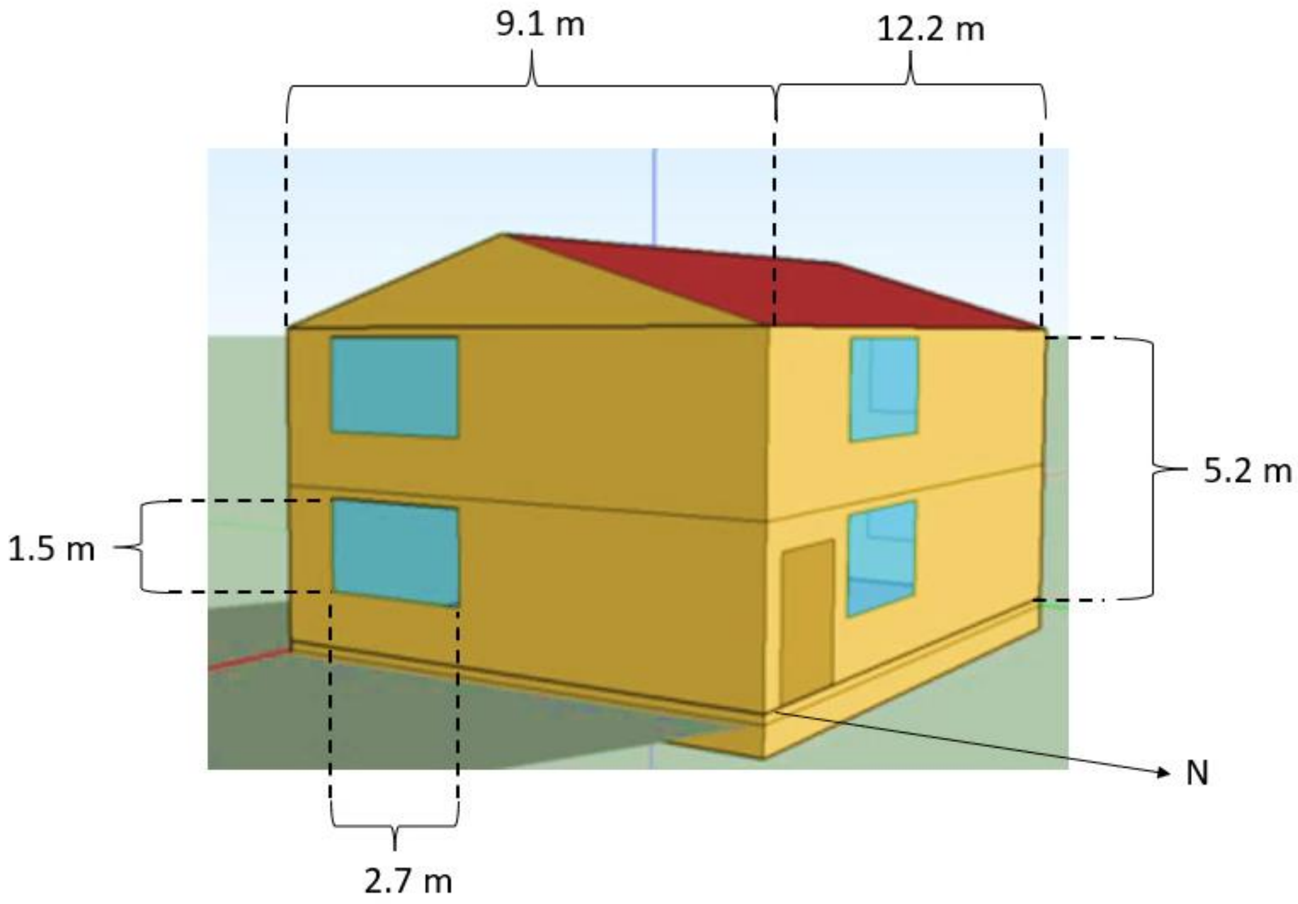


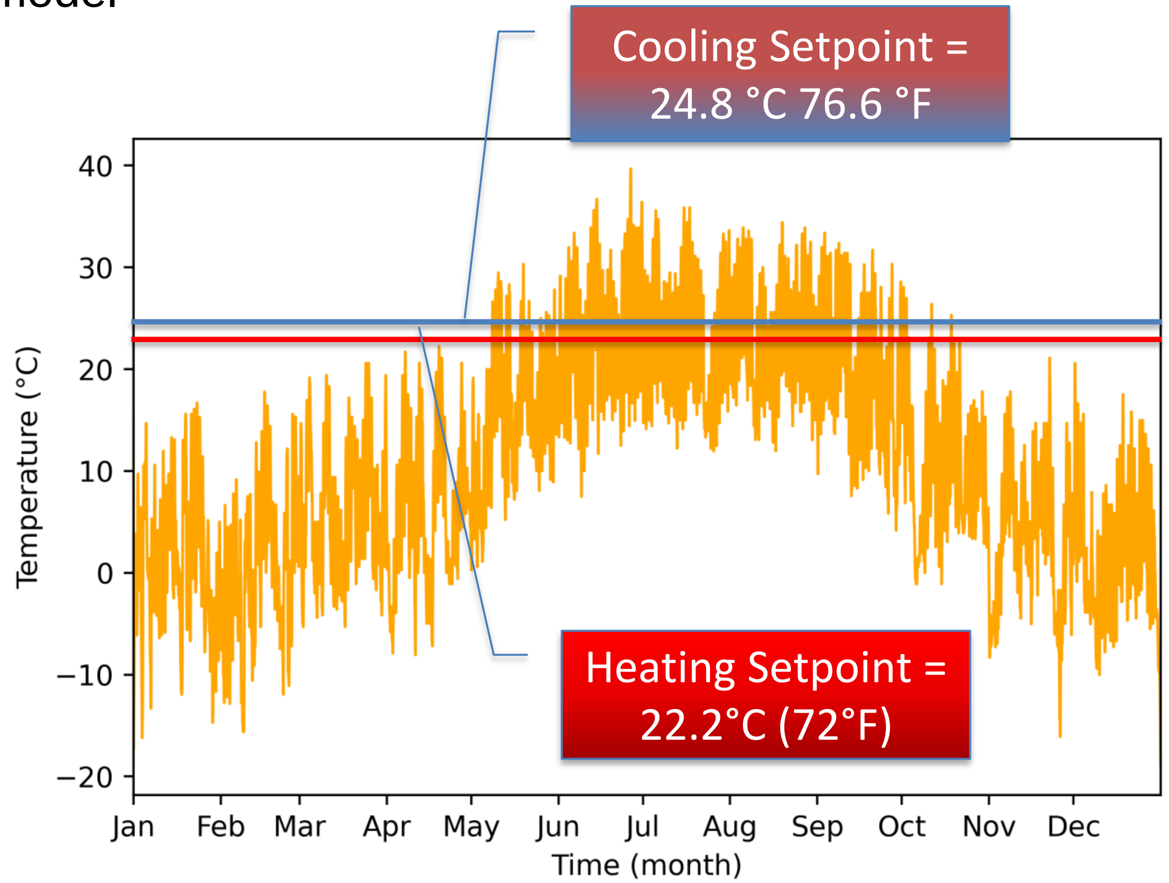
Image 20: Enlarged graph showing the temperature variation over a 24-hour period. The delay and attenuation of the heat wave are highlighted in the graph.

