

High Performance Factory Built Housing

2015 Building Technologies Office Peer Review



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Jordan Dentz, jdentz@levypartnership.com
ARIES / The Levy Partnership, Inc.

Project Summary

Timeline:

Start date: **November 2010**

Planned end date: **October 2015**

Key Milestones:

1. TO2 Detailed Test & Work Plan, Phase 1: Planning; May 2011
2. TO2 Technical Report, Phase 2: Prelim Design–Development; Feb 2012
3. TO3 Technical Report, Phases 2 & 3: Advanced Design–Development; May 2013
4. TO4 Technical Report, Phase 3: Prototyping; Mar 2014
5. TO5 Technical Report, Phase 4: Prototyping and Testing; Oct 2015

Budget:

Total DOE \$ to date: **\$810,426**

Total future DOE \$: **\$1,090,113 proposed**

Key Partners:

Accuvent	AFM
Bayer Material Science	BASF
CertainTeed	Dow
Factory Home Builders	Hunter Panels
Johns Manville	Louisiana Pacific
Mitsubishi	MHI
Owens Corning	SBRA
Senco	Tjernlund

Target Market/Audience:

Manufactured housing industry

Project Goal:

Provide factory homebuilders with high performance, cost effective alternative envelope designs as a comprehensive solution for reaching net zero energy use

Relevance to BTO Needs and Objectives

BTO Objective: Develop and deploy technologies and systems that reduce building energy consumption by 50%

BTO' Strategies	How this Project Fulfills BTO's Needs and Objectives
Research and develop advanced technologies	Develop and test technologies to reduce new MH energy use by half
Stimulate the market for innovations	Partner with those responsible for 80%+ of all new MH through a process referred to as "Collective Impact"
Develop and implement codes and standards	Participate in the ongoing MH standards development process – informed by the R&D work

Purpose and Objectives: Problem Statement

How to move a highly price-sensitive industry to exemplary levels of energy efficiency.

Barriers

- 1st cost is king
- Communicating energy benefits faces major hurdles

Challenges

- Technologies must be production friendly
- New building methods must be HUD approved
- Sold by dealers like autos

Knowledge Gaps

- Industry mindset focused on 1st cost; must shift to total ownership costs
- Few examples of high performance homes
- HUD energy standards last updated in 1994, many iterations behind the IECC



Purpose and Objectives: Target Market and Audience

- Manufactured Homes (MH) are built in plants across the nation and shipped to sites nearly ~95% complete.
- ~70% of unsubsidized affordable housing nationally (Congressional study)
- Preemption of HUD standards enables home standardization, key to achieving efficient production
- 10-12% of all new homes on average
- Financial crisis hurt affordable housing hardest and earliest. MH is likely to bounce back fast due to pent up demand and attractive pricing.

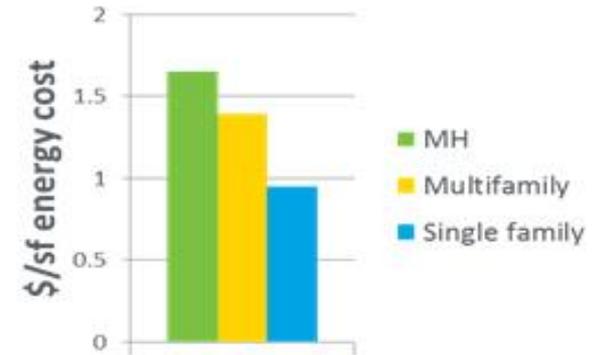


Purpose and Objectives: Target Market and Audience

75% of MH are owner-occupied (Foremost)



Nearly 7 million MH use 0.47 quad Btu/yr (site) (RECS)



Homeowners quality of life greatly impacted by efficiency. Energy costs can be as high as home payments.



Purpose and Objectives: Impact

Project Output

- Demonstrated solutions for building affordable, high performance MH; clear guidelines for plants and installers.

Measuring Achievement

- Interim—testing and prototype evaluation.
- Ultimate—number of homes built using high performance measures.

Impact Path

- Working with manufacturers to develop and demonstrate solutions
- Mfgs will drive the adoption: “affecting the operation of a few companies will change the industry.”
- If successful, can be wildly successful
- Industry needs cost-effective strategies for complying with the new energy code

Goals

- Near-term (through 2016): Pilot projects; limited adoption by progressive plants.
- Intermediate-term (2017-2019): New HUD standards drives adoption.
- Long-term (2020+): Reach critical mass; adoption starts in north then spreads south. SBRA helps facilitate adoption.

Approach: Collective Impact

Collective Impact is the commitment of a group of actors from different sectors to a common agenda for solving a specific problem, using a structured form of collaboration.

