

October 31st & November 1st

VIRGINIA ENERGY EFFICIENCY COUNCIL





October 31, 2022

ENERGY EFFICIENCY FORUM



Proof of Concept

High Performance Window Update

Robert Hart, Berkeley Labs

Katie Henderson, Efficient Homes (moderator)





Diverse multi-family housing types













 $\hbox{*pictures gathered from Google search for "multi-family housing"}$

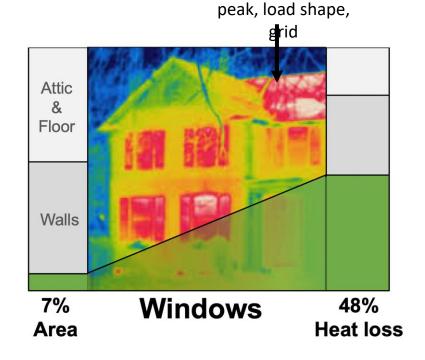
Why Windows Matter

Windows in the Building **Envelope**



Building energy 10 4 % US total energy % 100

%



building envelope

^{*}Apte, J., Arasteh, D., Huang, Y.J. (2003) Future Advanced Windows for Zero-Energy Homes. ASHTRAE Transactions. LBNL-51913

^{**}Based on 2,000 sf 2-story house, IECC 2015

Windows Market Characterization

44 million Single-Pane Homes*



Total windows: **2.4B stock**

24M new construction/year

2020 RECS

*Many homes in cold climates have clear storm windows

Market Characterization



South Atlantic annual residential window sales

New Construction	Replacement
3.7M	3.4M



*2020 Ducker Frontier

Codes and Standards

Current VA code



	200)6	200	9	201	12	201	5	201	8	202	21
Climate Zone	U-factor	SHGC	U-factor	SHGC	U-factor	SHGC	U-factor	SHGC	U-factor	SHGC	U-factor	SHGC
1	1.20	0.40	1.20	0.30	NR	0.25	NR	0.25	NR	0.25	NR	0.25
2	0.75	0.40	0.65	0.30	0.40	0.25	0.40	0.25	0.40	0.25	0.40	0.25
3	0.65	0.40	0.50	0.30	0.35	0.25	0.35	0.25	0.32	0.25	0.30	0.25
4 except Marine	0.40	NR	0.35	NR	0.32	0.40	0.32	0.40	0.32	0.40	0.30	0.40
5 and Marine 4	0.35	NR	0.35	NR	0.32	NR	0.32	NR	0.30	NR	0.30	0.40
6	0.35	NR	0.35	NR	0.32	NR	0.32	NR	0.30	NR	0.30	NR
7 & 8	0.35	NR	0.35	NR	0.32	NR	0.32	NR	0.30	NR	0.30	NR



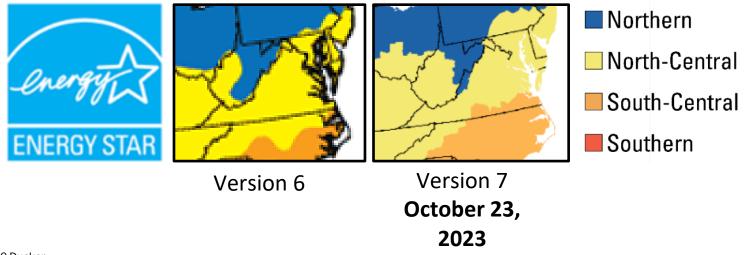
Climate Zone V5 - 2009		V6 - 2015	V7 - 2023
Cililiate Zone	U-factor SHGC	U-factor SHGC	U-factor SHGC
South	≤0.60 ≤0.27	≤0.40 ≤0.25	≤0.32 ≤0.23
South-Central	≤0.35 ≤0.30	≤0.30 ≤0.25	≤0.28 ≤0.23
North-Central	≤0.32 ≤0.40	≤0.30 ≤0.40	≤0.24 ≤0.40
North*	≤0.30 NR	≤0.27 NR	≤0.22 ≥0.17

*See ENERGY STAR specifications for North tradeoffs



U-factor ≤0.20

Energy Star Update



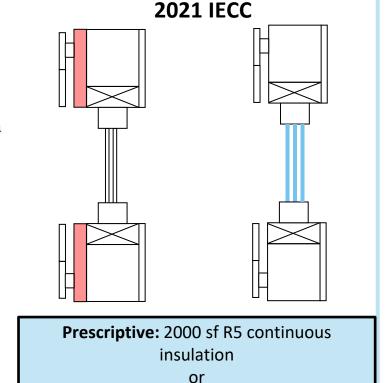
*2020 Ducker Frontier

Codes and Standards – Next Steps

 Demonstrated window wall-trade-off works in CZ-3 and above!

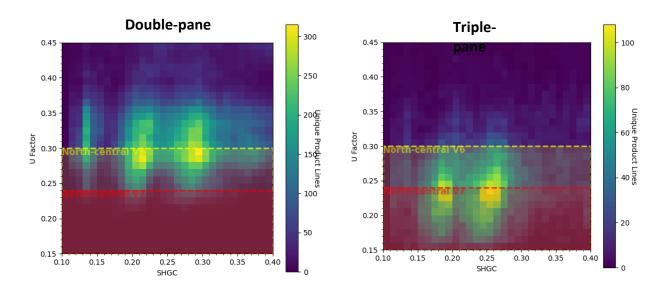
Cort, Katherine, Louie Edward; Hart, Robert. 2022. Using Triple-Pane Windows to Meet IECC Envelope Requirements. ASHRAE Journal 64 (3), 50-58

- **2024 IECC** under consensus committee process Moving to Energy Star v6
- California **T-24 2025** reviewing measures
- 2023 NY Stretch Passive house performance levels



Tradeoff: 300 sf high performance windows

Achieving EnergyStar - Deep Dive



Energy Star Transition Webinars for NFRC:

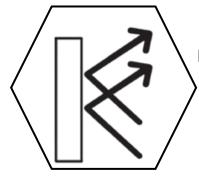
- Frames: https://www.youtube.com/watch?v=SXqoWMQjbMs
- IGUs: https://www.youtube.com/watch?v=-6z1u2_fGx0

Achieving EnergyStar Performance Levels

U-Factor	Most Common Technical Pathways	Incremental Consumer ('Retail') Cost Over the Market Baseline		
		SHGC > 0.25	SHGC ≤ 0.25	
0.32-0.35	1 Low-e coating, air-filled IGU and basic frames	Market Baseline	\$7.50	
0.28-0.31	1 Low-e coating with argon-filled IGU	\$6	\$13.50	
0.27	Low-e coating with argon-filled IGU and improved frames and spacers	\$18	\$25.50	
0.24-0.26	2 Low-e coatings (room-side low-e) with argon-filled IGU	\$29	\$36.50	
0.22-0.23	Triple-pane with 2 low-e coatings and argon-filled IGU	\$54	\$61.50	
0.21 and Below	Triple-pane with room-side low-e, argon- filled IGU, non-metal spacers, and improved and/or foamed frames	\$66	\$73.50	

 $https://www.energystar.gov/sites/default/files/asset/document/V7_Stakeholder%20Meeting_7-27-2021_final.pdf$

Achieving EnergyStar Performance Levels



Room-side Low-e

Widely available Multiple suppliers

Triple-Pane

More than 190 manufacturers with over 400 vertical slider series in NFRC CPD







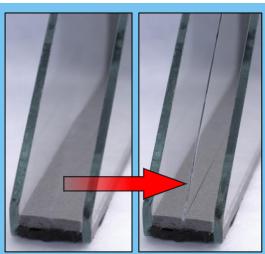


Thin-Triple Window Development



too heavy
too wide
too expensive
long ROI

low entry cost
double performance
minimal weight



Double-pane Thin-triple

Energy Savings Options

Technology	Application	Energy Savings Potential	References
High-R (triple pane) Window Replacements	New and existing homes	7–16% (total energy savings)	Hart, R et. al. 2019 "Thermal performance and potential annual energy impact of retrofit thin-glass triplepane glazing in US residential buildings." Building Simulation 12: 79-86
Secondary Glazing (low- e insulating window panels)	Existing buildings	10–30% (annual HVAC savings)	Culp, T. et al. 2015. Energy Savings of Low-e Storm Windows and Panels across US Climate Zones. Knox and Widder. 2014. Evaluation of Low-e Storm Windows in the PNNL Lab Homes. PNNL.
Interior Insulating Shades and Automation	New and existing homes	5–25% (heating and cooling HVAC savings)	Metzger, C et al 2017. Modeling Cellular Shades in Energy Plus. PNNL. (Cort, KA et. al) 2018. Testing the Performance and Dynamic Control of Cellular Shades. PNNL.
Exterior Shades	South- and west-facing windows	10–20% (cooling HVAC savings)	Hunt and Cort 2020. Evaluation of Exterior Shades at PNNL Lab Homes and Occupied Field Sites. PNNL.



