

SAFETY, SUSTAINABILITY AND PUBLIC PERCEPTION OF MANUFACTURED HOUSING IN HOT, HUMID CLIMATES

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ABSTRACT

Manufactured housing has become a staple in the US affordable housing market in spite of a prevailing public opinion that such housing is unsafe. However, University of Florida research shows units constructed after 1994 US code changes survived an unprecedented 2004 hurricane season with little damage. Produced in one-fifth the time and at half the cost of site-built homes, manufactured housing assembled in a factory environment uses fewer materials, generates less waste, and fosters greater worker productivity than comparable site-built construction. The following study compares the methods, materials, waste generation and energy use of manufactured housing to site-built homes in 180kmh (110-mph) wind speed zones. Public perception and market barriers associated with manufactured housing are also addressed. This research is intended to assist the building industry in providing safe, sustainable and affordable housing options for hot, humid climates experiencing population growth in disaster prone, resource constrained areas.

INTRODUCTION

Manufactured and modular housing in the US consists largely of factory assembled, transportable units, delivered or towed to the prospective home site. Ranging in size from 35-65m² (400-700ft²) of conditioned floor area, units are commonly fastened to a concrete pier or stem wall foundation (Figure 1). Wheel components and towing packages are removed and reused. Water, electric, sewer and natural gas utilities are connected to stub-outs pre-positioned along the undercarriage of the unit. Decorative skirting, landscaping, patios, driveways and other site enhancements usually follow unit placement. Limited in size by highway regulations, multiple units can be joined together using a common "marriage" wall to form composite units ranging from 85-260m² (900-2800ft²) in conditioned floor area.

In 2002, 22 million Americans, about 8% of the U.S. population, lived in manufactured housing (MHI, 2005). Of the \$US 310.6B single-family residential housing market in 2003, approximately 137,700 (10.7%) of dwelling units sold in the U.S. were manufactured (U.S. Census, 2003). With an average sales price of \$US 59,000, the \$US 20.1B manufactured housing industry (MHI, 2005) has consistently ranked among the nation's leading producers of affordable housing to underrepresented populations.

Despite 4%-5% average annual growth in the U.S. housing market since 1998, demand for manufactured housing has steadily declined. Comprising 14.8% of the single-family residential market in 2002, units sold fell to 10.7% (-27%) in 2003, and again to 8.9% (-17%) by August 2004 (MHI, 2004). Media coverage following an unprecedented 2004 Atlantic hurricane season may have contributed to a feeling among prospective U.S. homebuyers that manufactured housing is unsafe. Reinforced by pre-existing socioeconomic and cultural stereotypes, many believe people who live in manufactured housing do so only because they cannot afford anything else.

To address these and other prevailing public opinions, the following research compares the safety, sustainability and affordability of site-built homes under the most stringent U.S. hurricane code, the Florida Building Code (FBC), to comparable U.S. Housing and Urban Development (HUD) wind zone III manufactured housing units in the state of Florida. Results show that manufactured housing on average, is produced in one-fifth the time and at half the cost of comparable site-built homes. Units constructed after 1994 HUD code changes survived the 2004 hurricane season in Florida with little or no damage, as did comparable site-built homes placed after adoption of the 2002 FBC. Research also indicates that manufactured units produced in a controlled, factory environment use fewer materials, generate less waste, and require less production and life-cycle energy than comparable site-built units.



Figure 1. Manufactured and modular housing production facility (left). Prefabricated unit placement on concrete masonry unit (CMU) stem wall foundation (right) Jacobsen, 2005.

SUSTAINABILITY

Population growth, economic development and other environmental stressors increasingly compromise the sustainability of natural resources worldwide. Energy and material resources are being consumed faster than natural rates of regeneration. Wastes, emissions and other pollutants outpace nature's ability to assimilate them. Approximately 25%-40% of the earth's global net primary production, or the amount of solar energy captured in photosynthesis by primary producers, is consumed by humans. In 2004, U.S. energy use exceeded 29.37×10^9 MW (100.25×10^{15} Btu or "quads"), or approximately 22.6% of the world's fossil fuel consumption (DOE, 2004). The U.S. energy efficiency index provided by the Department of Energy (DoE) indicates that the built environment consumes 36% of all U.S. energy resources, with the

housing sector amounting to nearly 60% of this demand. Increasing in average floor area from 135m^2 ($1,450\text{ft}^2$) to more than 205m^2 ($2,200\text{ft}^2$) in the last 30 years (U.S. Census, 2003), the average U.S. single-family household now uses about 15,000kWh of energy per year.

Energy Efficiency

Both manufactured and site-built homes placed in Florida are required to "pass" the Florida Energy Code (FEC), which meets or exceeds the U.S. Model Energy Code (MEC). 2005 University of Florida site surveys of five HUD wind zone III production facilities found energy-related methods and materials used in 1994 HUD Code units remarkably similar to site-built homes constructed to the 2002 Florida Building Code in 180kmh (110mph) wind zones (Table 1).