NREL Study using Energy+

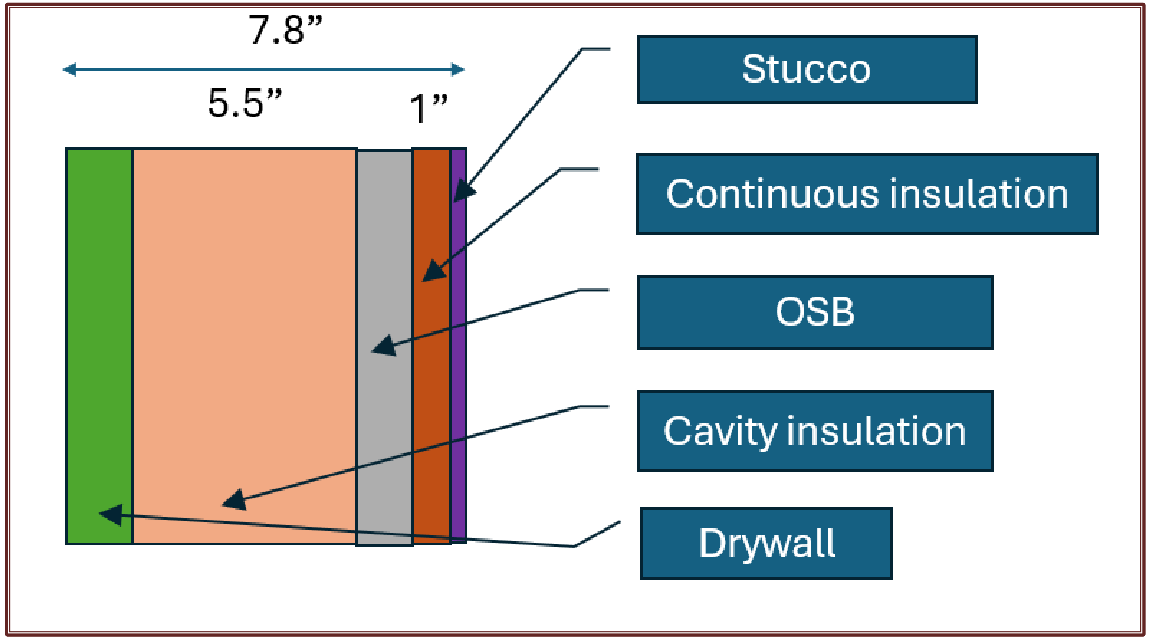
Building model

- IECC 2021 standard prototype building for Denver climate is used
- Only the exterior wall envelopes are changed to reflect the Colorado Earth EcoBlocks integration
- All other conditions are kept the same as the baseline model



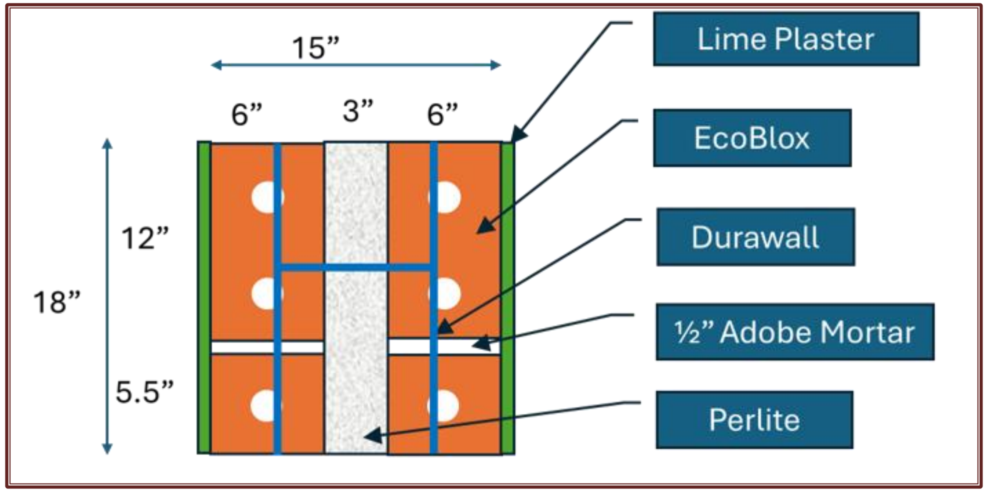


Building exterior wall R-values for different iterations using effective material properties

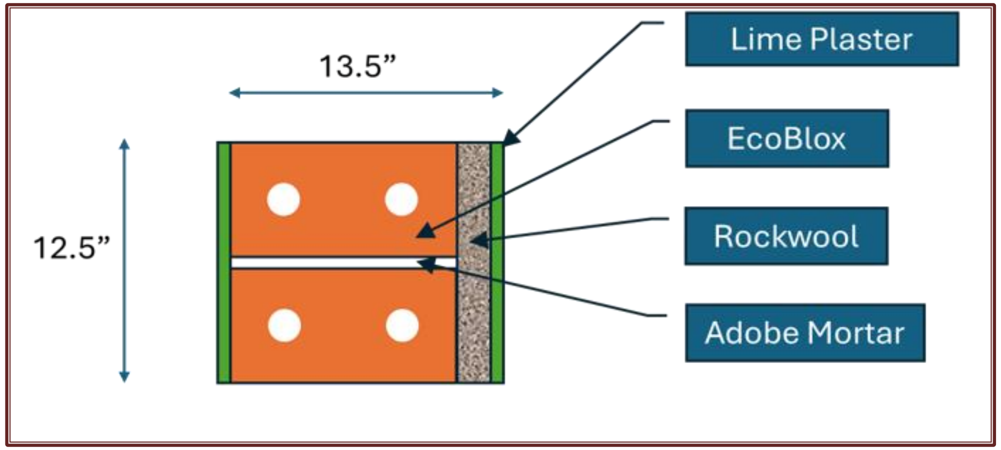


1. Baseline: 2”x6” FRAME Standard prototype building IECC 2021

Effective property values of Density, Specific Heat, Thermal Conductivity for each layer