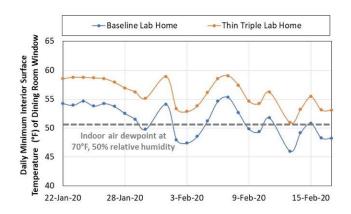


New ENERGY STAR multi-family site in Rotterdam, NY

4 apartment units with thin triple IGUs "dropped in" to double-pane frames,

Condensation Resistance rating increased from 45 to 65 with thin triples

*Courtesy of PNNL



Acoustic testing: Thin triple-pane windows reduced sound infiltration by ~10 dB relative to baseline double-pane windows (6-10 dB reductions are typically perceived as reducing sound by half)



Condensation and ice buildup on existing double-pane window



Same window after replacement with thin triple pane

March 2021 Helena, MT

*Courtesy of PNNL

Demonstrations: CEC GFO 19-307 Advanced Envelope Technologies

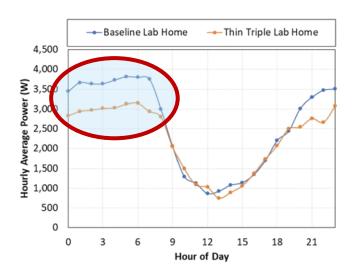




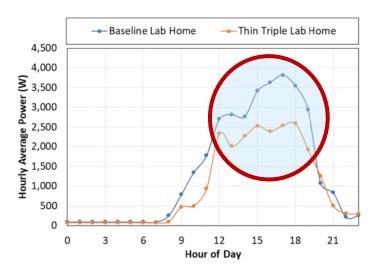


"Testing and demonstrating new building envelope measures with the goal of reducing costs and increasing energy performance for retrofits to existing low-rise multifamily and single family residential buildings..."

Thin-Triple Peak Electrical Load Reduction: 33%



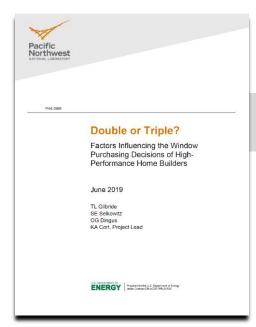
HVAC Load **Heating** Season



HVAC Load **Cooling** Season

*Courtesy of PNNL

Deeper Dive



Elaine Miller, Rick Dunn, John Jennings, Robert Hart, Steve Selkowitz, Katherine Cort, Marc LaFrance, Isaac Smith, Grace Diller, Walt Zalis. 2022. The Launch of the Partnership for Advanced Window Solutions: Give the People What They Want, Window Solutions! ACEEE Summer Study.

Gilbride, Theresa L., Selkowitz, Stephen, Dingus, Olivia G., and Cort, Katherine A. Double or Triple? Factors Influencing the Window Purchasing Decisions of High-Performance Home Builders. doi:10.2172/1557862

Cort, Katherine A., and Gilbride, Theresa L. Field Validation of High-R Windows: Market Assessment and Program Plan. United States: N. p., 2019. Web. doi:10.2172/1558104.

Rowan McCarthy, Katherine Cort, Christian Valoria, Allegra Steenson, Saniya Syed, D. Charlie Curcija and Robert Hart. 2022. Methods to Analyze the Energy Performance of Window Attachnation Acceptable Summer Study.

Robert Hart, Stephen Selkowitz, and Charlie Curcija. 2018. Thermal Performance and Potential Annual Energy Impact of Retrofit Thin-glass Triple-Pane Glazing in US Residential Buildings. Build. Simul. (2019) 12: 79. https://doi.org/10.1007/s12273-018-0491-3

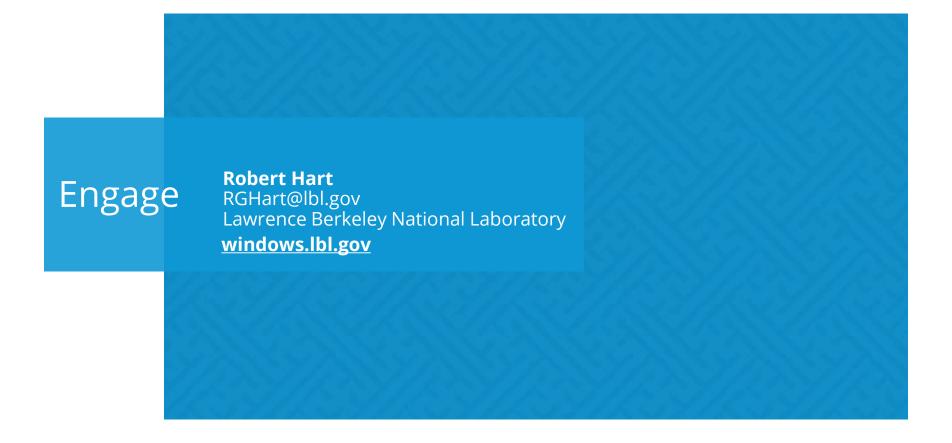
Collaborative Market Transformation



- Launched in July 2021 with 50+ partners including high level of manufacturers interest and support
- Launched 3 (of planned 5) focused workgroups
 - Utility Workgroup: scale program 24 Utility Programs
 - Development of Codes, Standards and Certifications
 - Stakeholder Campaigns and Initiatives
- Launching regional and statewide MT programs in NW, MN
 and IL 35 million customers
- Gained interest on HPW from large production builders



Energy Secretary Jennifer Granholm at Berkeley Lab





TRIPLE PANE WINDOWS

Robert Hart, Berkeley Labs Katie Henderson, Efficient Homes



Proof of Concept

RURAL STUDIO & FRONT PORCH INITIATIVE

Betsy Farrell Garcia, Front Porch Initiative

Mackenzie Stagg, Front Porch Initiative

Brett Hood, CHP Energy Solutions (moderator)