Table 1. Comparison of common energy-related components of 1994 HUD Code manufactured units and comparable 2002 FBC site-built units.

Category	Manufactured	Site-built
Fenestration	Insulated (double pane)	Insulated (double pane)
Floor system	50x200mm (2x8in) wood frame, 180mm (R-22) batt insulation	100mm (4in) monolithic concrete on grade, uninsulated
Exterior wall system	50x150mm (2x6in) wood frame, 150mm (R-19) batt insulation	50x100mm (2x4in) wood frame, 100mm (R-13) batt insulation
Ceiling system	50x75mm (2x3in) wood truss, 200mm (R-26) blown insulation	50x100mm (2x4in) wood truss, 250mm (R-30) blown insulation
HVAC system	Cooling – split 12 SEER Heating – 7.0 HSPF heat pump	Cooling – split 12 SEER Heating – 7.0 HSPF heat pump
Ducts	50mm (R-6) insulation	50mm (R-6) insulation
Hot water system	0.89 electric efficiency	0.89 electric efficiency



Figure 2. Manufactured unit R-19 wall insulation (left). R-26 blown ceiling insulation (right) Jacobsen, 2005.

2002 FBC compliant site-built homes are usually constructed of either 200mm (8in) hollow core concrete masonry unit (CMU) walls or 50x100mm (2x4in) dimensional wood frame walls placed on cast-in-place (CIP) concrete floor systems. Manufactured units are constructed of 50x100mm (2x4in) or 50x150mm (2x6in) dimensional wood frame walls placed on wood floor systems, fastened to transportable steel chasses, and installed on pier or stem wall foundations. The use of 50x150mm (2x6in) dimensional lumber permits use of 150mm (6in) cavity insulation with a U-value of 0.053 (R-19), approximately 30%-50% more than comparable site-built homes. Both 1994 HUD Code and 2002 FBC site-built units commonly use blown insulation in cases where roof cavities or attics remain accessible after placement of ceiling gypsum board (Figure 2).

Transportation restrictions on roof height may limit the depth of ceiling insulation in manufactured units to 180-200mm (7-8in), compared to 230-300mm (9-12in) in site-built homes. Comparable fenestration, heating, ventilating and air conditioning (HVAC), and water heating equipment are used in both manufactured and site-built units to meet the requirements of the FEC (Table 1).

Using the information in Table 1, the energy performance of 1994 HUD Code manufactured units was compared to the energy performance of 2002 FBC site-built homes using two (2) sample unit floor plans (Figures 3 and 4). These floor plans are representative of nearly 80% of the U.S. single-family home market with habitable floor area ranging from 115-280m² (1,200-3,000ft²).

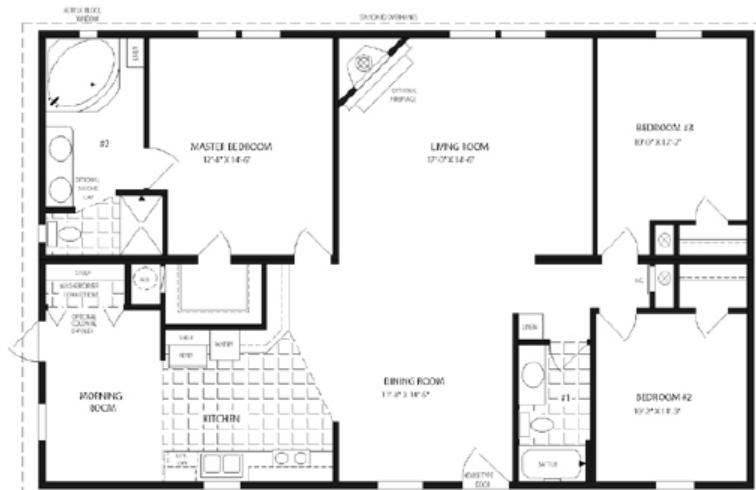


Figure 3. 1994 HUD Code and 2002 FBC site-built unit energy simulation floor plans (Jacobsen, 2005).
Case study unit "A": 3 bedroom, 137m² (1,472 ft²).