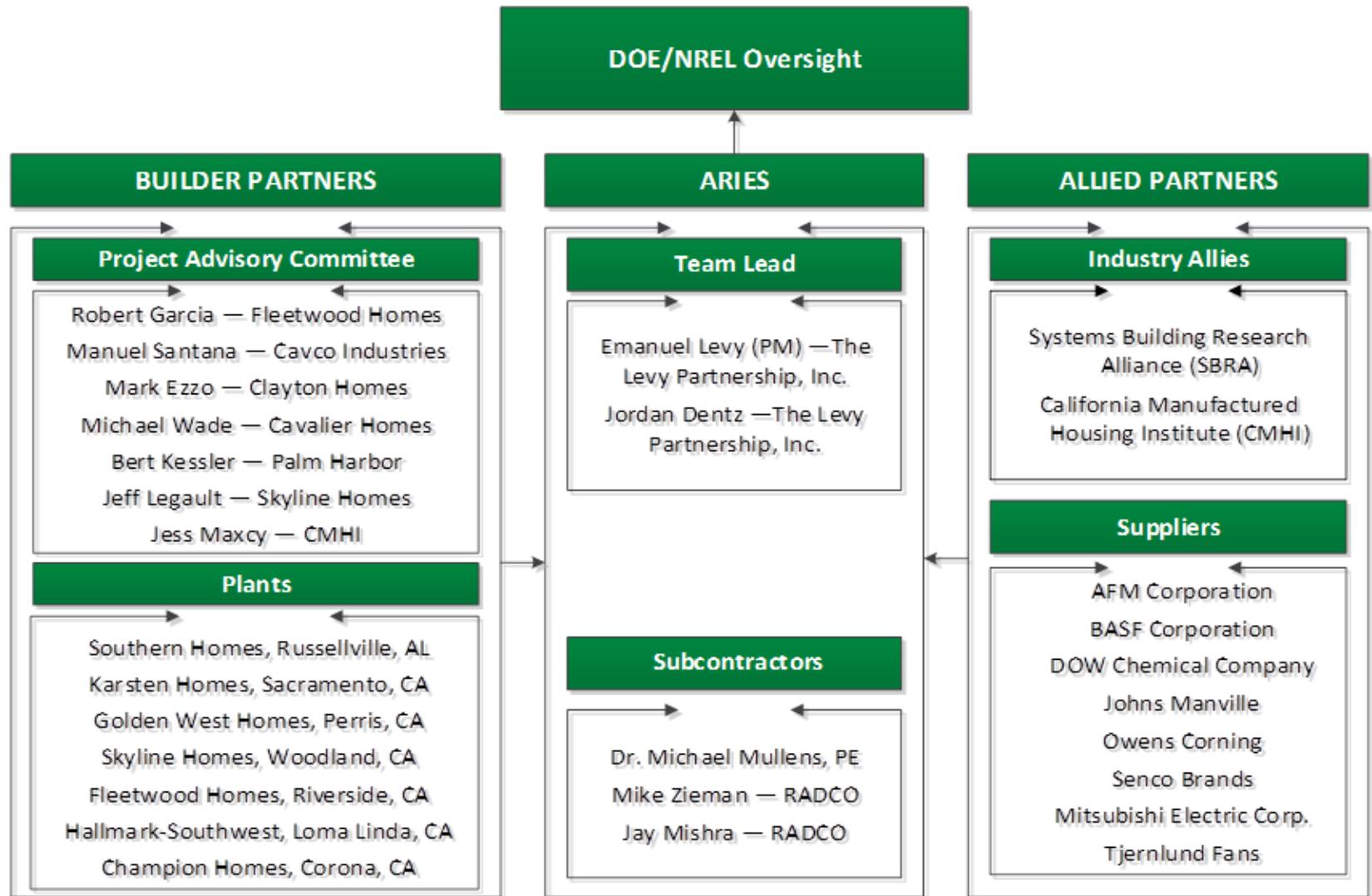
The Five Conditions of Collective Impact

- Common agenda
- Shared measurement
- Mutually reinforcing activities
- Continuous communication
- Backbone support



The concept of collective impact is clearly articulated in the 2011 [Social Innovation Review](#) article *Collective Impact*, by John Kania and Mark Kramer.