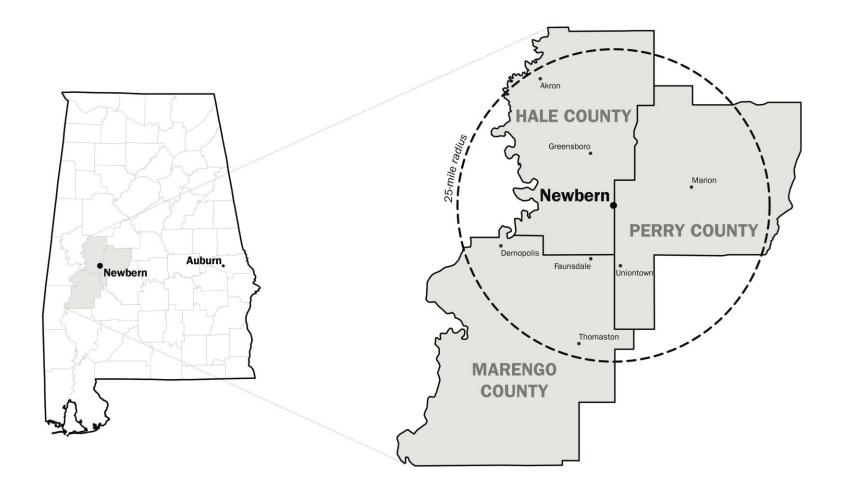




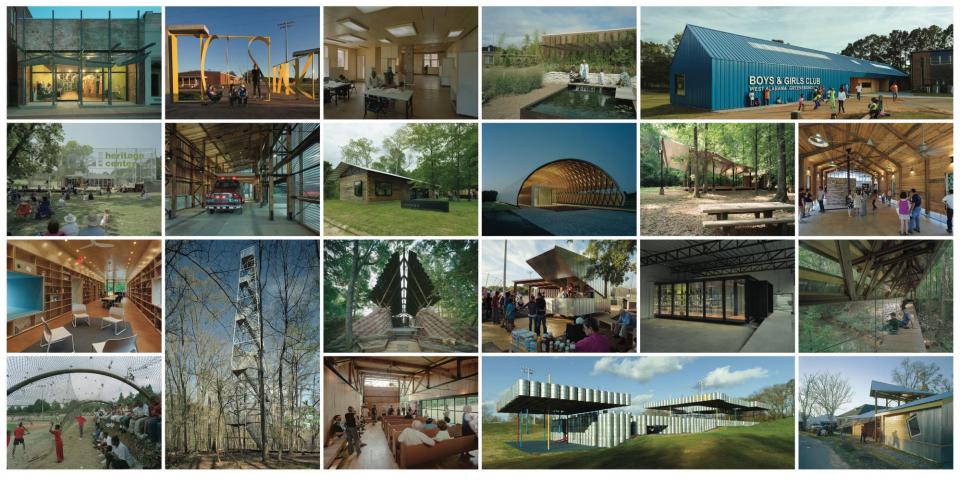


photo © Timothy Hursley





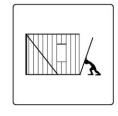












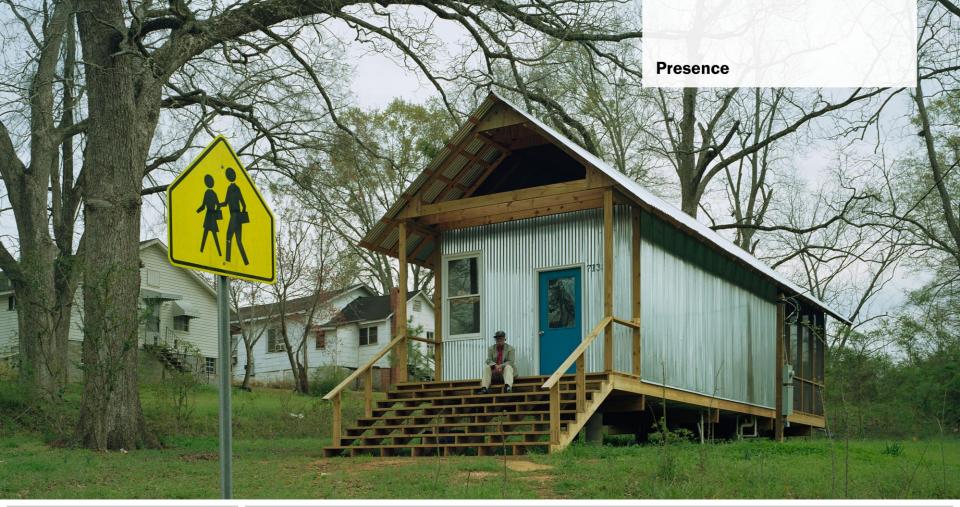
BUILDABLE



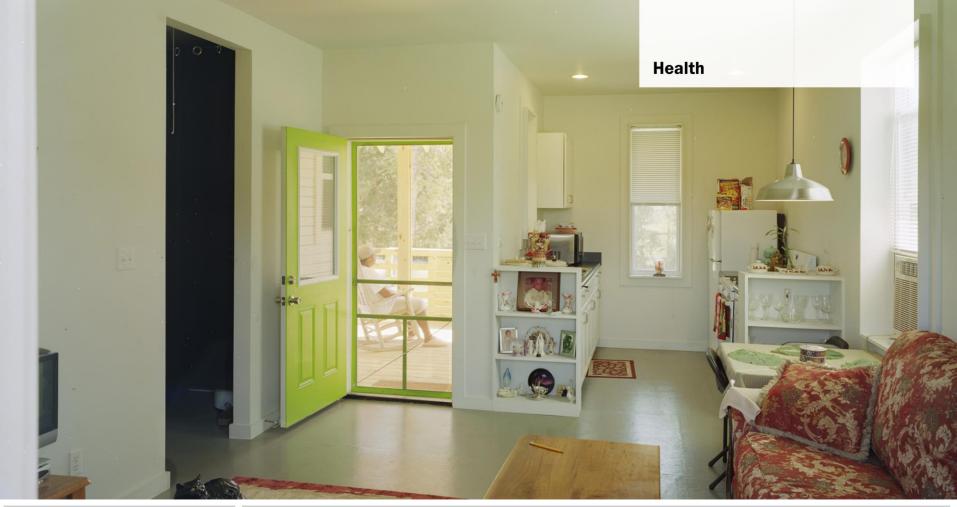
WEATHERPROOF

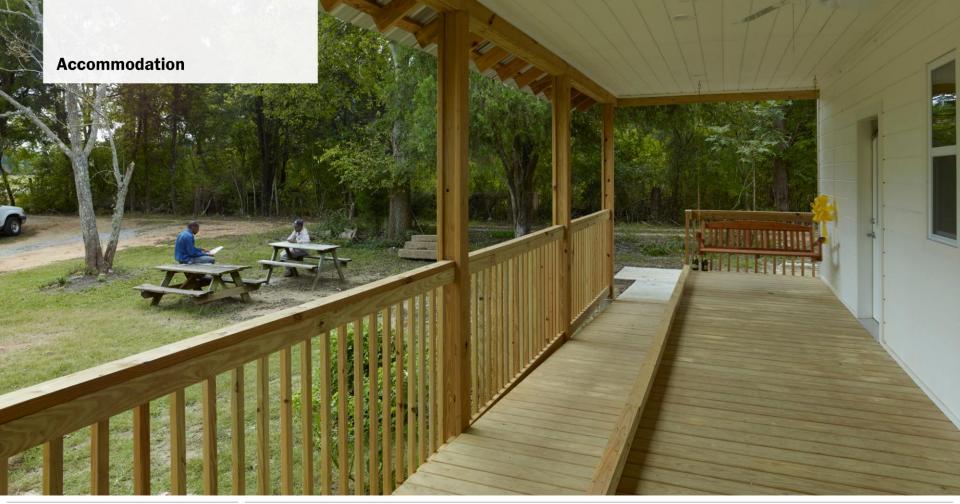


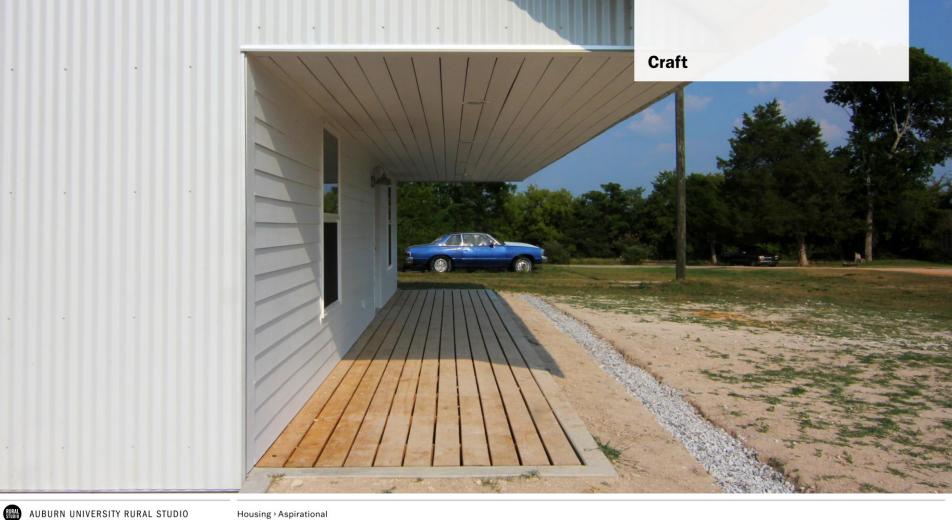
SECURE







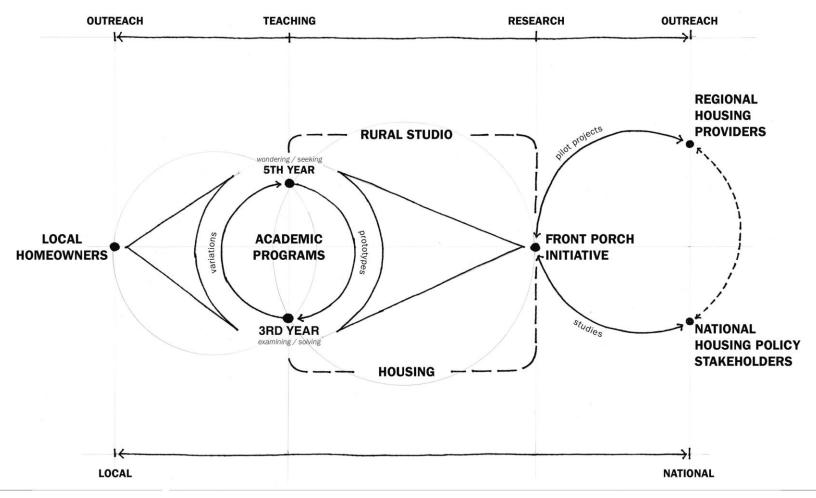


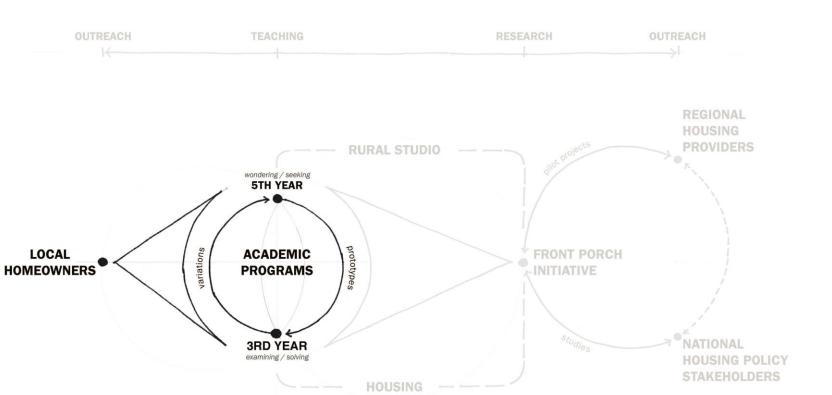




Front Porch Initiative

The Front Porch Initiative seeks to extend the impact of Rural Studio's applied research in housing affordability by developing a scalable, sustainable, and resilient process for delivering homes in under-resourced rural communities.