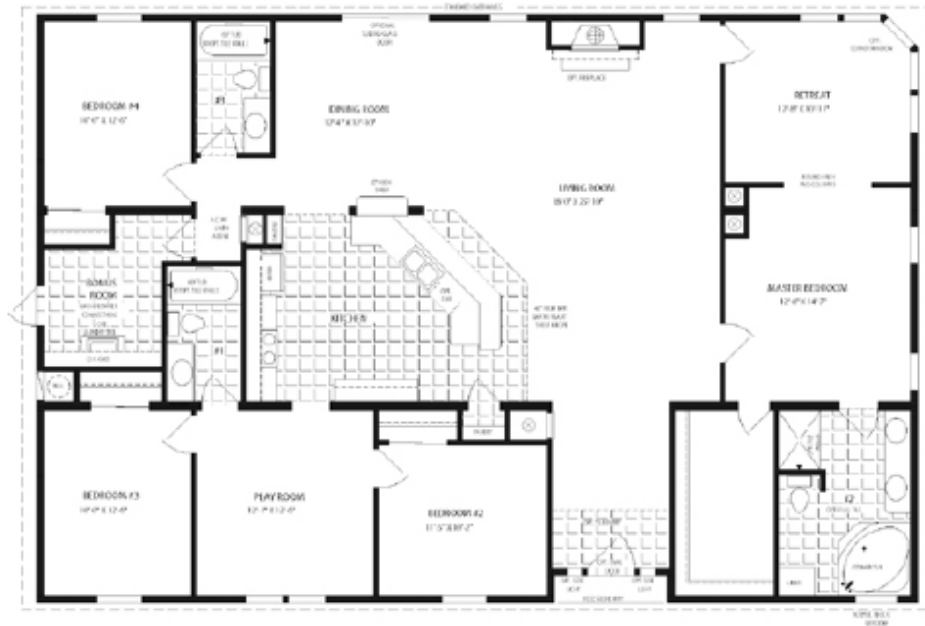


Figure 4. 1994 HUD Code and 2002 FBC site-built unit energy simulation floor plans (Jacobsen, 2005).
Case study unit “B”: 4 bedroom, 230m² (2,460 ft²)

REM Design v. 8.21 home energy analysis software was used to simulate the energy performance of manufactured and site-built materials and equipment in Orlando, a temperate, subtropical region of Florida having on average 15,840 heating and 33,985 cooling *degree hours* per year. A degree hour is defined as a one-hour period where the outside temperature is one degree Fahrenheit below the 65°F (18°C) heating baseline temperature, or, above the 74°F (23°C) cooling baseline temperature.

“Constructing” the floor plans provided in Figures 3 and 4 with respective equipment and materials provided in Table 1, results indicate little difference in energy consumption between 1994 HUD Code units and comparable 2002 FBC site-built homes meeting the FEC. In fact, both floor plans constructed to 1994 HUD Code standards performed slightly better than the same floor plans constructed to 2002 FBC site-built standards (Table 2).

Table 2. Comparison of computer-simulated energy performance of 1994 HUD Code manufactured units and comparable 2002 FBC site-built units (kW/yr).

Category	Manufactured		Site-built	
	Unit A	Unit B	Unit A	Unit B
Heating Load	1,319	2,725	1,905	3,252
Cooling Load	11,368	14,181	11,427	14,240
Water Heating Load	3,604	3,604	3,633	3,633
Heating Consumption	645	1,319	938	1,582
Cooling Consumption	3,223	4,043	3,252	4,043
Water Heating Consumption	3,692	3,692	3,692	3,692
Lights and Appliances	5,684	5,743	5,684	5,743
Total	13,244	14,797	13,566	15,060
Annual Cost (\$US)*	1,191.96	1,331.73	1,220.94	1,355.40

* Electricity rate \$0.09/kWh. Excludes utility service fees.

Energy performance parameters were modified slightly to represent common differences in manufactured home construction and site-built home construction in Florida. First, it was assumed that an unconditioned, uninsulated garage was integrated into the design and construction of the site-built home at one end wall location. Since integrated garage units are not common in manufactured home construction, the thermal buffer of the unconditioned garage provided an energy-efficiency advantage for the site-built unit. It was further assumed that air handling unit (AHU) and domestic water heating (DWH) equipment in the site-built unit was located in unconditioned (garage) space. The AHU in the manufactured unit was located in conditioned space along a marriage wall. The DWH in the manufactured unit was located in an insulated, unconditioned space, at sidewall, endwall or marriage wall locations. Positioned for ease of installation during the production process, the respective locations of both AHU and water heating equipment in manufactured housing reduces heat gain and heat loss significantly over the same equipment installed in typical site-built homes.

The greatest energy performance difference between manufactured and site-built units appears in heating load and heating consumption. Assuming a winter design temperature of 3°C (38°F) and a heating set point of 20°C (68°F), the difference in temperature (ΔT) between outside and inside is 17°C (30°F). Comparatively, the ΔT of a 34°C (93°F) summer design temperature and a 25°C (78°F) cooling set point is roughly half. The manufactured unit having 150mm (6in) of exterior wall insulation may in part be responsible for heating load reductions of 15%-30% over comparable site-built homes having 30%-50% less exterior wall insulation. The

value of added exterior wall insulation is more apparent in case study unit "A", since smaller units have greater wall surface area relative to floor area. Also, because of roof height limitations, HVAC ducts in manufactured units are commonly installed within the ceiling insulation, whereas ducts in site-built homes are usually suspended above ceiling insulation.