2. EcoBlock + Perlite layer in the middle

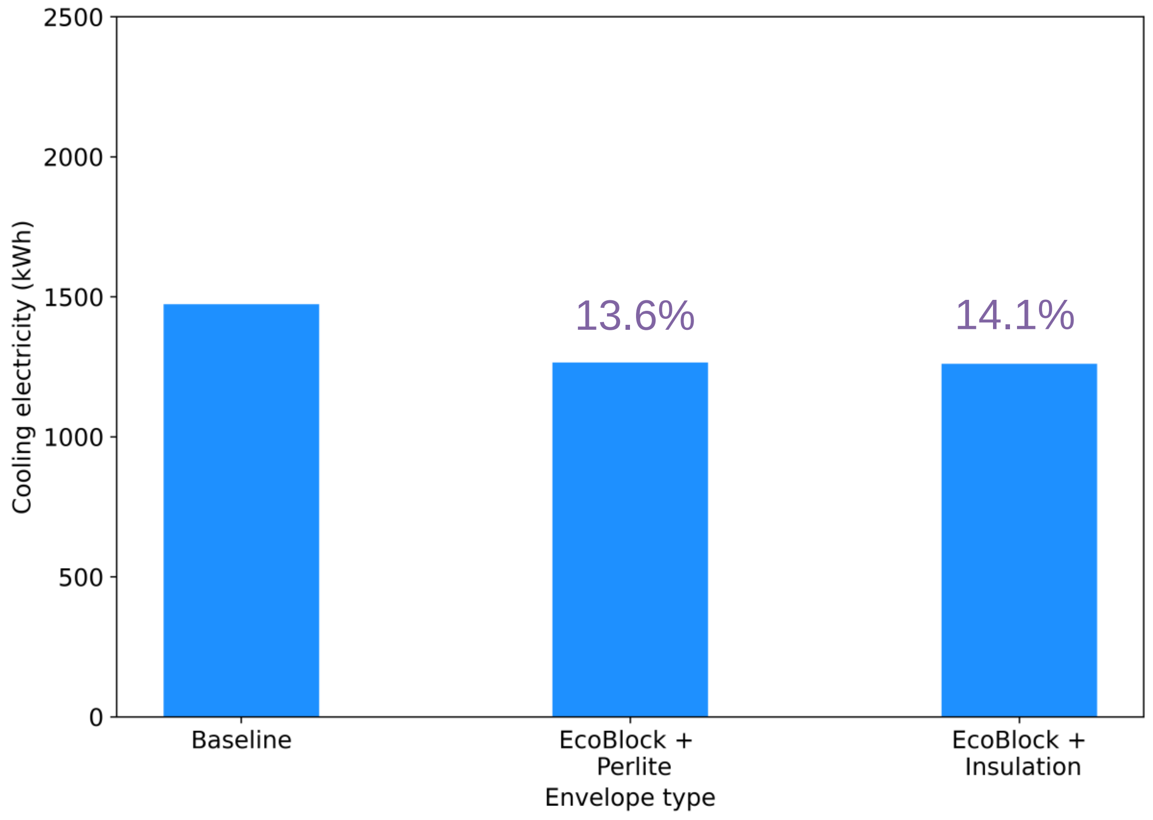


3. EcoBlock + Insulation towards exterior

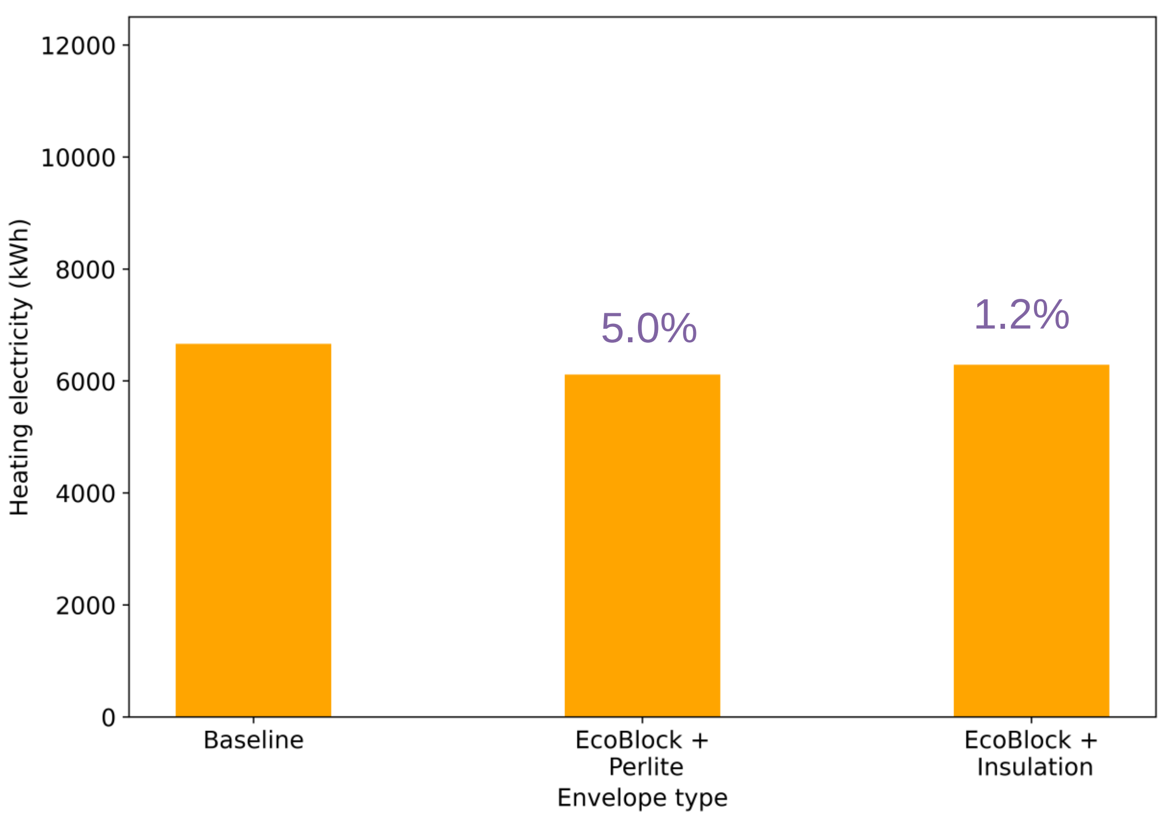
Annual cooling and heating electricity consumption

- Baseline building is the reference IECC envelope
- Building uses a heat pump: electricity for both heating and cooling
- Climate zone 5B, Denver weather is used for simulations