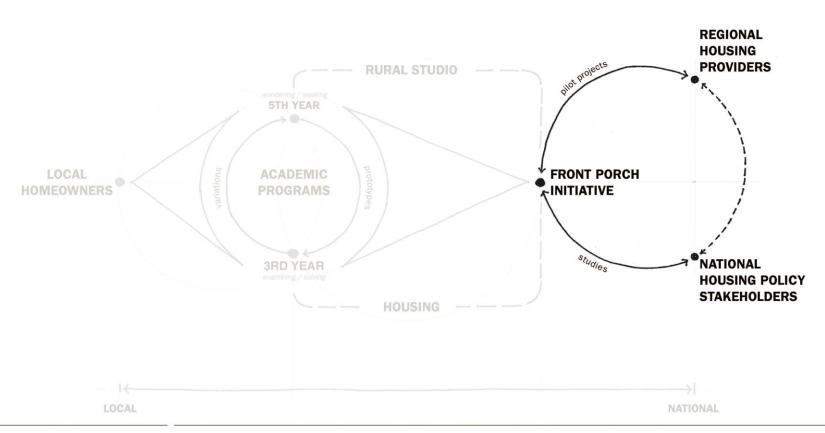


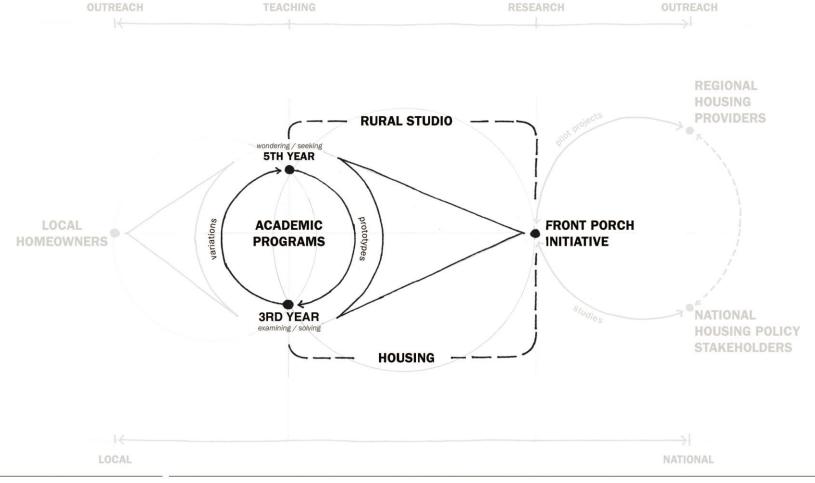


NATIONAL

LOCAL









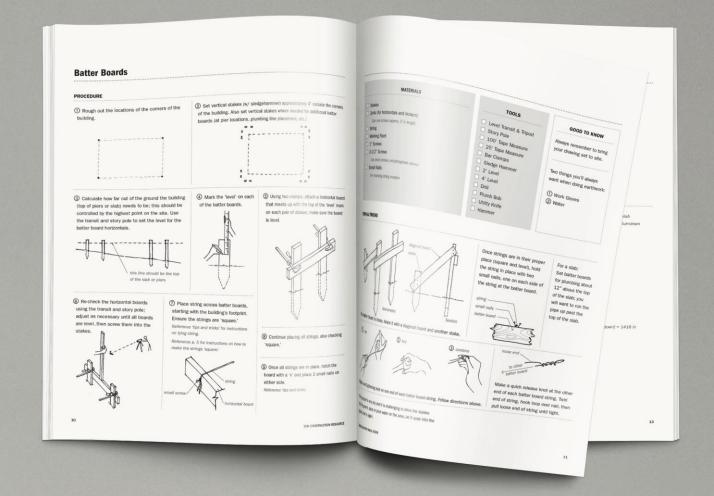


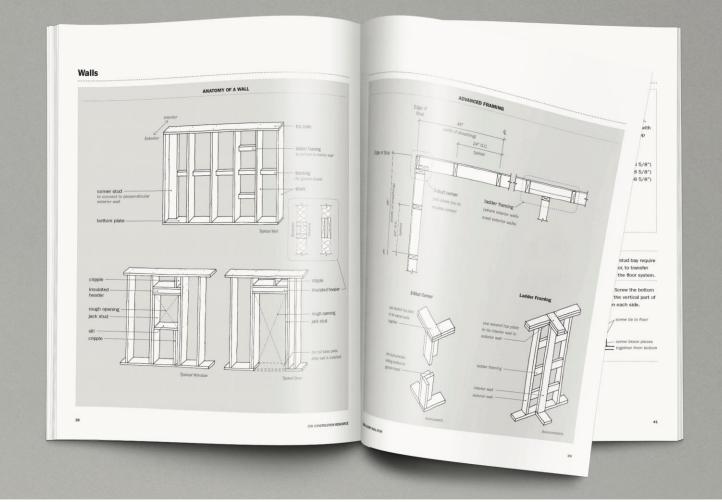


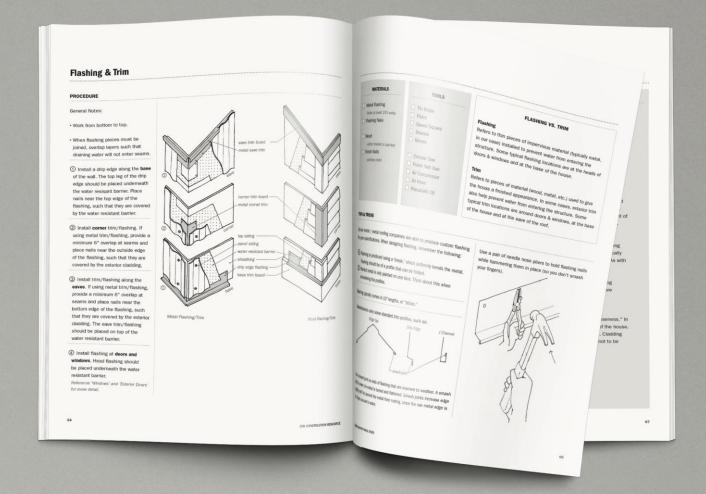


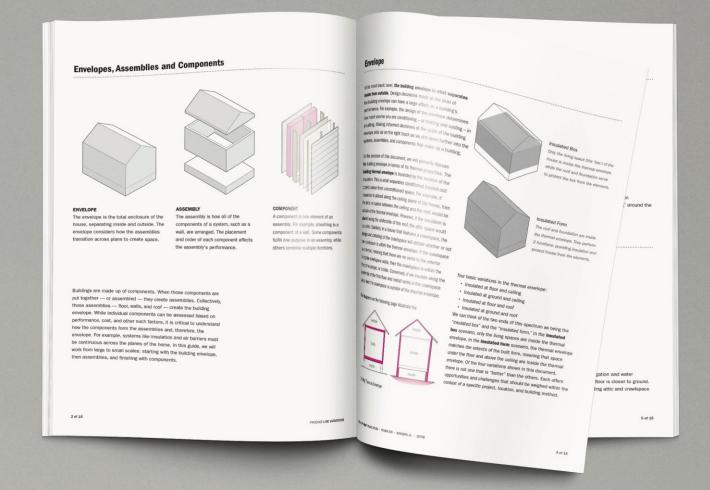


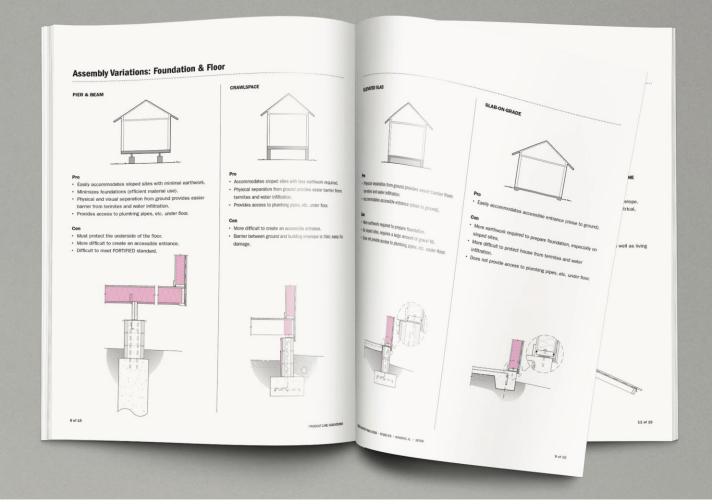










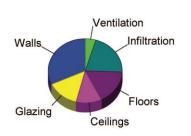


PRIORITIZING IMPROVEMENTS

Data from an energy model can identify areas with greatest potential for impact, informing recommendations for beyond-code investment.

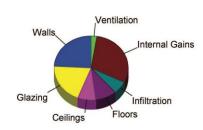
Heating

Component	Btuh/ft²	Btuh	% of load
Walls Glazing Doors Ceilings Floors Infiltration Ducts Piping Humidification Ventilation Adjustments Total	2.3 11.3 0 1.1 1.9 1.4	3372 1494 0 1183 1819 2213 0 0 493 10573	31.9 14.1 0 11.2 17.2 20.9 0 0 4.7



Cooling

Component	Btuh/ft²	Btuh	% of load
Walls Glazing Doors Ceilings Floors Infiltration Ducts Ventilation Internal gains Blower Adjustments Total	1.5 13.6 0 0.6 0.9 0.4	2174 1790 0 713 835 566 0 226 2690 0	24.2 19.9 0 7.9 9.3 6.3 0 2.5 29.9 0



Efficiency

Efficient homes smooth out the month-to-month variability of energy use by reducing peak use in the hottest and coldest times of year. These more predictable use patterns increase the homeowner's financial stability.



Community

In rural areas, homes are assets passed down through generations. building both individual and family wealth. Homes which strengthen community networks provide stability to the entire community.

Wellness

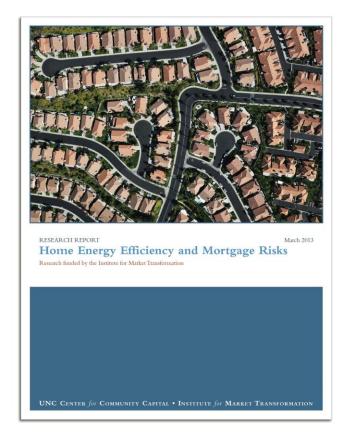
There is a well-established link between housing and health. Healthy homes not only provide increased thermal comfort, but also reduce environmental hazards. Healthy homes facilitate healthy occupants and reduce instances of environment-induced illness.

Resilience

Resilient homes are better built to withstand storm events, which both improves homeowner safety and minimizes displacement from the home.