Materials and Waste

More than a third of all U.S. construction is residential. Roughly 80% of U.S. residential construction is single-family housing. U.S. single-family homebuilders generate approximately 5.5×10^{10} kg (60 million tons) of construction and demolition (C&D) waste each year. Depending on location, disposal costs for construction waste in the U.S. is approximately \$US 0.03-0.08/kg (\$US 30-75 per ton). Surveys conducted by DOW U.S.A. and the U.S. National Association of Home Builders (NAHB) found that contractors spend approximately \$US 500 per newly constructed residence on disposal costs. Recyclable wood, drywall and cardboard can make up 60% or more of residential construction waste by volume. As much as 15% of residential wall framing and sheathing material delivered to a residential construction site ends up as disposed cut-off waste.

Findings from a 1993 NAHB study indicate that the U.S. average waste generation rate is 14.6-25.4kg/m² (3.0-5.2lb/ft²). Comparatively, a 1997 University of Florida study of three homebuilders in Florida found waste generation rates for site-built homes averaging 356m² (3,830ft²) of floor area to be roughly 9,872kg (21,764lbs) per unit, or 27.6kg/m² (5.6lb/ft²). By volume, waste generation rates in this study averaged 25.8m³ (33.7yd³) per unit, or, 0.07m³/m² (0.24ft³/ft²) of floor area (Table 3).



Figure 5. Typical site-built home construction site.

Table 3. Site-built home waste generation. Alachua County, Florida (Uhlik, 1997).

Category	Average Volume (m ³)	Average Weight (kg)	Average Weight (kg/m ²)
Solid Wood	11.06 (41%)	3,076 (31%)	8.80
OSB (Chip Board)	2.98 (12%)	786 (8%)	2.09
Plywood	0.41 (2%)	146 (1%)	0.40
Gypsum Board	2.78 (11%)	973 (10%)	2.54
Metals	0.35 (1%)	85 (1%)	0.22
Cardboard	1.81 (7%)	220 (2%)	0.65
Paper	0.53 (2%)	57 (1%)	0.15
Plastics	0.79 (3%)	67 (1%)	0.18
Concrete	2.52 (10%)	1,954 (20%)	5.71
Brick/Tile	0.60 (2%)	575 (6%)	1.37
Shingles	1.01 (4%)	428 (4%)	1.24
Insulation	0.75 (3%)	39 (1%)	0.13
Siding	0.70 (3%)	361 (4%)	1.05
Misc. Residual Waste	n/a	1,239 (13%)	3.42
Totals	25.81	9,872	27.57

A 2005 University of Florida survey of single-family homebuilders throughout Florida found that 5%-10% of all construction material delivered to the site, or approximately \$US 3,170 per 215m² (2,320ft²) unit, ultimately becomes part of the project waste stream (Figure 6). Combined with average waste disposal (tipping) fees of \$US 300 per bin, or

between \$US 600-900 per site-built unit, cut-off wastes and other debris cost the contractor more than \$US 4,000 per unit, or \$US 19.40 per m² (\$US 1.80 per ft²). Considering average construction costs of \$US 485-645 per m² (\$US 45-60 per ft²), wasted materials and subsequent disposal fees are roughly 3%-5% of total direct job costs.

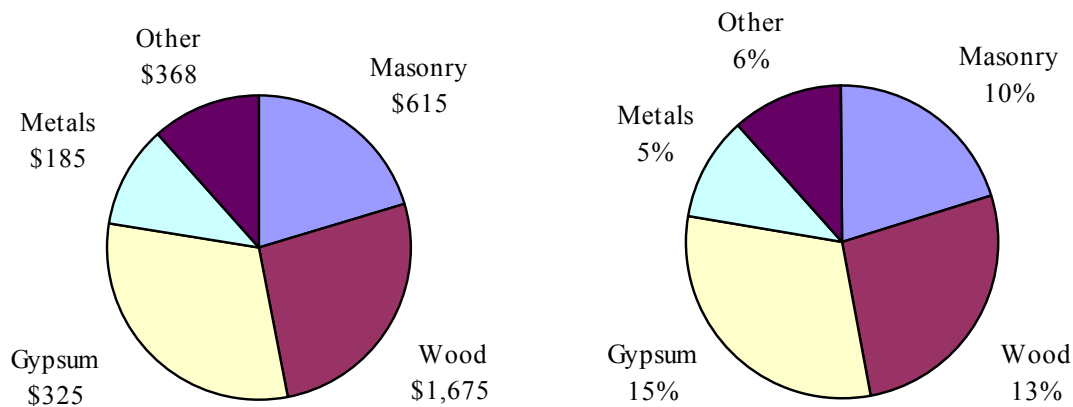


Figure 6. Site-built home wasted material cost in Florida.

