

THE BUILDING AMERICA INDUSTRIALIZED HOUSING PARTNERSHIP (BAIHP)

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ABSTRACT

The Building America Industrialized Housing Partnership (BAIHP) is one of five competitively selected U.S. DOE Building America teams and began work on 9/1/99. BAIHP focuses on improving the energy efficiency, durability and indoor air quality in manufactured homes. Team members, Cavalier Homes, Fleetwood Homes, Palm Harbor Homes, Southern Energy Homes, and manufacturers in the Super Good Cents/Natural Choice program produce over 100,000 manufactured homes/yr currently.

In addition, the BAIHP team provides technical assistance to about 30 site builders and modular home manufacturers including Habitat for Humanity affiliates throughout the nation.

BAIHP is also charged with enhancing the energy efficiency and learning environment in portable classrooms in the northwestern states of WA, OR and ID.

This paper summarizes the multifaceted work being performed by BAIHP and provides specific data on 310 homes constructed in the Gainesville FL area with technical assistance from Florida Home Energy and Resources Organization. The paper also summarizes typical causes and cures for moisture problems in manufactured homes.

INTRODUCTION

The Building America Industrialized Housing Partnership's goals are to:

1. Cost effectively reduce the energy cost of industrialized housing and portable classrooms by up to 50% while enhancing indoor air quality, durability and productivity.
2. Assist in the construction of thousands of energy efficient industrialized houses annually.
3. Make our team members pleased and proud to be working with us.

Industrialized housing includes manufactured housing (built to the HUD code), modular housing

(factory built housing modules assembled on site) and production housing (site built housing produced in a systematic manner). The project scope also includes portable classrooms.

The Florida Solar Energy Center (FSEC) of the University of Central Florida (UCF) serves as the prime contractor. Subcontractors include the Washington State University Energy Program, the American Lung Association of Central Florida, the Oregon Office of Energy, the Idaho Department of Water Resources, Florida Home Energy and Resources Organization (FL.H.E.R.O.), D.R. Wastchack, LLC and Alten Design. A current list of over 30 industry partners and other collaborators may be found on our web site www.baihp.org.

HOMES MANUFACTURED AND BUILT

From project inception in September 1999 through December, 2001 over 43,000 homes have been manufactured or built with BAIHP technical assistance as detailed in Table 1.

Table 1. Homes constructed with BAIHP technical assistance

Homes manufactured to Energy Star or greater energy savings

Super Good Cents west of the cascades (With appropriate ventilation system)	475
Homes by FL H.E.R.O. in Gainesville, FL	418
Palm Harbor Homes	007
Habitat for Humanity, south Florida	002
Habitat for Humanity, Americus, GA	016
Fallman Design and Construction	001
Homes by D.R.Wastchak in Phoenix, AZ	2,179
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Subtotal	3,098

Homes produced with a HERS score of around 85 (25% better than MEC)

Super Good Cents - Electric	5,808
Natural Choice (Nat Gas/ Propane) Homes	1,858
Energy Efficient Homes (PHH div. In NC)	1,645
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Subtotal	9,311

**Homes produced with airtight duct systems
(around 15% savings in Htg and Cooling Energy)**

Palm Harbor Homes	22,000
Southern Energy Homes	8,000
Cavalier Homes	1,000
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Subtotal	31,000

Technical measures incorporated in BAIHP homes include some or many of the following features - better insulated envelopes (including Structural Insulated Panels and Insulated Concrete Forms), unvented attics, "cool" roofs, advanced air distribution systems, interior duct systems, fan integrated positive pressure dehumidified air ventilation in hot humid climates, quiet exhaust fan ventilation in cool climates, solar water heaters, heat pump water heaters, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems.

**HOMES BY THE FLORIDA HOME ENERGY
AND RESOURCES ORGANIZATION
(FL.H.E.R.O.)**

Over 400 single and multifamily homes have been constructed in the Gainesville, FL area with technical assistance from FL H.E.R.O. These homes were constructed by over a dozen different builders. In this paper data from 310 of these homes is presented. These homes have featured better envelopes and windows, interior and/or duct systems with adequate returns, fan integrated positive pressure dehumidified air ventilation, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems. The innovative outside air (OA) system is described below.