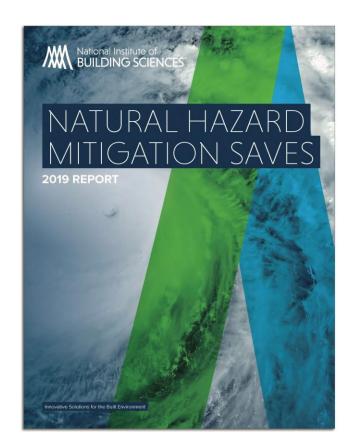
Default risks are on average 32% lower in energy-efficient homes, controlling for other loan determinates.

Institute for Market Transformation



Mitigation can result in significant savings in terms of safety, preventing property loss, and preventing distruption of day-to-day life. For example, exceeding building codes on average saves \$4 per \$1 spent.

National Institute of Building Sciences



A survey of homes in Alabama saw a 6.8% increase in resale value when the home was designated as FORTIFIED.

Alabama Center for Insurance Information & Research

Estimating the Effect of FORTIFIED Home™ Construction on Home Resale Value¹

Sebastain Awondo, PhD – University of Alabama
Harris Hollans, PhD – Auburn University
Lawrence Powell, PhD – University of Alabama
Chip Wade, PhD – University of Mississippi



¹ This research is sponsored by the Alabama Center for Insurance Information and Research (ACIIR), Culverhouse College of Commerce, The University of Alabama, Tuscaloosa, Al. 35487. Please address correspondence to Interpretation and Control of Contro

The fact that improved housing means improved health has been accepted for well over a century. As important as it is, the link between housing conditions and health effects constitutes only half of the knowledge needed. We need a better understanding of the housing interventions that demonstrably improve health.

National Center for Healthy Housing

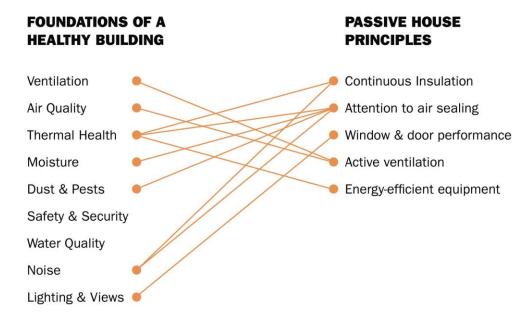


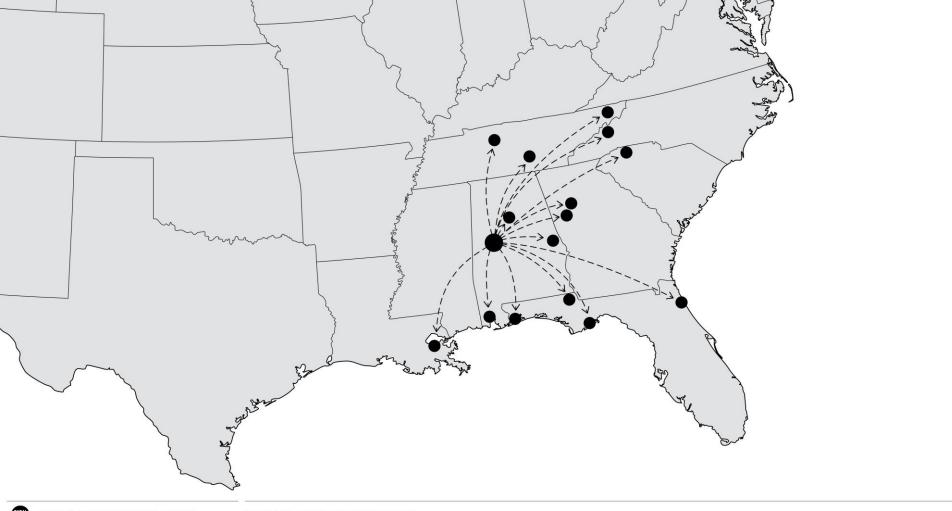
Housing Interventions and Health:

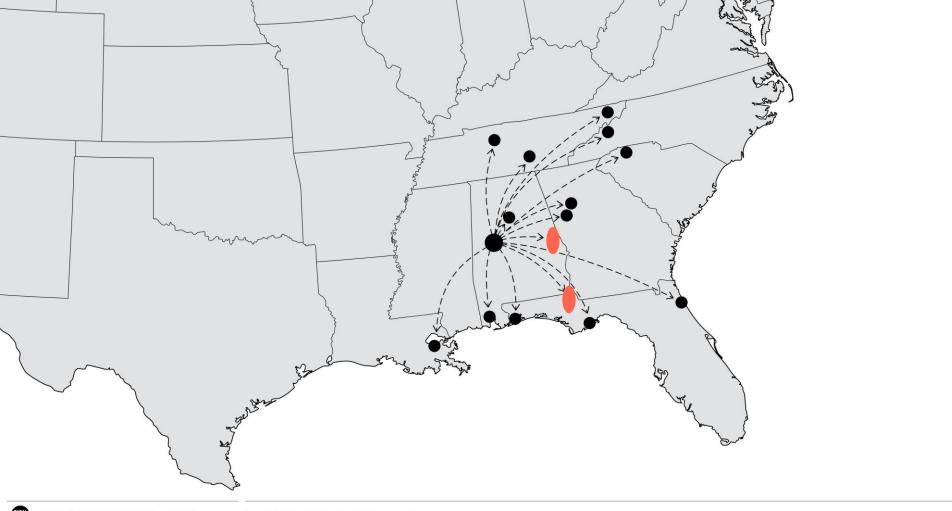
A Review of the Evidence



January 2009 National Center for Healthy Housing













House 66 PHIUS + FORTIFIED

House 68 ZERH + FORTIFIED



PASSIVE HOUSE

Making high-performance passive building the mainstream market standard.