Palm Harbor Homes, the third leading U.S. producer of manufactured homes, collects wood cut-off waste from various production areas. Dimensional lumber is reworked into a variety of building components such as dormers, overhangs and roof cap assemblies. Panel products such as 13mm (1/2") and 19mm (3/4") plywood and oriented strand board (OSB) are collected and reused for

weatherproofing strips, access panels and duct drops (Figure 7). Larger cut-off waste is reused directly within floor, wall and roof assembly areas. Optimizing material cut sizes are also considered in the design process. Cut-off waste too small to be reused is taken to recycling bins where it is either recycled into OSB, particleboard or ground into mulch. Unlike site-built homes, bulk lumber is

purchased in truckload quantities and shipped direct from wholesale lumber mills, reducing cost, handling, weather exposure and subsequent damage. Recyclable materials that cannot be reused such as cardboard, paper, scrap steel, aluminum and copper wire, are collected and sold to local waste recyclers.

Resale of recycled wood, paper and gypsum products can range from \$US 0.02/kg (\$US 20/ton), to \$US 0.66/kg (\$US 600/ton) for vinyl and aluminum siding. Additionally, production line workers receive recognition and cash awards for their innovations in material reuse and recycling.



Figure 7. Reused dimensional lumber and OSB cut-off waste.

Nobility Homes, a producer of approximately 20 finished manufactured units per week, averages two 61.2m² (80yd³) compaction waste bin “pulls” per week. The remaining materials are reused or recycled. Assuming an average “double-wide” unit floor area of 130m² (1,400ft²), landfill waste is approximately 0.05m³/m² (0.15ft³/ft²), or 35%-40%

less than comparable site-built homes. Table 4 (below) provides a summary comparison of common policies and practices in both manufactured housing and site-built housing industries that affect material use efficiency and subsequent waste generation, reuse, recycling and disposal activities in Florida.

Table 4. Summary comparison of manufactured housing and site-built housing material use efficiency and subsequent waste generation, reuse, recycling and disposal activities.

Option	Manufactured	Site-built
Modular dimensions	Units designed and fabricated by single entity; minimizing materials and cut-off waste a major design element.	Units usually designed and constructed by separate entities; little design focus on materials, cut-off waste.
Material storage	Units fabricated in climate controlled environment, minimizing weather exposure and material damage.	Units and materials exposed to weather until 40%-60% complete, resulting in moisture damage and indoor air quality (IAQ) issues.
Material reuse	Units fabricated by permanent work teams under single-point supervision. Sufficient floor space available for cut-off waste storage and source separation bins for reuse and recycling. Work platforms and fabrication templates provided by permanent equipment. Work teams provided profit sharing for reducing waste and disposal costs.	Units constructed by 12-15 temporary subcontractors; little or no waste reuse between trades. Limited on-site storage space for cut-off waste and recycling bins. Scaffolding, form work, and other temporary shoring reduce material reuse quality. Some subcontracts (i.e., unit price) provide incentive to waste materials.

Production efficiency	Units produced in “assembly line” fashion, reducing fabrication time and labor costs relative to material costs. Material reuse and source separation usually feasible.	Units constructed in multiple stages on decentralized sites increasing construction time and labor cost. Labor investment into material reuse and source separation usually not feasible.
Waste disposal	Manufacturer closely monitors waste tipping fees; often source separates unusable waste for recycling to reduce costs and improve profit margins	General contractor generally provides waste disposal; subcontractors have little or no incentive to reduce waste. Commingled waste difficult to reuse or recycle. “Drive by” dumping can add as much as 30% more waste.

SAFETY

In 1974, Congress required the Secretary of U.S. Housing and Urban Development (HUD) to establish minimum requirements for manufactured housing construction and safety. In response to Hurricane Andrew in 1992, HUD amended its regulations governing mobile home construction in 1994 (DHSMV, 2004). The 1994 HUD amendments created a “Wind Zone III” category for 14 coastal counties of Florida, requiring manufactured housing placed in these areas to withstand 180kmh (110mph) wind loads (Jordan, 2004). HUD 160kmh (100-mph) Wind Zone II remained in effect throughout the rest of Florida since no area of the state is greater than 65 miles from the coast. The 1994 amendments required manufactured housing to be designed by a professional engineer, and, to withstand the wind loads and airborne debris impact requirements of each wind zone. Wind load analysis indicates that wind zone III units are approximately 25% stronger than 1976 compliant units. To simplify production processes and avoid market barriers, many manufacturers have opted to produce wind zone III units exclusively, since the added cost of these units is approximately \$US 500 or less of zone II homes.

Common engineered changes in manufactured housing located in Wind Zone III included:

- 26ga. galvanized strap connections between floor, wall and roof assemblies spaced 405mm (16in) apart
- 50x200mm (2x8in) and 50x255mm (2x10in) floor joists spaced 405mm (16in) apart
- 16mm (5/8in) and 19mm (3/4in) sub-floor sheathing
- 50x100mm (2x4in) and 50x150mm (2x6in) side-wall and end-wall studs spaced 405mm (16in)
- Double 50x100mm (2x4in) marriage walls
- Improved attachment of exterior coverings and sheathing (6 fasteners per shingle)
- Increased resistance and protection of windows to wind loads and airborne debris
- Increased number of shear walls (4-6 per unit)
- 10mm (3/8in) and 13mm (1/2in) wall and roof sheathing
- Trusses spaced 405mm (16in) and doubled within 1.0m (3ft) of each end



Figure 8. 13mm (1/2in) OSB roof sheathing (left). Doubled trusses within 1m (3ft) of each gable end with uplift tie-downs and straps (right) Jacobsen, 2005.