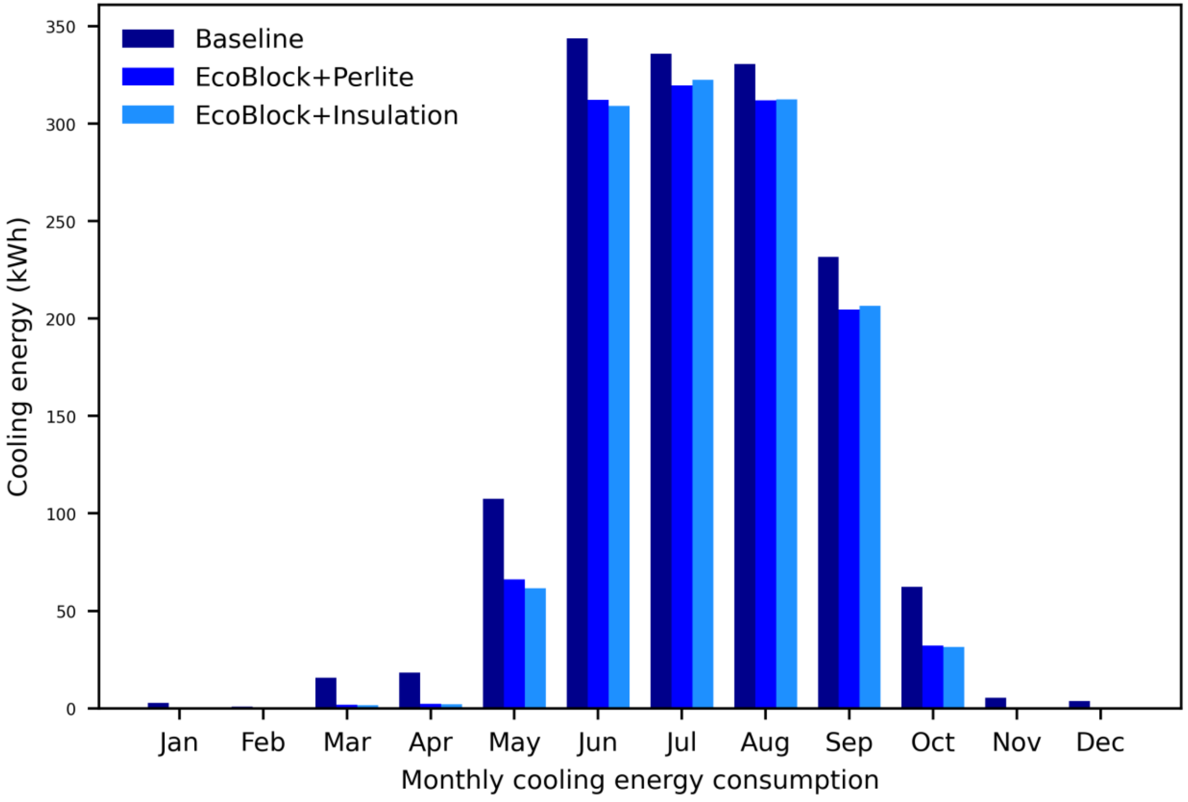
Cooling electricity

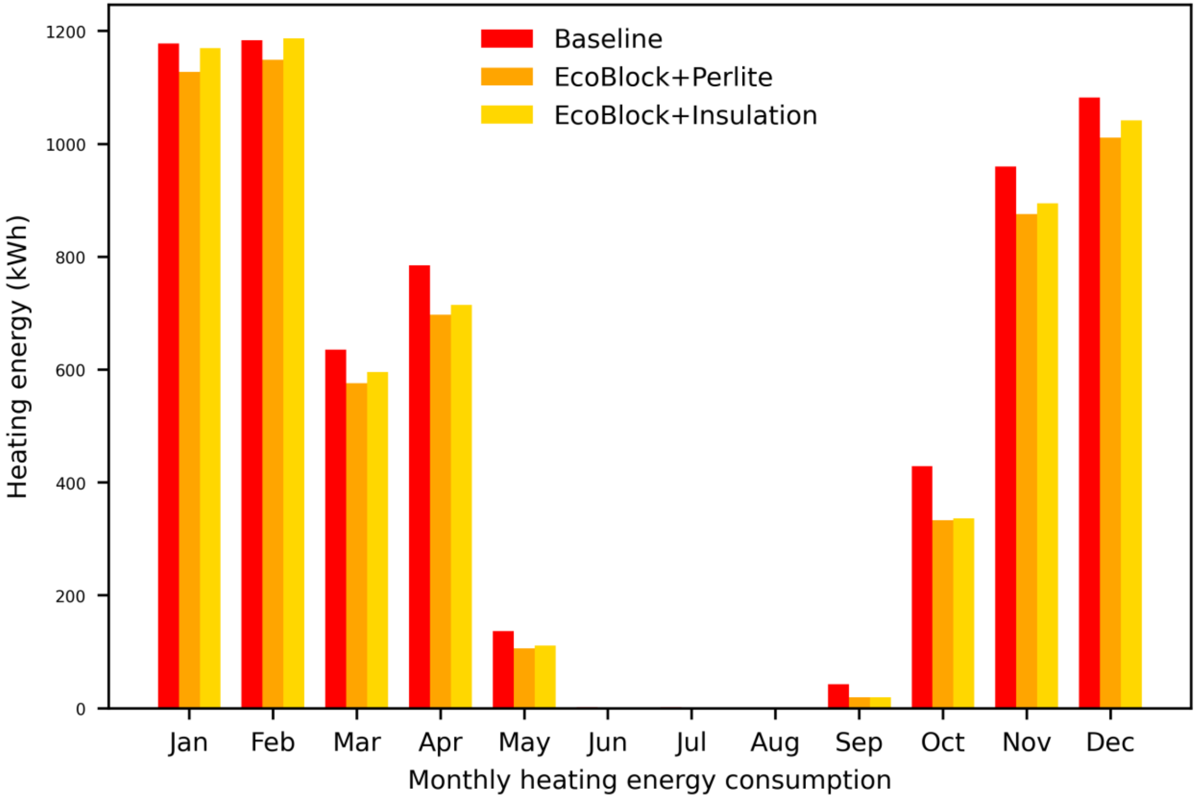


Heating electricity



Monthly energy consumption





Energy Compliance

TABLE R402.1.3 INSULATION MINIMUM *R*-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c, g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c, g] WALL *R*-VALUE
0	NR	0.75	0.25	30	13 or 0&10ci	3/4	13	0	0	0
1	NR	0.75	0.25	30	13 or 0&10ci	3/4	13	0	0	0
2	0.40	0.65	0.25	49	13 or 0&10ci	4/6	13	0	0	0
3	.30	0.55	0.25	49	20 or 13&5ci[h] or 0&15ci[h]	8/13	19	5ci or 13[f]	10ci, 2 ft	5ci or 13[f]
4 except Marine	.30	0.55	0.40	60	30 or 20&5ci[h] or 13&10ci[h] or 0&20ci[h]	8/13	19	10ci or 13	10ci, 4 ft	10ci or 13
5 and Marine 4	0.30[i]	0.55	0.40	60	30 or 20&5ci[h] or 13&10ci[h] or 0&20ci[h]	13/17	30	15ci or 19 or 13&5ci	10ci, 4 ft	15ci or 19 or 13&5ci
6	0.30[i]	0.55	NR	60	30 or 20&5ci[h] or 13&10ci[h] or 0&20ci[h]	15/20	30	15ci or 19 or 13&5ci	10ci, 4 ft	15ci or 19 or 13&5ci
7 and 8	0.30[i]	0.55	NR	60	30 or 20&5ci[h] or 13&10ci[h] or 0&20ci[h]	19/21	38	15ci or 19 or 13&5ci	10ci, 4 ft	15ci or 19 or 13&5ci

In our current IECC there is an allowance for reduced R-values for Mass Walls

The IECC defines mass walls concrete block, concrete, ICF, masonry cavity, brick, adobe, **compressed earth block**, rammed earth, solid timber, mass timber, or solid logs.

The Performance Path

The Ekotrope software - a Home Energy Rating System (HERS) rating software - has a Graphical User Interface (GUI) that allows users to construct the assembly to create the library entry virtually.

Information provided to Energy Rater:

- Insulation materials and the R-Value per assembly
- Window U-Value and Solar Heat Gain Coefficient (SHGC)
- Methods and systems used to heat, cool, and ventilate the home

Steamboat Springs Residence in Climate Zone 7 at 6900 feet elevation

Design exceeded requirements for IECC 2018 Performance compliance by 19.2%

Opportunities

Allow for product concept of EcoBlox to be qualified by climate zone and investigate hygrothermal properties

Understand effectiveness of PCMs

Evaluate of effective heat transfer properties of air and reflectivity

Thank you

www.nrel.gov

Preliminary Data for ORNL Stor4Build Conference

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NREL Transforming ENERGY

Additional Slides

Observations

- Adding EcoBlox in place of insulation reduces the thermal resistance of the exterior wall and can lead to energy penalties due to that.

- High density and the high specific heat capacity increases the thermal mass and reduces thermal diffusivity and therefore yields cooling energy savings for the EcoBlox.

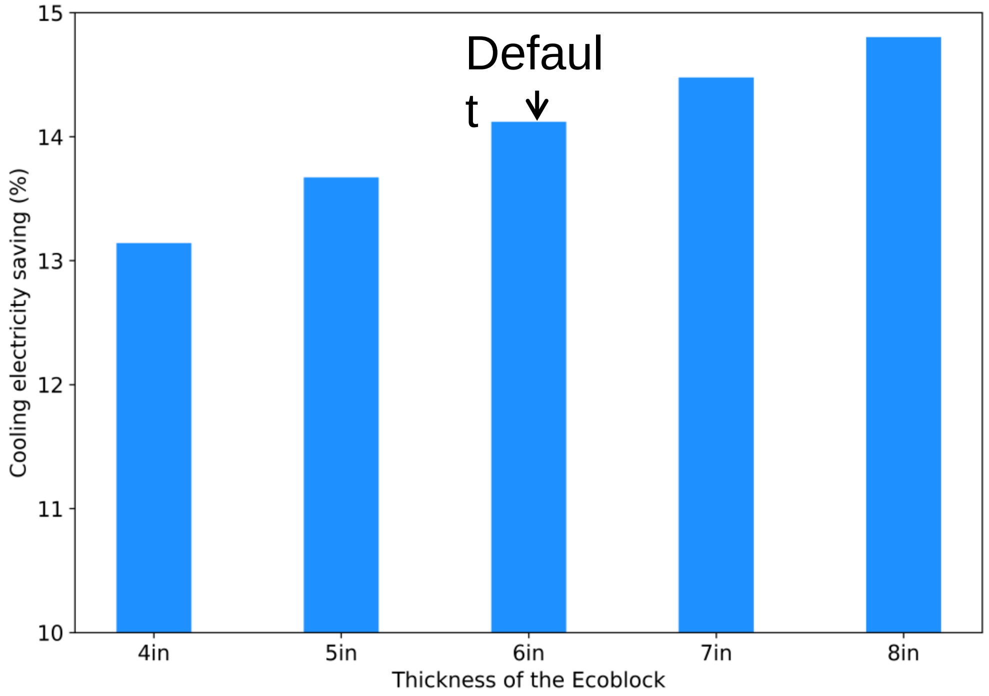
- Adding insulation layer on the exterior side in addition to EcoBlox leads to both cooling and heating savings.