- 1. Continuous insulation (no thermal bridging)
- 2. Attention to air sealing
- 3. Window & door performance
- 4. Active ventilation
- 5. Energy efficient equipment
- 6. Active ventilation



FORTIFIED FOR HIGH WINDS

Strengthen home to improve resistance to damage from high winds.

- 1. Roof
- 2. Gable end bracing
- 3. Continuous load path



ZERO ENERGY READY HOMES

Optimize efficiency, manage related risks, and help ensure future readiness.

1. Optimize efficiency

Enclosure

Equipment

Appliances / lighting

2. Do no harm

Water protection

Ensured comfort

Indoor air quality

3. Ensure future ready

Solar ready

Forthcoming codes



MODEL



TEST

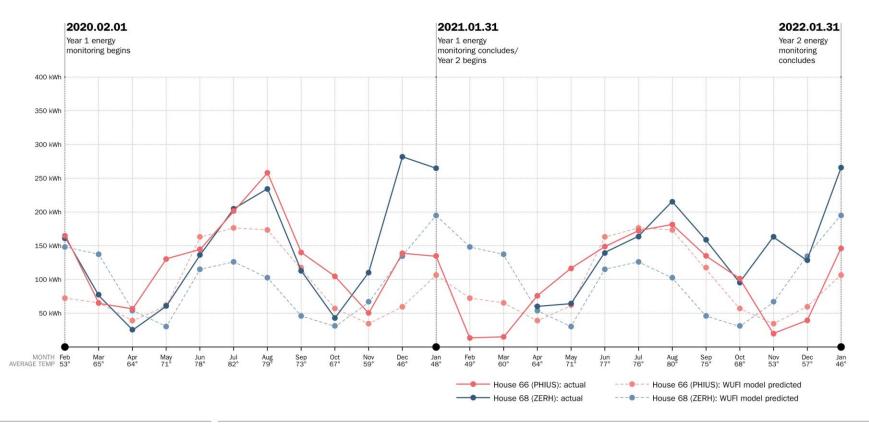


VERIFY



MONITOR

CATEGORY 1 (Heating, Cooling, & Ventilation)



What is the difference in cost to operate for PHIUS vs. ZERH?

Category 1

- Heating & Cooling
- Ventilation
- > Dehumidification

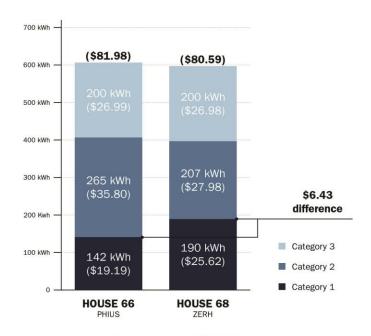
Category 2

- Lighting
- Water Heating
- > Large Appliances

Category 3

Plug Loads

AVERAGE MONTHLY ENERGY USE (kWh)



Note: Local utility rate average cost @ \$0.135/kWh



What is the difference in cost to operate for PHIUS vs. ZERH?

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- → Ventilation
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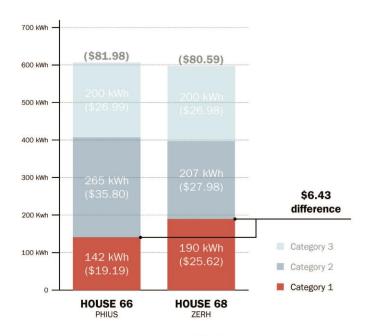
Category 2

- > Lighting
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Plug Loads

AVERAGE MONTHLY ENERGY USE (kWh)



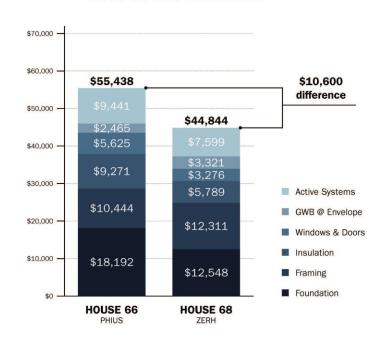
Note: Local utility rate average cost @ \$0.135/kWh



What is the difference in cost to build to PHIUS vs. ZERH?

Difference	\$8,752	\$1,842	\$10,594
House 68 (ZERH)	\$37,245	\$7,599	\$44,844
House 66 (PHIUS)	\$45,997	\$9,441	\$55,438
	Cost of Key Elements of Envelope	Cost of Active Systems	Total

COST OF KEY ELEMENTS



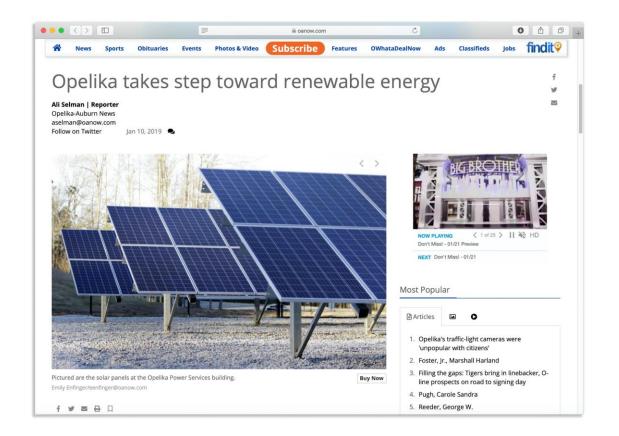
How does building to two different beyond-code standards affect costs for the homeowner?

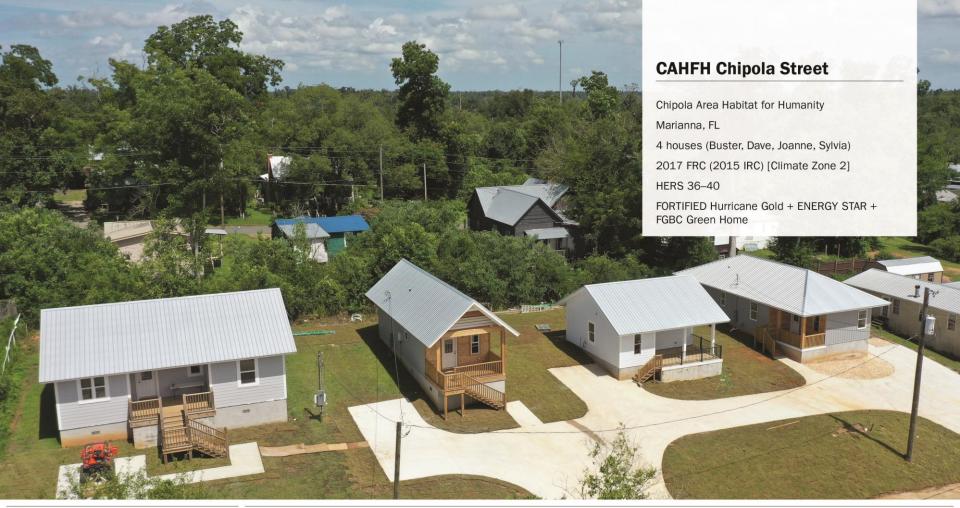
Difference	\$44.14/mo	- \$6.43/mo	= \$37.71/mo
House 68 (ZERH)	\$186.85/mo	\$25.62/mo	\$212.47/mo
House 66 (PHIUS)	\$230.99/mo	\$19.19/mo	\$250.18/mo
	Added Cost to Mortgage*	Avg. Cost of Cat. 1 Energy Use	Total Avg. Monthly Cost

^{*}Based on Habitat for Humanity's 20-year, 0% interest mortgage.