The OA duct is located in the back porch (Figure 1) or in the soffit (Figure 2). The OA is filtered through a 12"x12" filter (which is readily available) located in a grill (Figure 3) which is attached to the OA duct box. The flex OA duct size varies depending on the system size - 4" for up to 2.5 tons, 5" for 3 to 4 ton and 6" for a 5 ton system. The OA duct terminates in the return air plenum after a manually adjustable butterfly damper (Figure 4).



Figure 1 OA Intake Duct in Back Porch



Figure 2 OA Intake Duct in Soffit



Figure 3 Filter Backed Grill Covering the OA Intake



Figure 4 Butterfly Damper for OA control

The damper can be set during commissioning and closed by the homeowner in case the OA quality is poor (e.g. forest fire). This system introduces filtered and conditioned ventilation air only when the cooling or heating system is operational. The ventilation air also positively pressurizes the house. Data on the amount of ventilation air or positive pressurization is not available from a large sample of homes. A few measurements indicate that about 25 to 45 cfm of ventilation air is provided which pressurizes the house in the range of +0.2 to +0.4 pascals.

Measured Home Energy Ratings (HERS) and airtightness on these FL. H.E.R.O. homes is presented next in figures 5 through 8. Data is presented for both single family detached (SF) and multifamily homes (MF). See Table 2 below.

Table 2. Summary statistics on FL.H.E.R.O. Homes
n = sample size

	SF	MF
Median cond area	1,909	970
% constructed with 2x4 frame or frame and block	94%	100%
Avg. Conditioned Area, ft ²	1,993 (n=164)	1,184 (n=146)
Avg. HERS score	87.0 (n=164)	88.0 (n=146)
Avg. ACH50	4.5 (n=164)	5.2 (n=146)
Avg. Qtot (CFM25 as %of floor area)	6.9% (n=25)	5.0% (n=72)
Avg. Qout (CFM25 as %of floor area)	3.0% (n=15)	1.4% (n=4)