Figure 9. Galvanized auger anchors placed at a minimum depth of 1.2m (4ft) (left). Sidewall and frame ties spaced 1.6m (5.3ft) on center (right) Jacobsen, 2005.

In addition to the 1994 HUD amendments, the DHSMV implemented a mobile home installer program in 1996, requiring the testing, licensing and sanctioning of individuals who install mobile homes in accordance with Rule Chapters 15C-1 and 15C-2 of the Florida Administrative Code (FAC). These administrative rules provide standards for mobile home foundations, anchors and anchoring straps used to secure the unit to the ground. These rules were revised in 1999 in response to damage caused by F2 tornadoes in central Florida killing 39 people in manufactured homes during the early morning hours of March 9, 1998. Key 1999 changes to FAC 15C include:

- Galvanized auger anchors and straps placed at a minimum depth of 1.2m (4ft)
- Sidewall and frame ties spaced 1.6m (5.3ft) apart
- Longitudinal anchors, 2 per I-beam per end
- Centerline ties within 0.6m (2ft) of each end
- Anchor soil testing

2004 Atlantic Hurricanes

On Friday, August 13, 2004, Hurricane *Charley* came ashore on a fast 35kmh (22mph) northeast track from the Gulf of Mexico with 235kmh (145mph) sustained winds (Table 5). The eye of the hurricane traversed Charlotte Harbor and heavily damaged homes in nearby Punta Gorda before heading across central Florida and exiting the state near Daytona Beach. Late Saturday, September 5, 2004, Hurricane *Frances* made landfall near Stuart, Florida from the Atlantic with winds of 170kmh (105mph) moving slowly at 8kmh (5mph) to the west-northwest. The eye of this hurricane was so large the U.S. National Hurricane Center reported the eye wall to encompass three coastal counties. In the early morning hours of September 16, 2004, Hurricane *Ivan* came ashore west of Pensacola, exposing much of the Florida panhandle to hurricane force winds. As powerful as *Charley* and as large as *Frances*, the onshore, counterclockwise rotation produced storm surge exceeding 5m (15ft) (DHSMV, 2004).

Table 5. Category 3 or greater hurricanes impacting Florida in 2004 (InfoPlease, 2005).

Hurricane	Dates	Maximum Winds	Deaths	U.S. Damage (\$US Millions)
Charley	9-14 Aug	150	15	14,000
Frances	25 Aug – 8 Sep	145	7	8,860
Ivan	2-24 Sep	165	95	13,000
Jeanne	13-29 Sep	120	3000*	6,500
Totals				42,360

*Haiti and entire Atlantic basin.



Figure 10. Pre-2002 FBC site-built homes destroyed, post-2002 FBC site-built homes intact (left). Pre-1994 HUD Code manufactured home destroyed, post-1994 HUD Code manufactured home intact (FMHA, 2004).

Following a nearly identical track as Frances three weeks prior, Hurricane *Jeanne* became the fourth major (category 3+) hurricane to score a direct hit on Florida within a span of 6 weeks. From north of Miami to south of Jacksonville, this 645km (400mi) wide storm with sustained winds exceeding 195kmh (120mph) destroyed hundreds of manufactured housing units damaged or weakened by Frances three weeks earlier (DHSMV, 2004). Following these four major hurricanes, teams from DHSMV conducted damage assessments in 152 communities impacted by one or more 2004 hurricanes. Of the 29,275 manufactured homes surveyed, 3,583 pre-1994 HUD units were totally destroyed or non-reparable. In contrast, none of 4,056 post-1994 HUD units surveyed were destroyed or seriously damaged (Table 6).

Homes built prior to the 1976 HUD Code did not perform well. Damages were attributed to inadequate anchors, corroded anchors, or penetrations of the exterior walls and windows of the units by wind-borne debris. Car ports, screened rooms and other

add-ons attached to units failed and removed portions of walls and roof assemblies, exposing units to rapid pressurization and progressive fatigue and failure. In thirty-three communities surveyed immediately following Hurricane Charley for example, approximately 75% of carports, awnings, sheds and additions collapsed or became airborne debris hazards for adjacent structures. Roof-overs and one-piece membrane roof covers performed poorly, having too few fasteners and too little bight (length). This allowed a large percentage to be blown off, leading to progressive structural failure or unsalvageable water damage. U.S. Federal Emergency Management Agency (FEMA) flood zone requirements for elevating foundation I-beams above the base flood elevation resulted in catastrophic uplift. Concrete foundations (pads), patios and walkways placed in contact with tie-downs corroded straps. Moisture entrained by concrete and poor undercarriage ventilation less than 0.1m² (1ft²) per 14m² (150ft²) of floor area, led to premature rotting and termite damage of floor joists, wall plates and other structural components (Jordan, 2004).