NET MONTHLY COST TO HOMEOWNER







PRIMARY OBJECTIVES

Equitable Housing Access

Almost every area in the United States faces a shortage of housing stock. Increasing access to high-performance homes which preserve affordability and reduce displacement of low-to-moderate income households is critical to closing the economic and social opportunity gap.

Disaster Recovery

The crisis in housing stock is further amplified in disaster-impacted communities which have suffered a loss of inventory. Hurricane Michael damaged 70 - 75% of the area's housing stock. As we rebuild, it is critical that we build back better and strengthen our communities to sustain future impacts.

Workforce Development

In addition to a housing stock shortage, the country faces a shortage of skilled workers, as many age out of the workforce. Nationally, 81% of contractors have difficulty hiring and 72% cite the workforce shortage as their most pressing concern.* Training the next generation of workers, and preparing them for addressing resilient, durable, and efficient homes, is key to maintaining affordability.

High-Performance Homes

Homes built by Chipola Area Habitat for Humanity are not affordable because construction costs are low; their homes are affordable because they are designed to be resilient and to minimize operations and maintenance costs throughout the lifetime of the home.





MODEL



TEST



VERIFY



MONITOR



ENERGY STAR

Improve energy efficiency to lower energy bills and increase thermal comfort.

- 1. High-performance windows, doors, & insulation
- 2. Fully-aligned air barriers
- 3. Reduce thermal bridging
- 4. Air sealing
- 5. Heating & cooling equipment
- 6. Quality duct installation
- 7. Ventilation
- 8. Filtration



FORTIFIED FOR HURRICANE

Strengthen home to improve resistance to damage from high winds and rain.

- 1. Roof
- 2. Impact protection @ windows & doors
- 3. Overhang & gable end bracing
- 4. Continuous load path



FGBC GREEN HOME

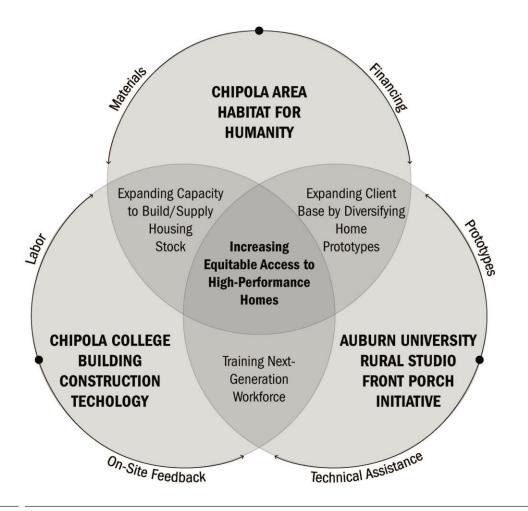
Address Florida-specific climactic conditions for improved efficiency, health, and resilience performance.

- 1. Energy performance
- 2. Water conservation
- 3. Site conditions (minimize disturbance)
- 4. Healthy materials
- 5. Local, efficient, recycled materials
- 6. Disaster mitigation







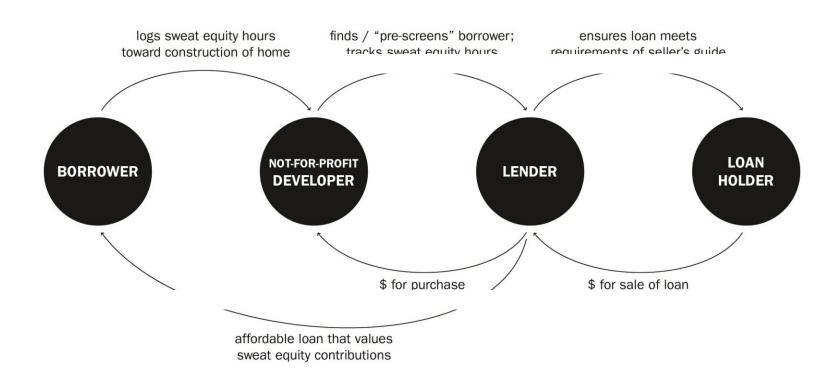


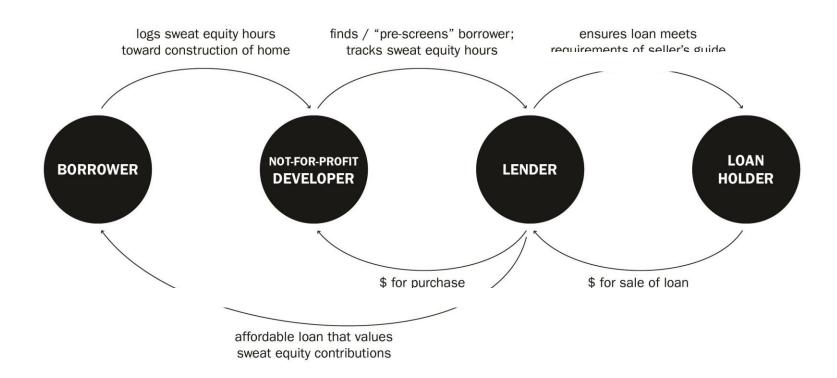
BY THE NUMBERS

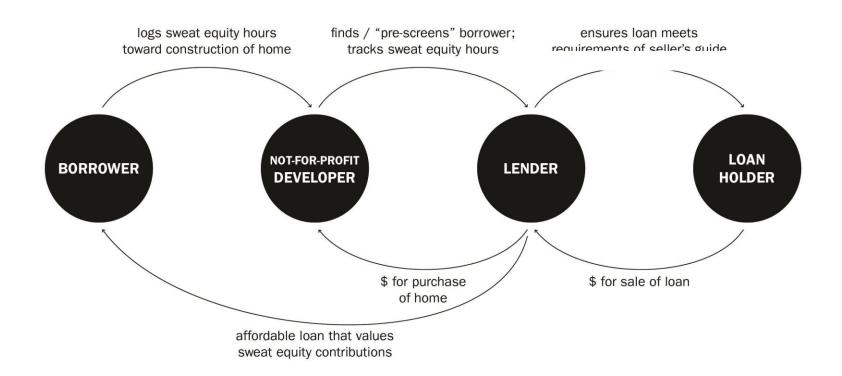
*preliminary numbers; not yet finalized

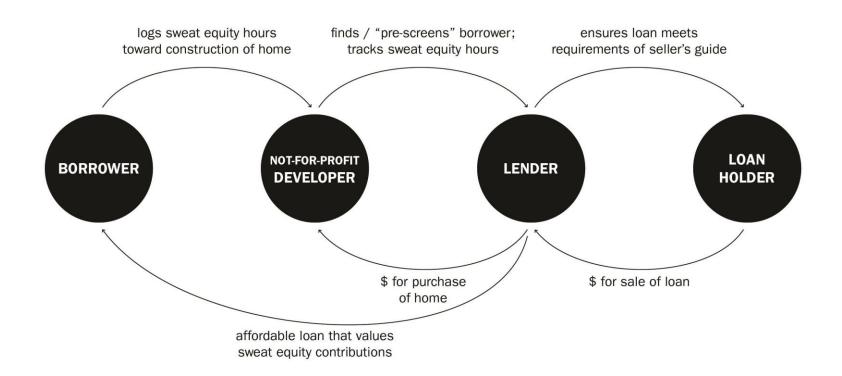
\$110,000	Construction Cost Property already owned by developer Estimated Value of Sweat Equity Includes value of sweat equity provided by homeowner & volunteers			
\$30,000				
\$140,000	Appraised Value			
\$140,000	Sales Price			
\$72,016	Total Downpayment			
	\$1,000	Borrower cash contribution		
	\$39,216	Sweat equity valuation*		
	\$5,000	SHIP program funding		
	\$25,000	HFHI disaster grant		
	\$4,000	Lender assistance (Regions)		
\$67,984	Unpaid Princ	ipal Balance (UPB)		