Approach: Partners



Approach: Key Issues

For a defined market segment, a holistic solution, including:



Thermal envelope:
wall, roof,
airtightness,
windows

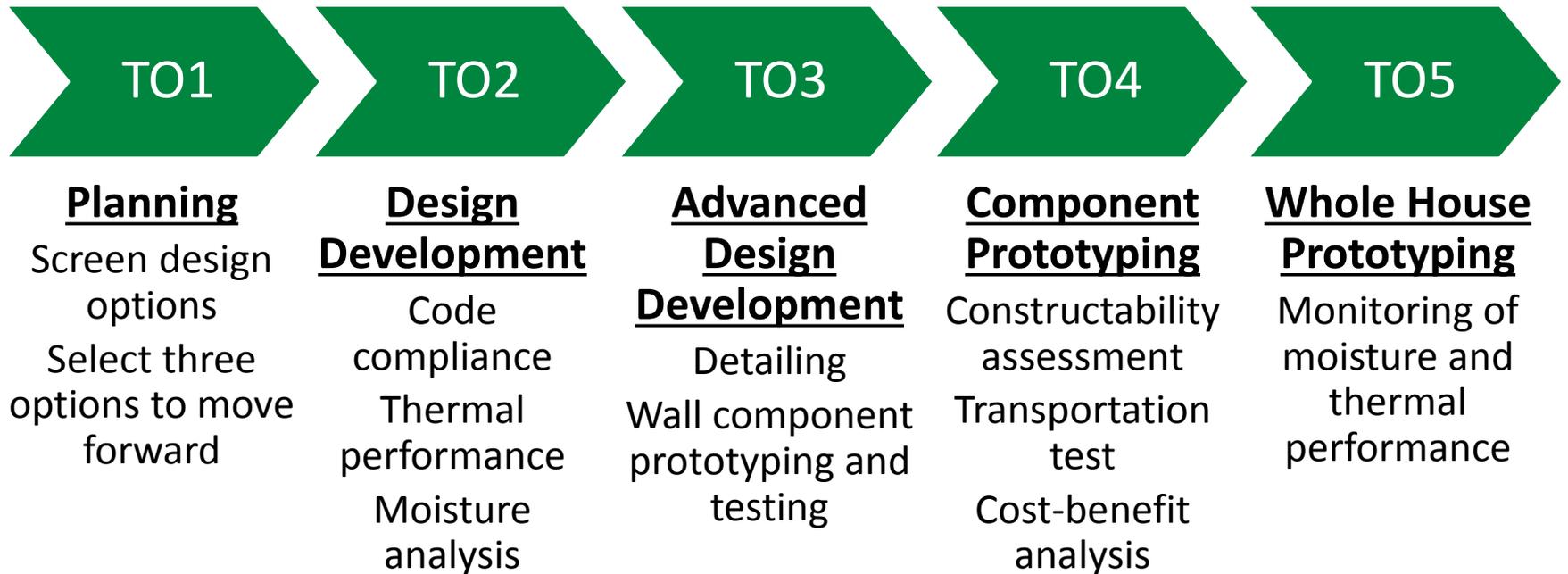
Space
conditioning
and ventilation

Integrating into
the building
process
(production
environment
requires
speed)

Cost and
installation:
quality key
considerations

Ultimate goal is market transformation

Approach: Planning



Approach: Heat Maps

Process for structuring committee input and focusing down on those solutions most likely to succeed in the long run

Option	DK	ME	BK	MW	BS	MS	KF	LS	Man.	Code	Thermal
1. Structural insulated panels or SIPs for ceilings	33 (7)	26 (3)	31 (5)	24 (4)	(6)	23 (5)	(4)	32 (6)	5	5	5
2. Structural insulated panels or SIPs for walls	23 (2)	25 (2)	34 (6)	20 (1)	(5)	23 (5)	(3)	23 (4)	2	4	4
3. Stud wall with insulating sheathing board	23 (2)	24 (1)	20 (1)	20 (1)	(2)	10 (1)	(2)	17 (1)	1	2	1
4. Un-vented attic with insulating sheathing board	24 (4)	31 (7)	26 (4)	25 (5)	(3)	11 (2)		27 (5)	2	6	3
5. Flash and batt wall construction	11 (1)	29 (5)	25 (3)	23 (3)	(1)	20 (4)	(1)	20 (3)	1	1	6
6. Poured closed cell foam	25 (5)	29 (5)	22 (2)	27 (6)	(4)	19 (3)		19 (2)	4	3	2
7. Innovative new floor	28 (6)	28 (4)	31 (5)	---	---	---			---	---	---

Scores indicate the simple sum of the qualitative ratings. Figure in parenthesis is the rank for that rater.

Key: red box = top pick; yellow box = second pick; green box = third pick.