- EcoBlox thickness increase as well as added insulation supports further savings

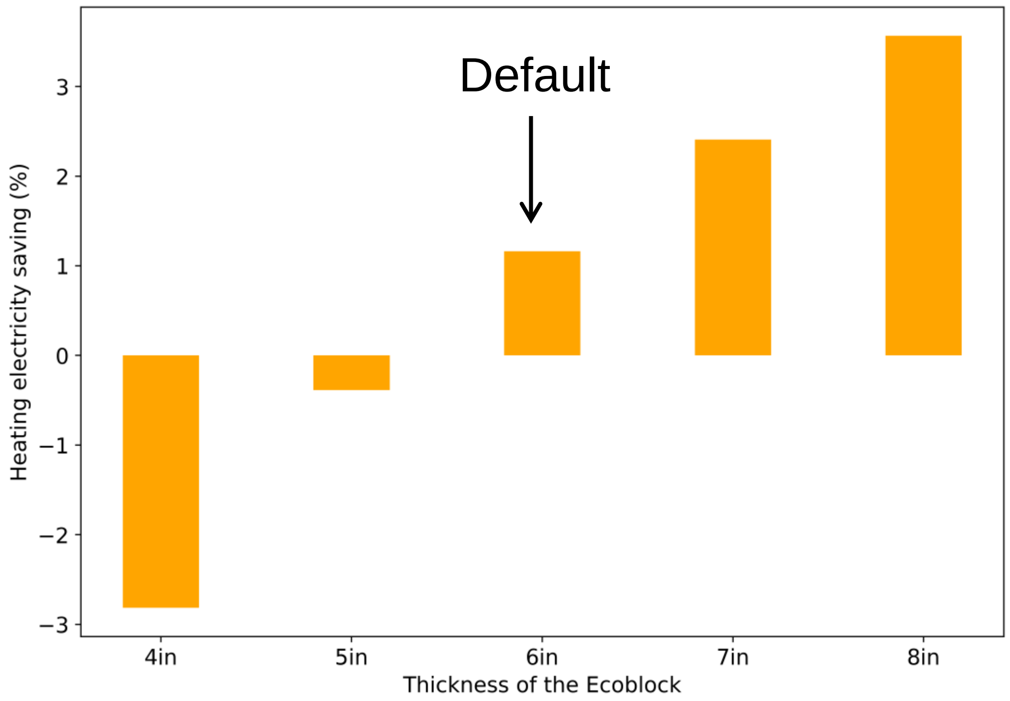
Insulation towards exterior case parametric study

- Above case 5. Colorado Earth: Insulation towards exterior is used to conduct a parametric assessment
- EcoBlock brick thickness is varied here to evaluate cooling and heating electricity savings

Cooling electricity



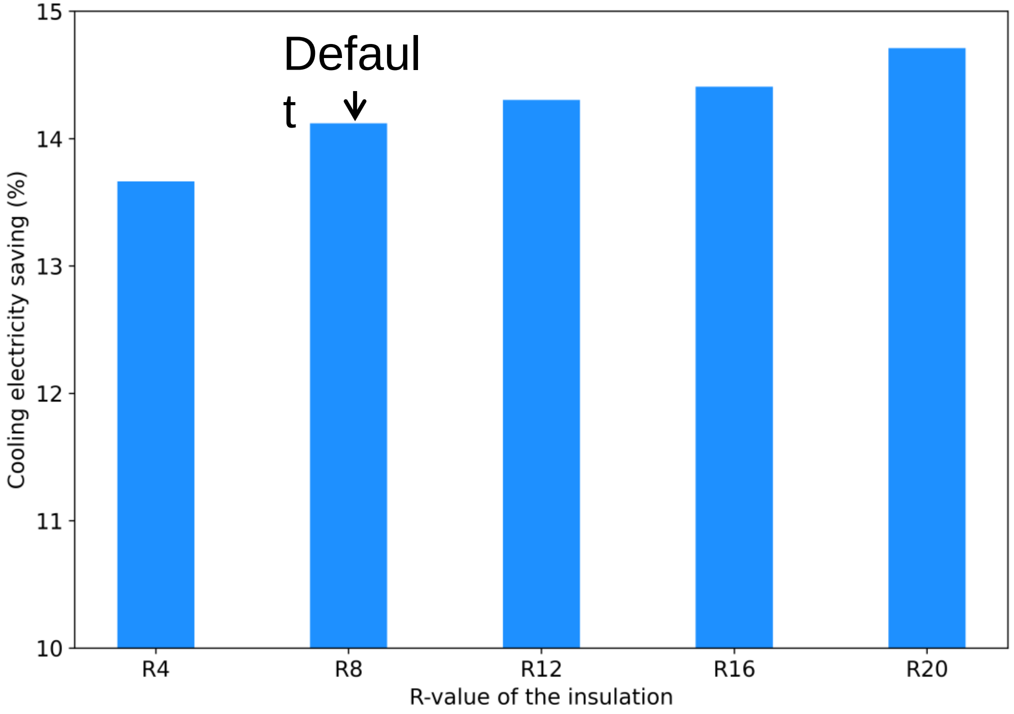
Heating electricity



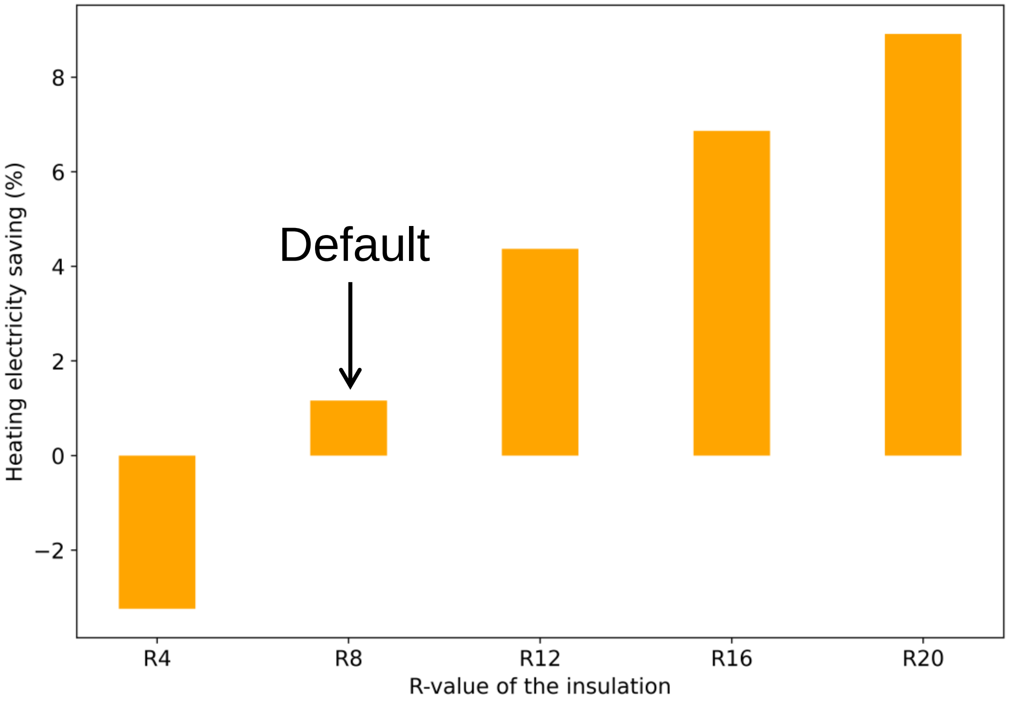
Insulation towards exterior case parametric study