Table 6. Hurricane survivability of pre-1994 HUD and post-1994 HUD manufactured housing (DHSMV, 2004).

Hurricane	Number of Manufactured Homes	Pre-1994 HUD	Destroyed	Post-1994 HUD	Destroyed or Seriously Damaged
Charley	11,909	9,011	2,413 (26.8%)	2,898	0 (0.0%)
Frances	7,089	6,961	99 (1.4%)	128	0 (0.0%)
Ivan	1,432	1,246	82 (6.6%)	186	0 (0.0%)
Jeanne	8,845	8,001	989 (12.4%)	844	0 (0.0%)
Totals	29,275	25,219	3,583 (14.2%)	4,056	0 (0.0%)

Table 7. Level of damage vs. household income (\$US) for occupants living in manufactured housing (Stroh and Smith, 2004).

Level of Damage	≤ 30,000	30,001-40,000	40,001-50,000	50,001-60,000	60,000+	Total
Destroyed	3,126	389	189	87	99	3,890
Major	9,347	1,029	426	187	183	11,172
Moderate	8,914	919	366	169	157	10,525
Minor	16,012	1,620	772	336	313	19,053
Totals	37,399	3,957	1,753	779	752	44,640

Damage experienced by manufactured units built after 1976 but prior to the 1994 amendments were similarly related to envelope exposures from the destruction of carports, screened rooms and awnings and impact damage from such add-on structures not covered by the HUD Code. A relatively smaller number of these units were observed to have shifted off their foundations when compared to pre-1976 HUD Code units (DHSMV, 2004). Post-1994 HUD units performed well, experiencing in all observed cases comparatively minor and repairable damage resulting from add-on failures and airborne debris damage. Unlike pre-1994 HUD Code units, post-1994 units did not experience progressive failure following the loss of an add-on structure. Damage was limited to the immediate and affected area of the attachment. (DHSMV, 2004). Homes installed or retrofitted in accordance with Rule Chapter 15C-1 (FAC), remained on their foundations with no movement as a result wind loads or floodwater, with the exception of three homes impacted by storm surge from Hurricane Ivan.

However, many retrofitted pre-1994 HUD units were destroyed by other causes unrelated to foundation stability (DHSMV, 2004). A study of Florida households sustaining structural damage from the 2004 Hurricanes using data compiled from FEMA disaster assistance registration shows that 3,890 (66%) of 5,901 dwelling units destroyed were manufactured homes. In addition, 44,640 (40%) of the state's 113,620 dwelling units receiving FEMA assistance for structural damaged were manufactured housing units. Of these, 37,399 (84%) had annual household incomes of \$US 30,000 or less (Table 7). In all, approximately 7.65% of the state's nearly 600,000 manufactured housing units sustained damage from one or more of the 2004 hurricanes compared to 1.8% of the single-family dwelling stock and 0.54% of multifamily units (Stroh and Smith, 2004).

PUBLIC PERCEPTION AND MARKET BARRIERS

In 2002, 22 million Americans, about 8% of the U.S. population, lived in manufactured housing (MHI, 2005). Of the \$US 310.6B single-family residential housing market in 2003, approximately 137,700 (10.7%) dwelling units sold in the U.S. were manufactured (U.S. Census, 2003). With an average sales price of \$US 59,000, the \$US 20.1B manufactured housing industry has consistently ranked among the nation's leading producers of affordable housing to low income and underrepresented populations. In spite of this, the market for manufactured housing has steadily declined since 2002. Comprising 14.8% of the single-family residential market in 2002, units sold fell to 10.7% (-27%) in 2003, and again to 8.9% (-17%) as of August 2004 (MHI, 2004). Florida, along with California and Texas, lead the nation in underrepresented populations, and ironically, in the number of manufactured housing units. In 2003, Florida ranked second only to Texas in the number of units (10,900) sold and placed (U.S. Census, 2003).

"Little boxes death traps in storm's fury...manufactured homes have no chance, yet we keep building them." (U.S. Media, 2004)

Following the 2004 hurricane season, media outlets inundated the public with images of destroyed mobile home communities throughout 60 of 67 counties in Florida. Comparatively little attention was given to manufactured units produced after 1994, when the U.S. Department of Housing and Urban Development (HUD) enacted wind-load amendments to the former 1976 HUD Code. In fact, preliminary reports by state and federal officials found that these units, and units installed to the Florida's 1999 tie-down requirements, suffered little or no damage as older units nearby sustained damage ranging from severe to catastrophic (DHSMV, 2004).

In response, the University of Florida commissioned research aimed at determining the role of media in shaping consumer opinions of manufactured housing. A procedure was developed to survey respondent's perceptions prior to and following media exposure. The survey population chosen consisted of university students ($n = 113$) considered potential new homebuyers within 1-5 years. A 5-point Likert format was chosen, giving participants a range of agreement or positive responses and disagreement or negative responses to each survey statement presented. Negative responses were coded values ranging from < 0 to -2 according to the strength of the response. Similarly, positive responses were coded values ranging from > 0 to $+2$.