Approach: Distinctive Characteristics

Collective Impact

Heat Maps

Three lab homes side by side – located at the production facility

Dovetail with code update process – hand in glove



Progress and Accomplishments

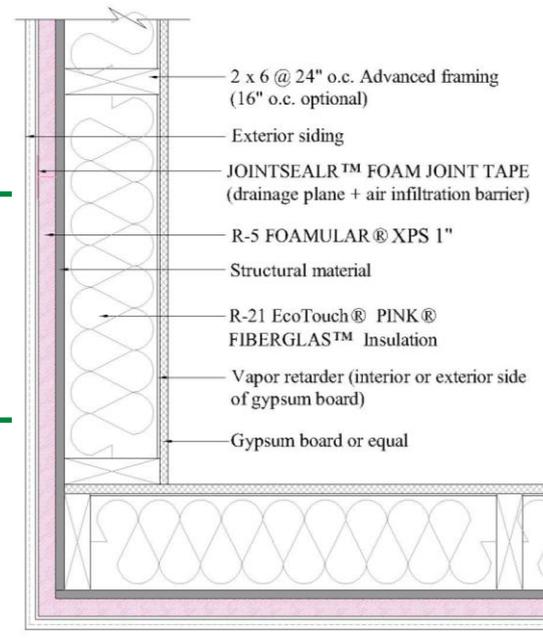


Progress and Accomplishments: TOs1-2

Developed advanced wall design that improves the thermal performance of the envelope and reduces annual energy use

Analysis of proprietary products

Supplier ⁶⁸	Product	Structural sheathing	WRB/ Sealant	VR	Fastener	FG Batts	Freight factor	TOTAL	
								\$/home	\$/sq. ft.
AFM	Nailbrace	✓	✓	✓	✓	---	✓	6,151	2.13
DOW	Styrofoam	---	✓	---	---	---	---	2,860	0.99
Johns Manville	ValuTherm	---	---	---	✓	---	---	1,415	0.49
	AP Foil	---	✓	---	✓	---	---	2,682	0.93
	Structural Insul. Sheathing	✓	✓	---	✓	---	---	2,942	1.02
Owens Corning	Foamular	---	✓	---	---	✓	---	3,252	1.13
Saint Gobain	Faced CertaPro	---	---	---	---	---	---	2,336	0.81
BASF	Neopor UnFaced	---	---	---	✓	---	---	1,966	0.68
	Neopor Poly/Foil	---	---	---	✓	---	---	2,053	0.71
	Neopor 3/8" OSB	✓	---	---	---	---	---	3,667	1.27



TO2 – Design development and material selection

Progress and Accomplishments: TOs 3-4

Tested, prototyped and perfected the advanced wall design over five prototype builds at different manufacturing plants.

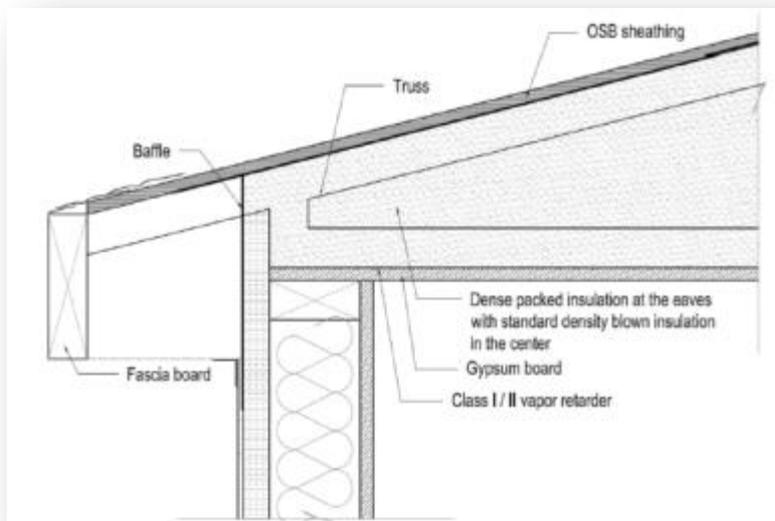
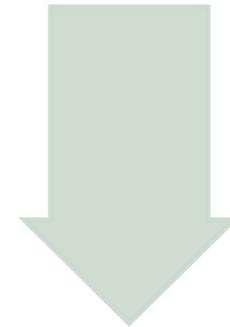
TO4 – Whole-house prototyping and constructability assessment

TO3 – Component prototyping and testing



Progress and Accomplishments: T05

Developed advanced roof design that reduces heat loss at the eaves – traditionally a weak link in the thermal performance of attics.



Advanced Roofs

Progress and Accomplishments: T05

Full-scale wall and roof prototyping; instrumentation and testing of advanced roofs, monitoring of moisture and thermal performance.