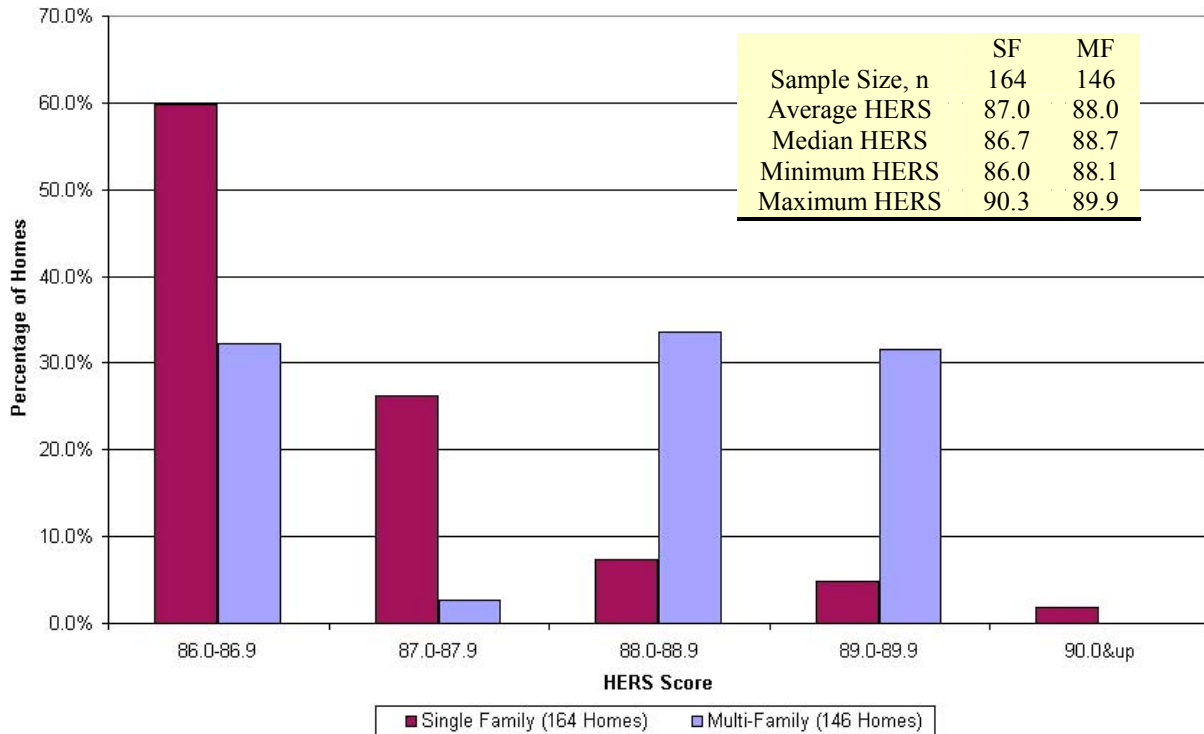


Figure 5 HERS Scores for FL H.E.R.O. Homes

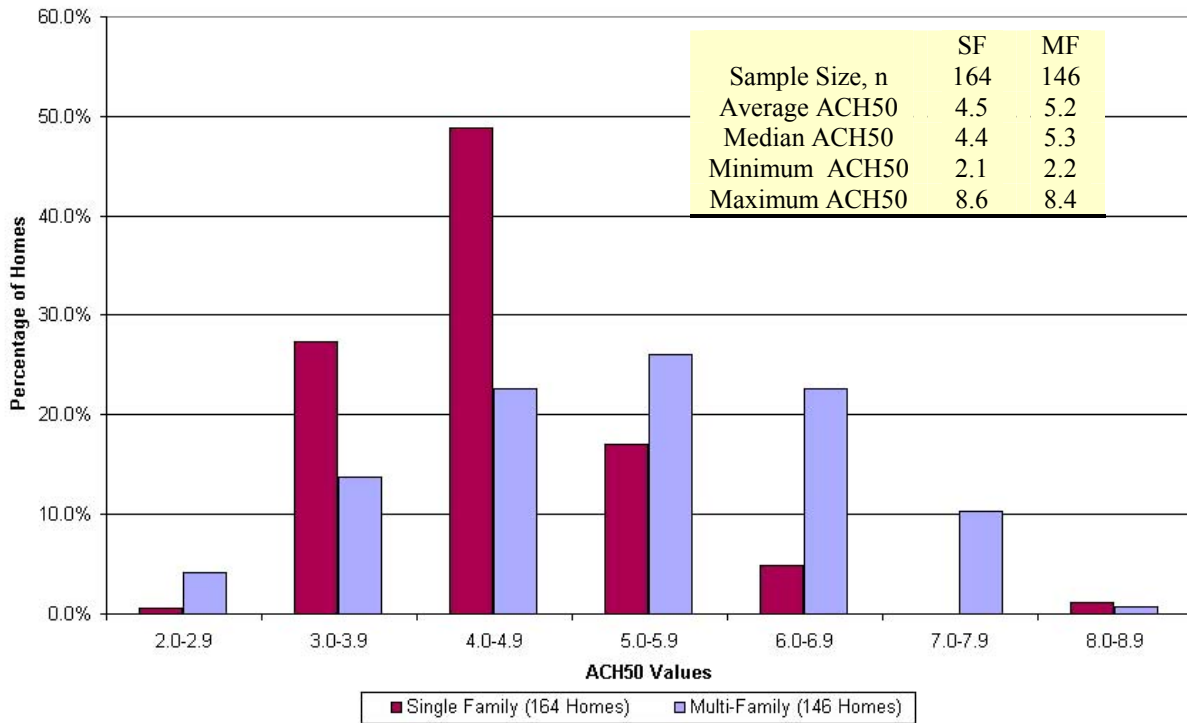


Figure 6 ACH50 Values for FL H.E.R.O. Homes

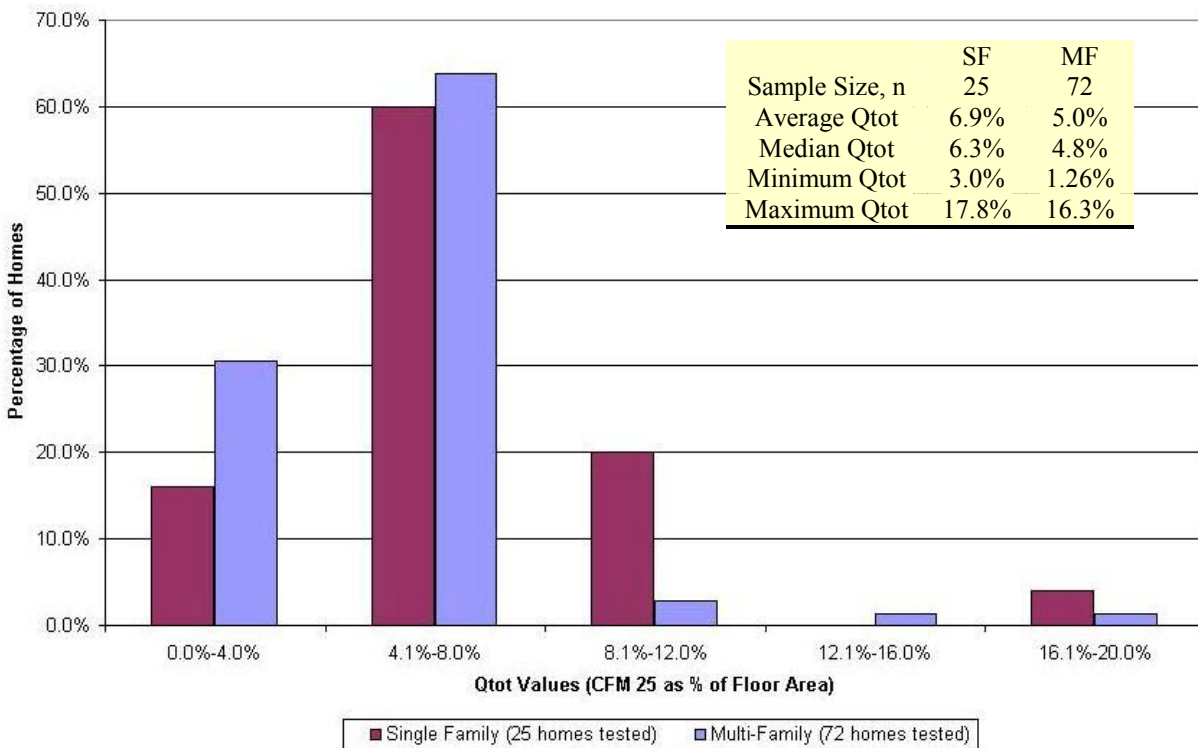


Figure 7 Qtot Values for FL H.E.R.O. Homes

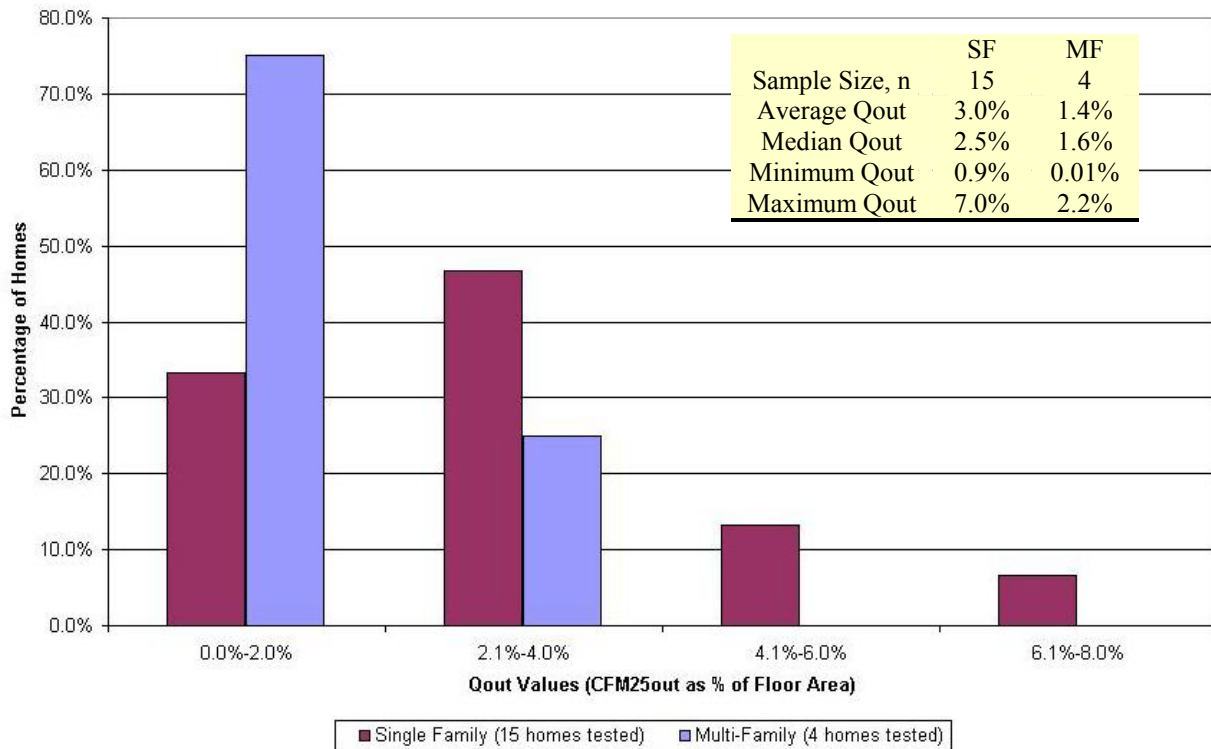


Figure 8 Qout Values for FL H.E.R.O. Homes

Data is available for other typical non BAIHP, new Florida homes (FPL, 1995 and Cummings et al, 2001). The FPL study had a sample size of over 300 single family homes and the median Qout was 7.5%, three times that of the FL H.E.R.O. homes. In the Cummings study of 11 homes the measured average values were: ACH50= 5.7, Q_{tot}=9.4% and Qout=4.7%. Although the sample sizes are small the FL H.E.R.O. homes appear to have significantly more airtight duct systems than typical homes.

The remainder of the paper presents status of other tasks of the BAIHP project.

OTHER BAIHP TASKS

Moisture Problems in HUD code homes

The BAIHP team expends considerable effort working to solve moisture problems in existing manufactured homes in the hot, humid Southeast.