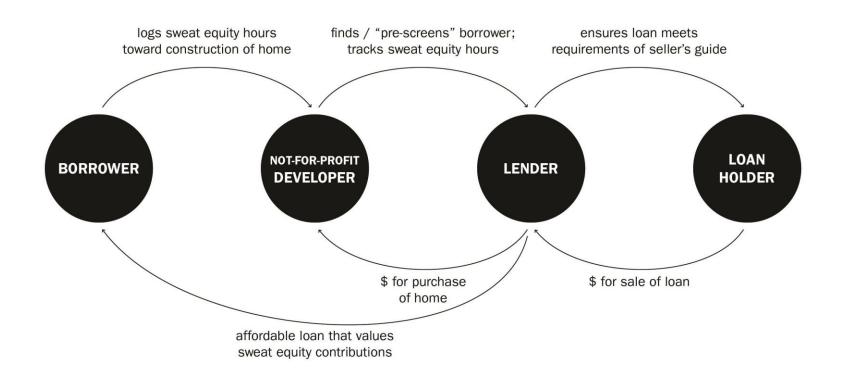
49% LTV (Mortgage insurance required if LTV is greater than 80%)

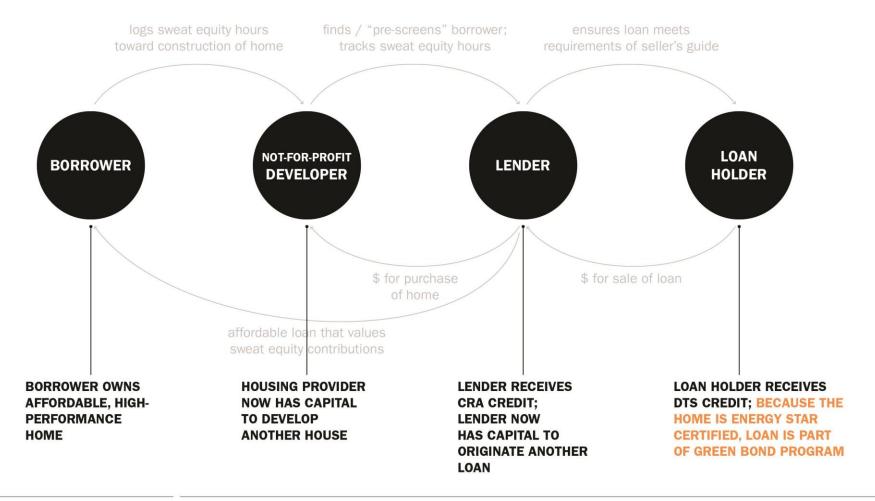














IMPLEMENTING ENERGY EFFICIENCY

Set expectations at the outset of the project.

Develop an energy model at the outset of the project to set performance expectations. This model can also be used as a tool to identify which components and assemblies are most impactful in decreasing predicted energy use.

Systems choices can influence ease/cost of third-party certifications.

Third-party certifications depend on third-party evaluation. However, they also sometimes depend on having certified installers. In areas with lower demand for beyond-code certification, certified installers can be hard to come by. However, there may be systems or components available that facilitate certification. For example, while ENERGY STAR requires a certified HVAC installer for ducted systems, packaged mini split systems, which require no balancing and testing, may be installed by any HVAC professional.

Test and course correct throughout the project.

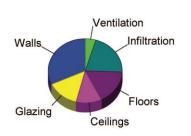
Tools such as blower doors and duct blasters can be used *during* the construction process to test envelope and system performance. These tools can identify specific deficiencies that can be corrected during construction in order to get a tighter, more efficient house without increasing construction costs.

PRIORITIZING IMPROVEMENTS

Data from an energy model can identify areas with greatest potential for impact, informing recommendations for beyond-code investment.

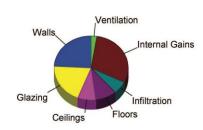
Heating

Component	Btuh/ft²	Btuh	% of load
Walls Glazing Doors Ceilings Floors Infiltration Ducts Piping Humidification Ventilation Adjustments Total	2.3 11.3 0 1.1 1.9 1.4	3372 1494 0 1183 1819 2213 0 0 493 0	31.9 14.1 0 11.2 17.2 20.9 0 0 4.7



Cooling

Component	Btuh/ft²	Btuh	% of load
Walls Glazing Doors Ceilings Floors Infiltration Ducts Ventilation Internal gains Blower Adjustments Total	1.5 13.6 0 0.6 0.9 0.4	2174 1790 0 713 835 566 0 226 2690 0 8995	24.2 19.9 0 7.9 9.3 6.3 0 2.5 29.9 0



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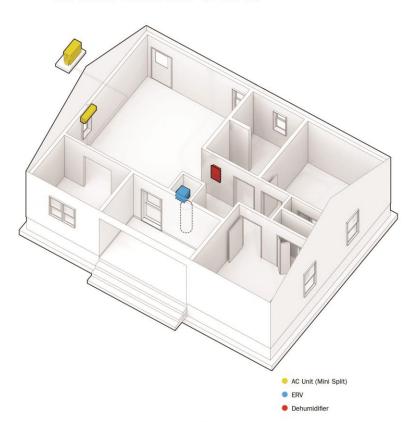
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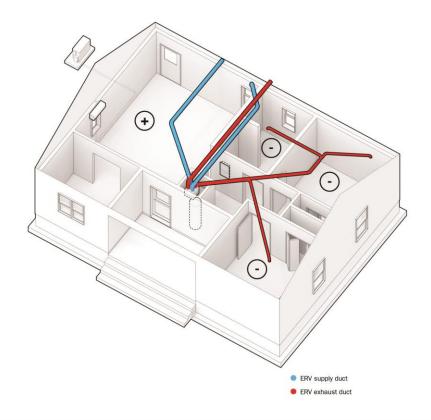
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THERMAL COMFORT SYSTEM



DUCTED ERV SYSTEM



IMPLEMENTING ENERGY EFFICIENCY

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AIR SEALING

2012 IRC: 7 ACH50

2018 IRC: 3 ACH50

	(pre-intervention) First Blower Door Test	(post-intervention) 2nd Blower Door Test	Final Blower Door Test	HERS
Joanne (41A)	6.3	3.7	2.9	52
Mac (41B)	7.6	3.7	3.5	51
Dave (43A)	6.3	3.9	3.3	54
Joanne (43B)	5.2	2.9	2.7	52
Average	6.35	3.55	3.1	52



POLICY CAN INCENTIVIZE UPTAKE OF INCREASED PERFORMANCE

Adoption of current building codes

Building codes set a minimum acceptable standard for construction. Newer building codes require more stringent performance measures. Adopting the most current building codes not only increases performance across the board, it also increases access to high-performance products such as more energy-efficient windows, insulation, and more.

Performance requirements on funds for housing assistance

Some state-sponsored programs are requiring homes meet third-party performance standards in order to access funds for housing assistance. For example, Florida's Homeownership Pool (HOP) Program requires certification to at least one of a selection of green building standards in order to qualify for purchase assistance.

Utility energy efficiency programs

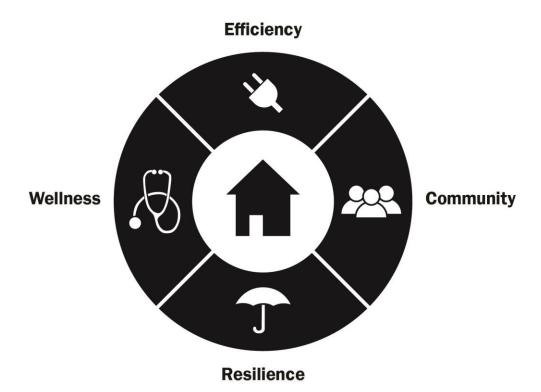
Utilities can incentivize energy efficiency in a number of ways. Through offering bidirectional metering and programs to sell energy to the grid, they increase accessibility to on-site energy generation. Many utilities also have retrofit/weatherization programs that allow homeowners to 'pay as you save.'

Tax credits / deductions / rebates

Developers, builders, and homeowners are eligible to receive various tax incentives for high-performance homes. For example, the 45L New Energy Efficiency Home Tax Credit provides up to a \$2000 federal tax credit for each qualifying home. And an increasing number of states are offering tax credits for mitigation measures and FORTIFIED homes.

Insurance premium discounts

Insurance companies have long used incentives to mitigate future expenditures – such as health insurers offering wellness checks or memberships to fitness programs. In many states, insurers offer homeowners insurance discounts for FORTIFIED homes.







RURAL STUDIO & FRONT PORCH INITIATIVE

Betsy Farrell Garcia, Front Porch Initiative Mackenzie Stagg, Front Porch Initiative Brett Hood, CHP Energy Solutions





October 31st & November 1st

VIRGINIA ENERGY EFFICIENCY COUNCIL