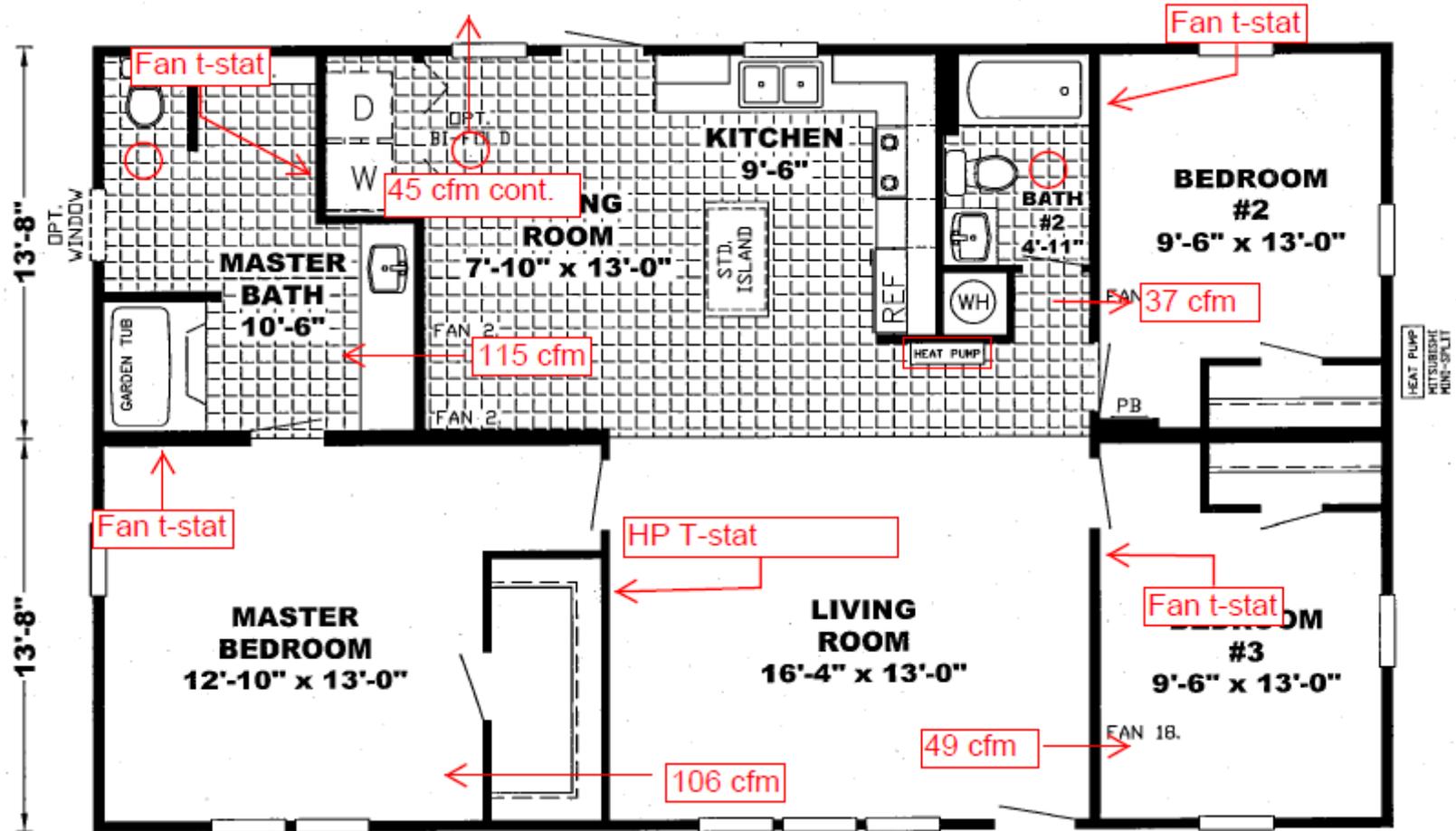
- Constructed and instrumented three side-by-side lab homes
- Monitored for one year (on going)



Traditional MH Home	Advanced (ZERH) MH
Standard fiberglass batt in wall cavities	Reduced thermal bridging with exterior rigid insulation
Cooling equipment site installed	High efficiency equipment plant-installed, commissioned
Ducts under floor and in crawl	No ducts
Code minimum 13 SEER / 8 HSPF or electric resistance	22 SEER / 12 HSPF
Envelope $U_o = 0.116$	Envelope $U_o = 0.063$

Progress and Accomplishments: T05

Better understanding of the interplay between heat pump, fan locations and home configuration