Some manufactured homes in Florida and the Gulfcoast have experienced soft walls, buckled floors, mold, water in light fixtures and related problems. According to the Manufactured Housing Research Alliance (MHRA), who we collaborate with, moisture problems are the highest priority

research project for the industry.

The BAIHP team has conducted diagnostic tests (blower door, duct blaster, pressure mapping, moisture meter readings) on about 40 such problem homes from five manufacturers in the past two years and shared the results with MHRA. These homes were newly built (generally less than 3 years old) and in some cases just a few months old when the problems appeared. The most frequent causes were:

- Leaky supply ducts and/or inadequate return air pathways resulting in long term negative pressures.
- Inadequate moisture removal from oversized a/c systems and/or clogged condensate drain, and/or continuous running of the air handler fan.
- Presence of vinyl covered wallboard or flooring on which moist air condenses creating mold, buckling, soft walls etc.
- Low cooling thermostat set point (68-75F), below the ambient dew point.
- Tears in the belly board and/or poor site drainage and/or poor crawlspace ventilation creating high rates of moisture diffusion to the floor.

Note that these homes typically experience very high

cooling bills as the homeowners try to compensate for the moisture problems by lowering the thermostat setpoints. These findings have been reported in a peer reviewed paper presented at the ASHRAE IAQ 2001. conference (Moyer et al)

The Good News:

As a result of our recommendations and hands-on training, BAIHP partner Palm Harbor Homes (PHH) has transformed duct design and construction practices in all of its 15 factories nationwide producing about 11,000 homes/yr. All Palm Harbor Home duct systems are now constructed with mastic to nearly eliminate air leakage and produced with return air pathways for a total cost of <\$10/home!! The PHH factory in AL which had a high number of homes with moisture problems has not had a single problem home the past year!