- Above case 5. Colorado Earth: Insulation towards exterior is used to conduct a parametric assessment
- Insulation R-value (ft^2·°F·h/BTU) is varied here to evaluate cooling and heating electricity savings

Cooling electricity

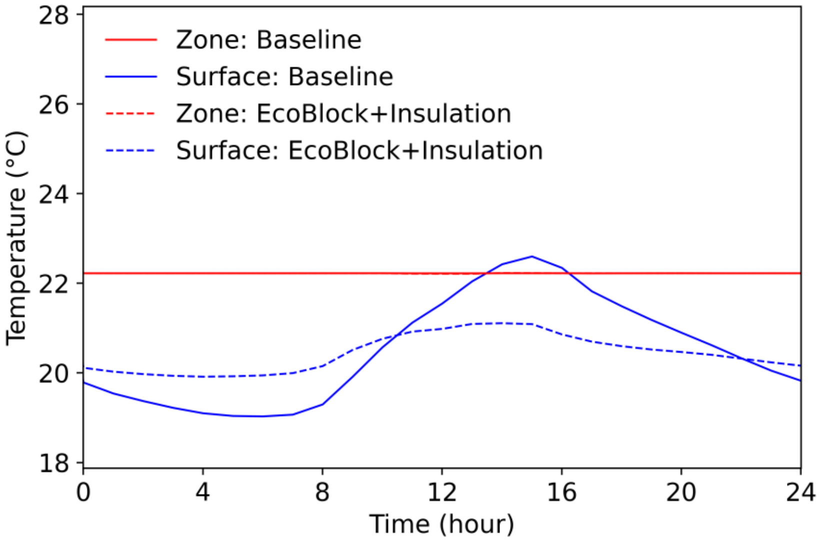


Heating electricity

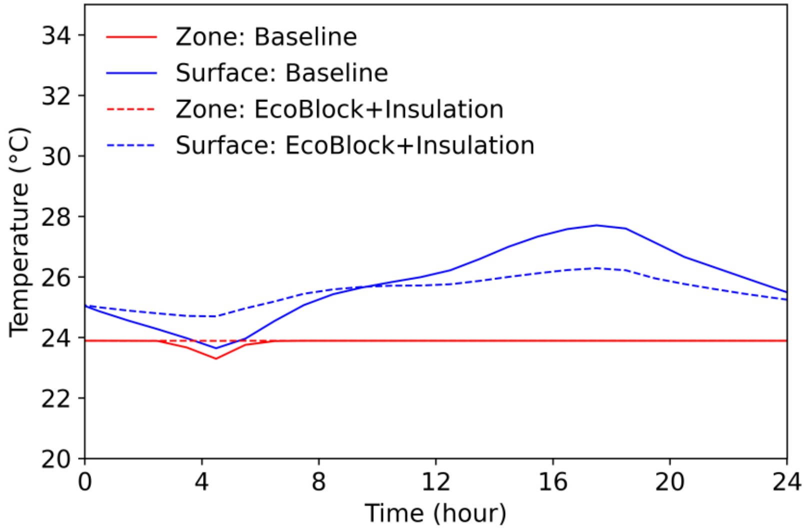


Brick solutions: Zone and wall surface temperature

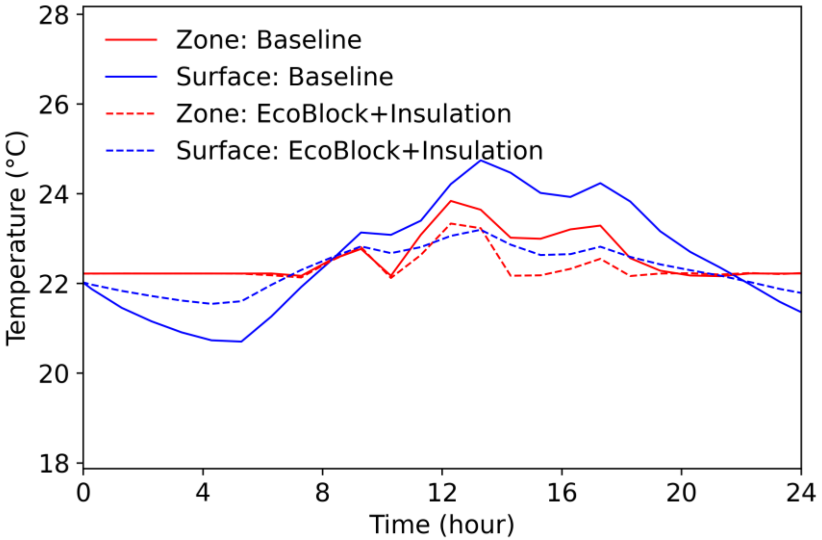
Extreme cold day



Extreme warm day



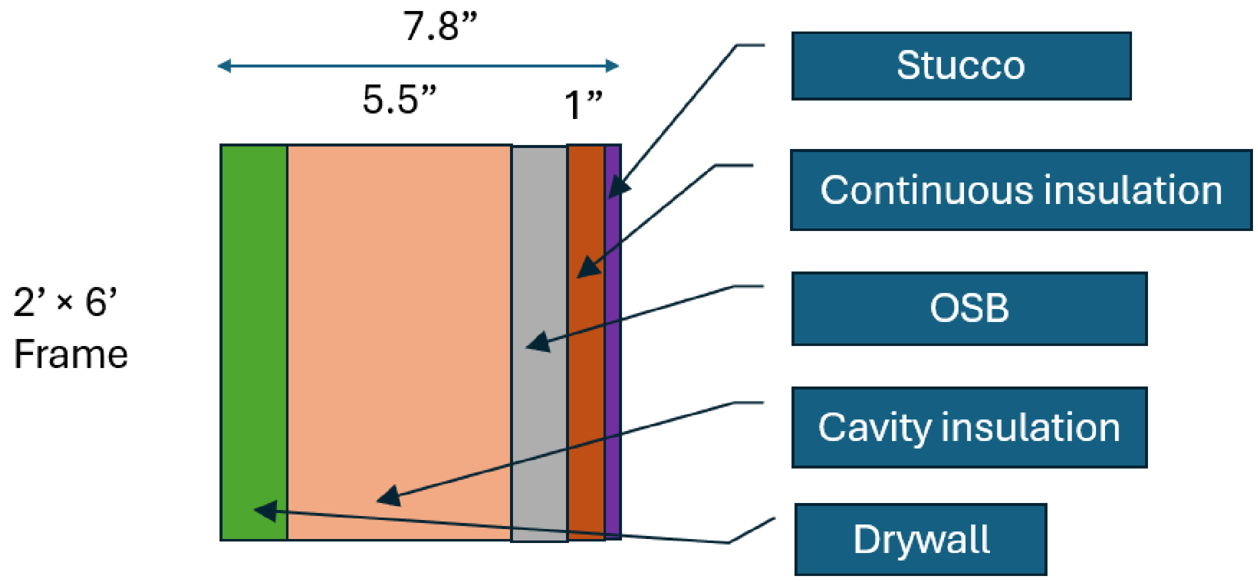
Moderate day



- Wall surface temperature fluctuation reduces due to thermal mass of the EcoBlock
- Brick+Insulation reduces the temperature fluctuation as well as reduces the temperature difference between the wall and the zone