Progress and Accomplishments: Advanced Wall Construction



Progress and Accomplishments: Advanced Roof Construction



Dense-pack insulation

Baffles and insulation dams



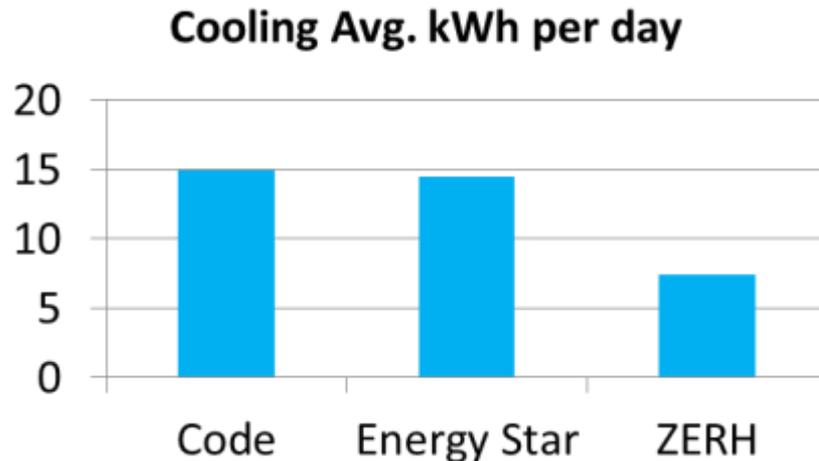
Progress and Accomplishments: Ductless Mini-split Heat Pump



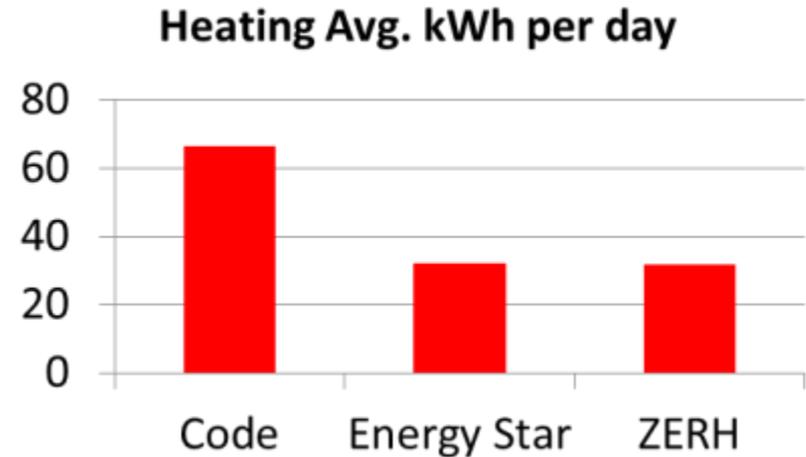
Progress and Accomplishments: Transfer Fan Distribution



Progress and Accomplishments: Lab Home Results



Code and ES used similar cooling energy because less cool-off for ES home in evening.



ES and ZERH used similar heating energy because the mini-split heat pump unexpectedly operated at about the same COP as a traditional, split system heat pump.

Other Results:

- Site-installed equipment problems – how typical is this?
- Transfer fan configuration in heating.
- Effective ventilation rates with traditional POS systems.

Progress and Accomplishments: Awards/Recognition

Building America Top Innovation Award 2014

BUILDING AMERICA TOP INNOVATIONS 2014 PROFILE

INNOVATIONS CATEGORY: Advanced Technologies and Practices, Building Science Solutions, Thermal Enclosures

INNOVATOR: ARIES Collaborative

Cost-Optimized Attic Insulation Solution for Factory-Built Homes

The low-cost, low-tech attic insulation technique is immediately applicable to the nearly 1.25 million new manufactured homes built each year. With widespread adoption, the one measure could save homeowners over 6 trillion Btus by 2030, equal to 630 million in savings that would go into the pockets of families with modest incomes.



Recognizing the innovation in building science – the U.S. Department of Energy Building America program was started in 2009 to provide research and development to the residential new construction and remodeling industry as a national center for world-class research, building America leads in integrated research in market-ready technology solutions through collaborative partnerships between building and remodeling industry leaders, nationally recognized building scientists, and the national laboratories. Building America Top Innovation awards recognize those projects that have had a profound or transformative impact on the new and altered housing industry on the road to high-performance homes.



Increasing attic insulation in manufactured housing has been a significant challenge due to strict production and transportation constraints. The complexity of this dense-pack solution as increasing attic insulation R-value provides real hope for widespread industry adoption.

The U.S. Department of Energy's ARIES research team, led by The Levy Partnership Inc., partnered with Clayton Home's Southern Energy Homes division and Johns Manville Corporation to develop and test a new attic insulation method that involves dense packing the shallow attic space in manufactured homes with blown fiberglass insulation.

With the new method of applying dense-pack insulation, installers are able to achieve a much higher attic insulation R-value than is typically installed in manufactured homes.