Field Monitoring

Several houses and portable classrooms are being monitored and the data displayed on the web. (Visit <http://www.infomonitors.com/>). Of special interest is the side-by-side monitoring of two manufactured homes on the campus of the North Carolina A & T U. where the advanced home is saving about 70% in heating energy and nearly 40% in cooling energy, proving that the Building America goal can be met in manufactured housing. Other monitored sites include the Washington State U. Energy House in Olympia, WA; the Hoak residence in Orlando, FL; two portable classrooms in Marysville, WA; a classroom each in Boise, ID and Portland, OR. See other papers being presented at this symposium for details on two recently completed projects giving results from duct repairs in manufactured homes (Withers et al) and side by side monitoring of insulated concrete form and base case homes (Chasar et al).

“Cool” Roofs and Unvented Attics

Seven side-by-side Habitat homes in Ft. Myers, FL. were tested under unoccupied conditions to examine the effects of alternative roofing strategies. After normalizing the data to account for occupancy and minor differences in thermostat set points and equipment efficiencies, the sealed attic saved 9% and the white roofs saved about 20% cooling energy compared to the base case house with a dark shingle roof for the summer season in South Florida. Visit <http://www.fsec.ucf.edu/%7Ebdac/pubs/coolroof/exum.htm> for more information.

Habitat for Humanity

Habitat for Humanity affiliates work in the local community to raise capital and recruit volunteers.

The volunteers build affordable housing for and with buyers who can't qualify for conventional loans but do meet certain income guidelines. For some affiliates, reducing utility costs has become part of the affordability definition.

To help affiliates make decisions about what will be cost effective for their climate, BAIHP researchers have developed examples of Energy Star homes for more than a dozen different locations. These are available on the web at http://www.fsec.ucf.edu/bldg/baihp/casestud/hfh_estar/index.htm. The characteristics of the homes were developed in conjunction with Habitat for Humanity International (HFHI), as well as Executive Directors and Construction Managers from many affiliates. Work is continuing with HFHI to respond to affiliates requesting a home energy rating through an Energy and Environmental Practices Survey. 36 affiliates have been contacted and home energy ratings are being arranged using combinations of local raters, Building America staff, and HFHI staff.

HFHI has posted the examples of Energy Star Habitat homes on the internal web site PartnerNet which is available to affiliates nationwide.

“Green” Housing

A point based standard for constructing green homes in Florida has been developed and may be viewed at <http://www.floridagreenbuildings.org/>. The first community of 270 homes incorporating these principles is now under construction in Gainesville, FL. The first home constructed and certified according to these standards has won an NAHB energy award.

BAIHP researchers are participating as building science - sustainable products advisor to the HUD Hope VI project in Miami, redeveloping an inner city area with over 500 units of new affordable and energy efficient housing.

Healthy Housing

BAIHP researchers are participating in the development of national technical and program standards for healthy housing being developed by the American Lung Association.

A 50-year-old house in Orlando is being remodeled to include energy efficient and healthy features as a demonstration project.

EnergyGauge USA®

This FSEC developed software uses the hourly DOE 2.1E engine with FSEC enhancements and a user-friendly front end to accurately calculate home

energy ratings and energy performance. This software is now available. Please visit <http://energygauge.com/> for more information.

Industrial Engineering Applications

The UCF Industrial Engineering (UCFIE) team supported the development and ongoing research of the Quality Modular Building Task Force organized by the Hickory consortium, which includes thirteen of the nation's largest modular homebuilders. UCFIE led in research efforts involving factory design, quality systems and set & finish processes. UCFIE used research findings to assist in the analysis and design of two new modular housing factories – Excel homes, Liverpool, PA and Cardinal Homes - Wyliesburg, VA.

CONCLUSIONS

The entire BAIHP team of over 20 researchers and students are involved in a wide variety of activities to enhance the energy efficiency, indoor air quality and durability of new housing and portable classrooms.

In addition to energy efficiency, durability, health, comfort and safety BAIHP builders typically consider resource and water efficiency. For example, in Gainesville, FL BAIHP builders have incorporated the following features in developments:

- Better planned communities
- More attention given to preserving the natural environment
- Use of reclaimed sewage water for landscaping
- Use of native plants that require less water
- Storm water percolating basins to recharge the ground water
- Designated recreational areas
- Better designed and built infrastructure
- Energy efficient direct vented gas fireplaces (not smoke producing wood)

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