1. Baseline 2x6 Frame

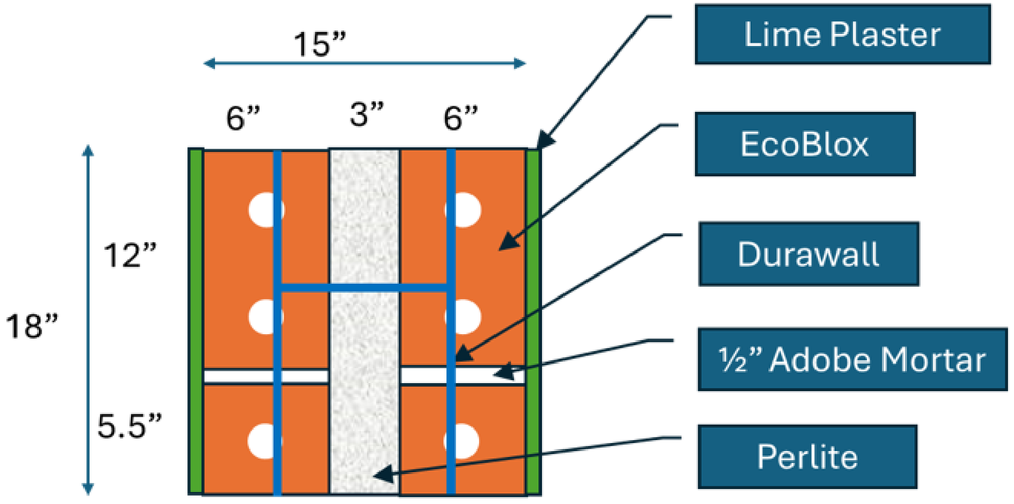
Baseline	Density (kg/m3)	Specific heat (J/kg.K)	thickness (m)	Thermal conductivity (W/m.K)	R-SI (m2·K/W)	R (Ft2·°F·h/BTU)
Syn stucco	400.00	878.64	0.00	0.09	0.04	0.20
Wall sheathing insulation	20.10	1465.42	0.03	0.04	0.88	5.00
OSB	544.62	1213.36	0.01	0.12	0.10	0.54
Wall consol insulation	120.80	1036.30	0.14	0.06	2.44	13.88
Drywall	800.92	1087.80	0.01	0.16	0.08	0.45
SUM			**0.20**		**3.53**	**20.07**

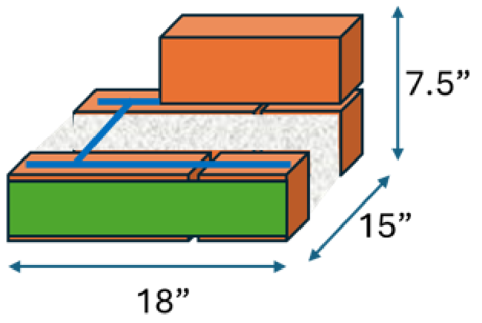


Effective property values for the layer

2. EcoBlox + Perlite cavity

Colorado Earth - perlite	Density (kg/m3)	Specific heat (J/kg.K)	thickness (m)	Thermal conductivity (W/m.K)	R-SI (m2·K/W)	R (Ft2·°F·h/BTU)
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
EcoBlock	2103.66	966.66	0.15	0.14	1.09	6.18
Perlite	**300.00**	**387.00**	**0.08**	**0.04**	**1.91**	**10.82**
EcoBlock	2103.66	966.66	0.15	0.14	1.09	6.18
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
SUM			**0.42**		**4.26**	**24.17**

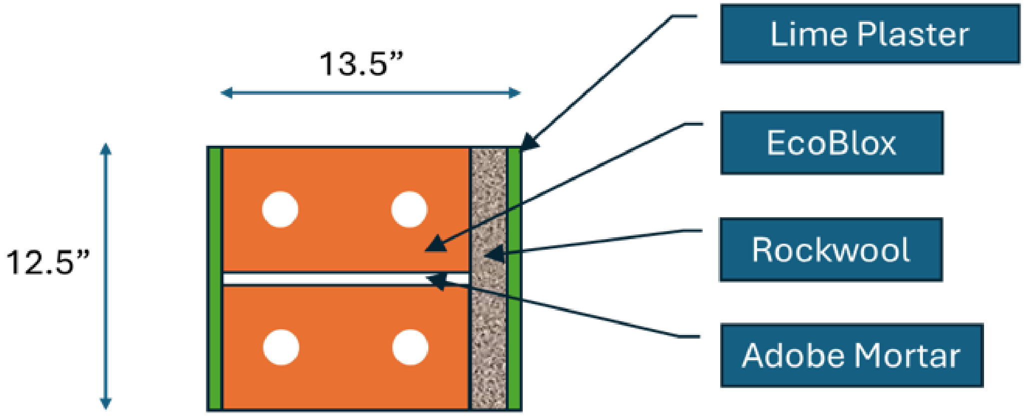


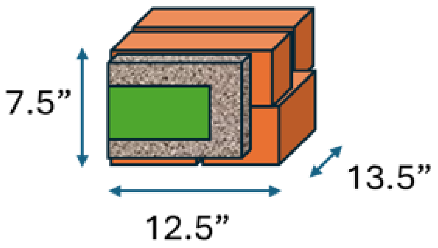


Effective property values for the layer

3. EcoBlox + Exterior Insulation

Colorado Earth - with insulation	Density (kg/m3)	Specific heat (J/kg.K)	thickness (m)	Thermal conductivity (W/m.K)	R-SI (m2·K/W)	R (Ft2·°F·h/BTU)
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
Rockwool insulation	120.00	1036.30	**0.05**	0.04	1.41	8.01
EcoBlock	2103.66	966.66	0.15	0.14	**1.09**	**6.18**
EcoBlock	2103.66	966.66	0.15	0.14	1.09	6.18
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
SUM			**0.40**		**3.76**	**21.37**



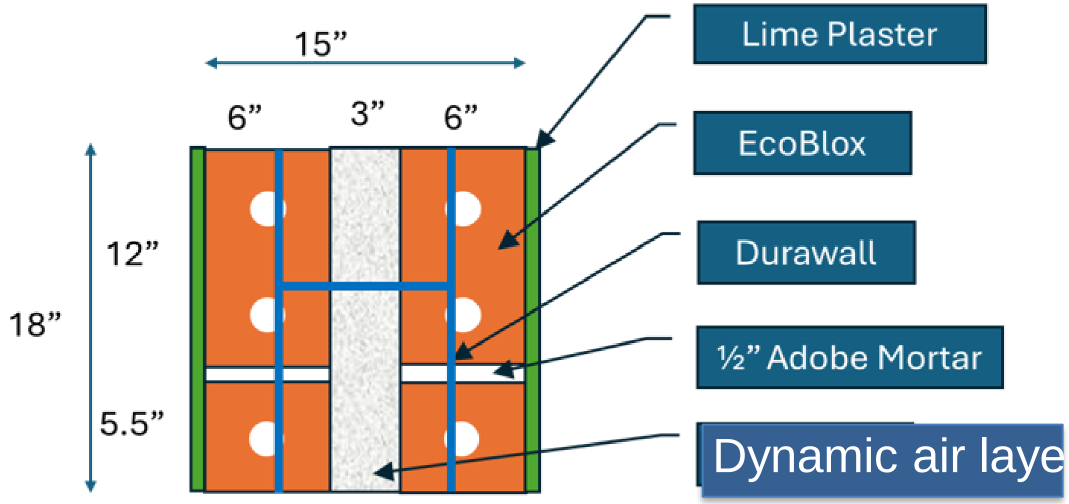


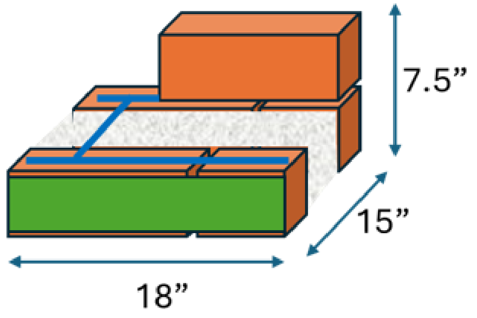
Effective property values for the layer

Dynamic Air Layer

2. Colorado Earth: Air layer with movement

Colorado Earth - air moving	Density (kg/m3)	Specific heat (J/kg.K)	thickness (m)	Thermal conductivity (W/m.K)	R-SI (m2·K/W)	R (Ft2·°F·h/BTU)
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
EcoBlox	2103.66	966.66	0.15	0.14	1.09	6.18
Air layer with movement	**1.28**	**1006.00**	**0.03**	**41.00**	0.00	0.00
EcoBlox	2103.66	966.66	0.15	0.14	1.09	6.18
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
SUM			**0.37**		**2.35**	**13.36**