Specifically, Southern Energy Home has achieved an overall average attic R-value of R-44.6 and an R-value of R-54.6 at the center or peak of the attic using this innovative new dense-packing method. For comparison, a home certified to the ENERGY STAR Qualified Manufactured Homes program typically has an average R-value of between R-30 and R-38 at the ceiling. The typical ceiling insulation level in a manufactured home in HUD Code zone 1 is around R-22 at the peak.

The method was tested in a home built by Southern Energy to the performance criteria of the DOE's Zero Energy Ready Home program, which seeks to achieve whole house energy performance that exceeds the requirements of the 2012 International Energy Conservation Code.

The home is being constructed for 15 months at Clayton's Russellville, Alabama, plant as a side-by-side test with homes built to ENERGY STAR and to the U.S. Department of Housing and Urban Development's Manufactured Home Construction and Safety Standards (commonly known as the HUD code).

On the left, the dense-pack roof insulation technique is being tested in a side-by-side comparison with two other manufactured homes – one built to ENERGY STAR and one built to the HUD code. The homes are undergoing 15 months of performance testing by the DOE's ARIES research team and National Renewable Energy Laboratory.

ZERH Housing Innovation Award 2014

DOE ZERO ENERGY READY HOME™

Southern Energy Homes

First DOE Zero Energy Ready Manufactured Home
Russellville, AL

BUILDER PROFILE

Southern Energy Homes, Inc.
(A Division of Clayton Homes)
Russellville, AL
David Brewer
david.brewer@claytonhomes.com
201-480-5467
www.claytonhomes.com
Owner: The Levy Partnership, Inc., Jordan Dantz,
jerdantz@levypartnership.com

FEATURED HOME DEVELOPMENT

- Project Data:
- Name: First DOE Zero Energy Ready Manufactured Home
 - Location: Russellville, AL
 - Layout: 3 bedrooms, 2 baths, 1 floor
 - Conditioned Space: 1,252 ft²
 - Climate Zone: IECC 3A, mixed humid
 - Completion: May 2014
 - Category: Affordable

Performance Data

- HERS Index without PV: 57
- Projected Annual Utility Costs without PV: \$59
- Projected Annual Energy Cost Savings (compared to homes built to the HUD Code) without PV: \$22
- Builder's Added Cost Over HUD Code (PERCS): \$137
- Annual Energy Savings without PV: 4,638 kWh

The country's first U.S. Department of Energy-certified Zero Energy Ready manufactured home is up and running in Russellville, Alabama. The manufactured home is being put through its paces along side of a standard to-code manufactured home and an ENERGY STAR manufactured home. The manufactured home, built by Clayton Home's Southern Energy Homes subsidiary, has an impressive suite of energy-saving, water-saving, high-tech features that say home would be proud of. "The DOE Zero Energy Ready home is a potential game changer for the factory building industry," said Jordan Dantz, a building scientist for The Levy Partnership, a research partner in the DOE Building America program who is collaborating with Clayton Homes and the National Renewable Energy Laboratory to do 15 months of side-by-side performance testing on the three homes.

Testing began May 2014 and preliminary cooling-season results are already showing the DOE Zero Energy Ready Home as a strong leader in this energy savings race, using half the space conditioning energy of a manufactured home built to the U.S. Department of Housing and Urban Development's Manufactured Home Construction and Safety Standards (commonly known as the HUD code), which is the building standard for all U.S. manufactured housing. The other manufactured home, which was built to the ENERGY STAR criteria for manufactured homes has about a 15% savings over the HUD Code home.

The DOE Zero Energy Ready Home meets all of the requirements that are built homes must meet to qualify for this high-performance home labeling program. The home is built to meet all of the air sealing and construction quality requirements of ENERGY STAR Certified Homes Version 3.0. It also meets the indoor air quality and water-saving elements of the U.S. Environmental Protection Agency's Indoor AirPLUS and WaterSense programs. The DOE



The U.S. Department of Energy invites home builders across the country to meet these extraordinary levels of excellence and quality specified in DOE's Zero Energy Ready Home program (formerly known as Challenge Home). Every DOE Zero Energy Ready Home starts with ENERGY STAR-Certified Homes Version 3.0 for an energy-efficient home built on a solid foundation of building science research. Advanced technologies are designed in to give you superior construction, durability, and comfort, both by indoor air high-performance HVAC, lighting, and appliances, and solar-ready components for low or no utility bills in a quality home that will last for generations to come.