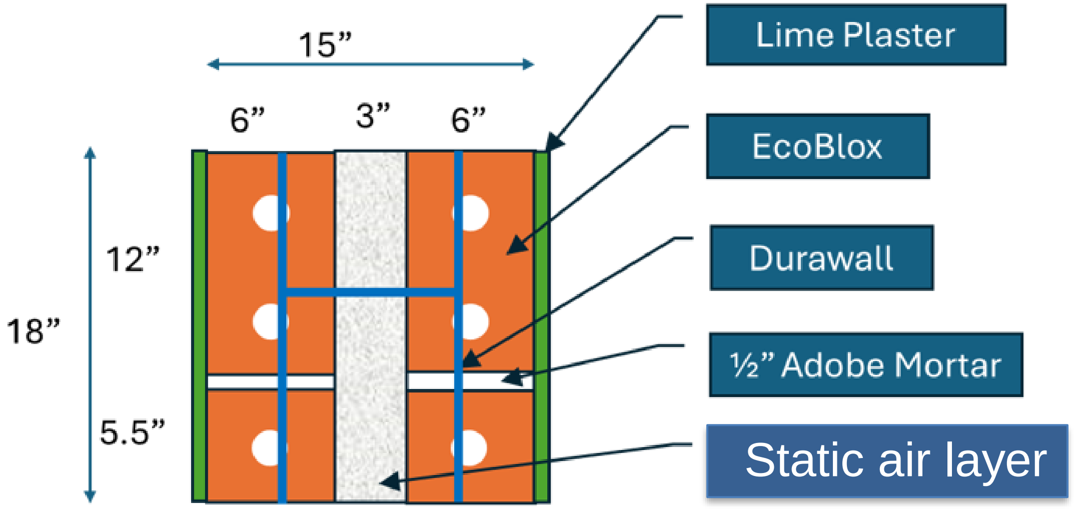


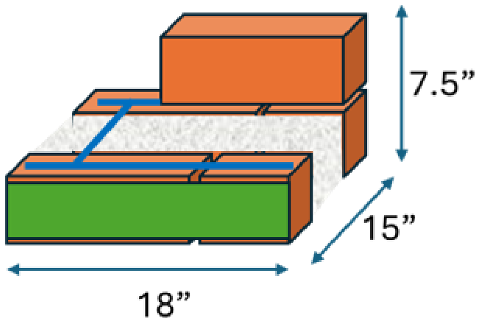
Effective property values for the layer

Static Air Layer

3. Colorado Earth: Static air layer

Colorado Earth- static air	Density (kg/m3)	Specific heat (J/kg.K)	thickness (m)	Thermal conductivity (W/m.K)	R-SI (m2·K/W)	R (Ft2·°F·h/BTU)
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
EcoBlox	2103.66	966.66	0.15	0.14	1.09	6.18
Air layer static	**1.28**	**1006.00**	**0.08**	**0.02**	**3.13**	**17.77**
EcoBlox	2103.66	966.66	0.15	0.14	1.09	6.18
Lime plaster	1700.00	900.00	0.02	0.25	0.09	0.50
SUM			**0.42**		**5.48**	**31.12**





Effective property values for the layer

Energy Compliance

Home Energy Rating Certificate
Final Report

Rating Date: 2024-06-20
Registry ID: 148730816
Ekotrope ID: vob3QKXd

HERS® Index Score:

-4

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

Annual Savings

$4,057

*Relative to an average U.S. home

Home:
181 Mohawk Cir
Superior, CO 80027

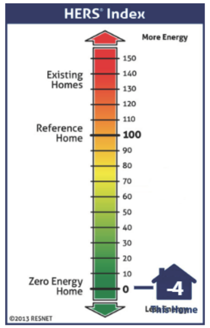
Builder:
Matteo Rebeschini

Your Home's Estimated Energy Use:

	Use [MBtu]	Annual Cost
Heating	20.5	$548
Cooling	1.2	$39
Hot Water	2.8	$79
Lights/Appliances	25.3	$732
Service Charges		$50
Generation (e.g. Solar)	-54.0	-$1,398
Total:	**-4.3**	**$50**

This home meets or exceeds the criteria of the following:

ENERGY STAR v3.2
ENERGY STAR v3.1
ENERGY STAR v3
2021 International Energy Conservation Code



Home Feature Summary:

Home Type:	Single family detached
Model:	N/A
Community:	N/A
Conditioned Floor Area:	3,295 ft^2
Number of Bedrooms:	6
Primary Heating System:	Air Source Heat Pump • Electric • 10 HSPF
Primary Cooling System:	Air Source Heat Pump • Electric • 18.5 SEER
Primary Water Heating:	Residential Water Heater • Electric • 4 Energy Factor
House Tightness:	507 CFM50 (0.80 ACH50)
Ventilation:	87 CFM • 62 Watts • ERV
Duct Leakage to Outside:	Forced Air Ductless
Above Grade Walls:	R-17
Ceiling:	Vaulted Roof, R-60
Window Type:	U-Value: 0.15, SHGC: 0.24
Foundation Walls:	R-20
Framed Floor:	R-49

Rating Completed by:

Energy Rater: Max Nuttelman
RESNET ID: 3685830

Rating Company: Energy Innovations

Rating Provider: Building Efficiency Resources
PO Box 1769 Brevard, NC 28712
800-399-9620

Max Nuttelman

Max Nuttelman, Certified Energy Rater
Date: 6/25/24 at 2:05 PM

ekotrope

Ekotrope RATER - Version:4.0.2.3425
The Energy Rating Disclosure for this home is available from the Approved Rating Provider.
This report does not constitute any warranty or guarantee.

Blower Door Test

0.7 ACH 50

Basic Terminology

Thermal Mass = Thermal Capacity = ability of a material to absorb, store and release heat while experiencing a temperature change. Direct relationship to density and specific heat. The IECC defines mass walls -> heat capacity of at least 6 Btu/ft2 x oF (123 kJ/m2 x K)

The higher the **specific heat**, the more energy a material can store with the same temperature change.

Density is related to the volume of a material – the more density, the thinner the material can be. The greater the density of a material, the more energy is required to change the temperature.

Thermal lag = time lag = the rate at which a material absorbs and releases heat, and the temperature change over time. Response of temperature from the surface of the exterior wall to the interior surface of the wall.

Performance vs Prescriptive method of the Energy code

Latent Heat = the amount of energy needed to cause a phase change in a material

The IECC defines mass walls concrete block, concrete, ICF, masonry cavity, brick, adobe, **compressed earth block**, rammed earth, solid timber, mass timber, or solid logs.