Progress and Accomplishments: Summary

Lessons Learned

In-situ performance of mini-split heat pump in heating unexpected (further analysis needed)

Accomplishments

Developed, tested advanced wall and roof designs that improve envelope thermal performance, reduce energy use, cut CO₂ emissions, reduce equipment size, improve comfort and durability

Market Impact

Impacted ASRAC process –new standard based on IECC 2015. Engaged many factories in demonstrating new building methods

Awards/ Recognition

BA Top Innovation Award 2014 and
ZERH Housing Innovation Award 2014

Project Integration



Left to Right: Emanuel Levy, TLP; Brian Lieburn, DOW; Kevin Clayton, Clayton Homes; Bryan Mallon, DOW; Jim Morey, DOW; Sam Rashkin, DOE; David Brewer, Southern Homes

Stakeholders participate and guide the research

Bi-monthly stakeholder conference calls

All major decisions owned by steering committee

Participation of many companies, not just those involved in the prototyping

More than 70% of industry

In-kind contributions \$274k

Demos/prototyping/testing at industry facilities

Project Collaboration

- **Funding Partners:** DOE, TVA, CEC
- **Research Collaboration:** NREL on lab home instrumentation, experiments and analysis
- **Industry Partners:**



Project Integration and Collaboration: Roles

Industry Partner	Role
Clayton Homes	Engineering, plant selection and logistics
Southern Homes	Manufacturer of lab homes
Mitsubishi	Provider of space conditioning equipment and technical support
DOW	Provider of wall insulation, flashing system and technical support
Johns Manville	Provider of roof insulation and technical support
Accuvent	Provider of roof ventilation system and technical support
Tjernlund	Provider of transfer fans and technical support
Senco	Provider of fasteners, fastening tools and technical support



Collaboration on Lab Home Construction

Project Integration and Collaboration: Communications

- MHI Meetings
- MH Congress & Expo
- MH NewsWire
- The Journal
- BA Reports
- CFED and others



Next Steps and Future Plans: Ongoing CEC Work

Roof test structure: Five roof configurations being tested in Jamestown, CA



2015 Plans:

- Radiant barrier/cool roof testing
- Full scale production testing
- Multiple full-scale homes at multiple plants
- Multiple occupied homes monitoring

Next Steps and Future Plans: Integrated Solution

Ongoing experiments will answer important outstanding questions pertinent to high performance MH and site built homes, including:

- In-situ performance of mini-split heat pumps
- Performance of transfer fan distribution strategy (heating & cooling)
- Impact of open doorways on airflow and comfort

Future Work – Important for commercialization

- Understand airflow dynamics via calibrated CONTAM/TRNSYS model
- Level of envelope efficiency by climate necessary for success of point-source space conditioning strategy
- Interaction of real life homeowners with advanced home

REFERENCE SLIDES

Project Budget

Total Project Budget: \$1,084,364 (\$810,425 DOE; \$273,939 cost-share)

Variiances: \$95,000 increase in TO5 for additional tasks/modified scope of work

Cost to Date: 81% of project budget expended to date (FY2011-FY2015 to date)

Additional Funding: California Energy Commission, Tennessee Valley Authority, Industry partners

Budget History

FY2011–FY2014 (past)		FY2015 (current)		FY2016–FY2018 (proposed)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$580,570	\$95,647	\$229,855	\$178,262	\$1,090,113	\$353,500

Project Plan and Schedule

Project Schedule																						
Project Start: November 2010	Completed Work												Active Task (in progress work)									
Project End: October 2015	◆	Milestone/Deliverable (Originally Planned)												◆	Milestone/Deliverable (Actual)							
		FY2011				FY2012				FY2013				FY2014				FY2015				
Task	Q4 Nov-Dec	Q1 Jan-Mar	Q2 Apr-Jun	Q3 Jul-Sep	Q4 Oct-Dec	Q1 Jan-Mar	Q2 Apr-Jun	Q3 Jul-Sep	Q4 Oct-Dec	Q1 Jan-Mar	Q2 Apr-Jun	Q3 Jul-Sep	Q4 Oct-Dec	Q1 Jan-Mar	Q2 Apr-Jun	Q3 Jul-Sep	Q4 Oct-Dec	Q1 Jan-Mar	Q2 Apr-Jun	Q3 Jul-Sep	Q4 Oct-Dec	
Past Work																						
TO1: 1.2 Draft Project Plan	◆																					
TO1: 1.3 Final Project Plan	◆																					
TO2: 2.1 Detailed Test and Work Plan		◆	◆																			
TO2: 2.2.1 Draft Technical Report					◆																	
TO2: 2.2.2 Final Technical Report						◆																
TO3: 2.1.1 Test Plan						◆																
TO3: 2.1.2 Draft Technical Report									◆	◆												
TO3: 2.1.3 Final Technical Report									◆	◆												
TO4: 2.1.1 Draft Technical Report														◆	◆							
TO4: 2.1.2 Final Technical Report														◆	◆							
TO5: 3.1.1 Test Plan																						
Current Work																						
TO5: 3.1.2 Draft Technical Report																					◆	
TO5: 3.1.3 Final Technical Report																					◆	