Prior to information and image exposure, respondents were asked questions relating to their general familiarity and perception of manufactured housing (Table 8). Half of all respondents (48.7%) considered their knowledge of manufactured housing to be lacking as 43.4% had not lived in manufactured housing or had personally known anyone living in manufactured housing. Almost 9 out of 10 respondents (86.7%) considered manufactured housing to be unsafe with 46.0% believing people who live in manufactured housing do so only because they cannot afford anything else. Fewer than 1 in 10 respondents (8.0%) felt manufactured homes are suitable investments as secondary residences or vacation homes. Next, respondents were divided into three groups and again asked questions relating to manufactured housing safety, quality and value. Prior to each question however, respondents were presented with scripted and graphic information regarding production methods, building codes, and finished product. The first survey group or "positive" group, was exposed to photographs of current production methods and materials *exceeding* that of FBC compliant site-built homes and images of post-

1994 HUD units surviving the 2004 hurricane season undamaged. The second survey group or "neutral group", was shown images of methods and materials *comparable* to FBC compliant site-built homes and images of 2004 hurricane property damage in general, without specific images or inferences to manufactured housing. The third survey group or "negative group", was exposed to stereotypic trailer mount and "double-wide" images as well as photographs of pre-1994 HUD units severely damaged or destroyed by one or more 2004 hurricanes. The intent of the survey procedure was to evaluate the possible effects of media bias on respondent perception of manufactured housing. Statistical analysis was performed on each of the three groups to account for differences in perception, if any, prior to introduction of the media. On a scale of -2 to 2 , respondent perceptions of manufactured housing prior to the introduction of survey media bias was moderately negative (-0.88 to -1.13). At 95% confidence ($\pm 5\%$ error), no statistically significant differences were found between groups (Table 8).

Respondent perceptions of manufactured housing improved in *all* groups when exposed to images of manufactured housing production methods and finished product. The overall (average) opinion of respondents exposed to positive media improved most, from -0.88 to 0.26 ($+1.14$). Improvement among respondents exposed to neutral and negative media was comparatively less, -1.13 to -0.47 ($+0.66$) and -1.10 to -0.85 ($+0.25$) respectively. However, only respondents in the "positive" group concluded the study with a favorable opinion of manufactured housing. At 95% confidence ($\pm 5\%$ error), an analysis of variance determined that statistically significant differences existed between *all* groups exposed to different media bias (Table 9).

Table 8. Public perception of pre-media exposure groups to manufactured housing.

	Positive Group	Neutral (Control) Group	Negative Group
	$n = 38$	$n = 46$	$n = 29$
Question			
1	- 0.74	-0.43	-0.66
2	- 0.79	-1.26	-1.34
3	- 0.87	-1.33	-0.97
4	- 1.11	-1.50	-1.45
Mean	-0.88	-1.13	-1.10
Standard Deviation	0.76	0.85	0.76
95% Confidence (\pm)	0.24	0.27	0.24

Table 9. Public perception of post-media exposure groups to manufactured housing.

	Positive Group <i>n</i> = 38	Neutral (Control) Group <i>n</i> = 46	Negative Group <i>n</i> = 29
Question			
5	0.61	-0.41	-0.76
6	0.18	-0.83	-1.24
7	0.58	0.04	-0.34
8	0.37	-0.74	-0.83
9	0.08	-0.48	-0.52
10	-0.24	-1.52	-1.72
11	1.13	0.67	-0.07
12	0.21	-0.43	-0.86
13	-0.55	-0.50	-1.28
Mean	0.26	-0.47	-0.85
Standard Deviation	1.02	1.04	1.01
95% Confidence (±)	0.32	0.30	0.37

Statistical analysis using the Pearson product moment correlation coefficient (*r*) further indicated a significant correlation between media bias and public perception. Pearson *r*, a statistical index that ranges from -1.0 to 1.0, reflects the strength of a linear relationship between two data sets where 1.0 is a perfect positive correlation and -1.0 is a perfect negative correlation. Exposed to favorable (positive) media, respondent perceptions of manufactured housing improved when compared to perceptions of respondents in the neutral or “control” group (+0.73, *r* = 0.73). Exposed to less favorable (negative) media, respondent perceptions of manufactured housing declined when compared to perceptions of respondents in the neutral group (-0.38, *r* = 0.91).

When presented with the statement “manufactured dwellings are safe”, 66% of the respondents in the “positive” group agreed, compared to 69% in the “negative” group that disagreed (Figure 11). Similarly, 53% of respondents in the “positive” group felt that the quality control of manufactured home construction is as stringent as site-built homes, compared to only 14% in the “negative” survey group. Thirty-one percent (31%) of respondents in the “positive” group considered manufactured housing to be a better value than site-built homes, compared to only 21% of respondents exposed to negative media.

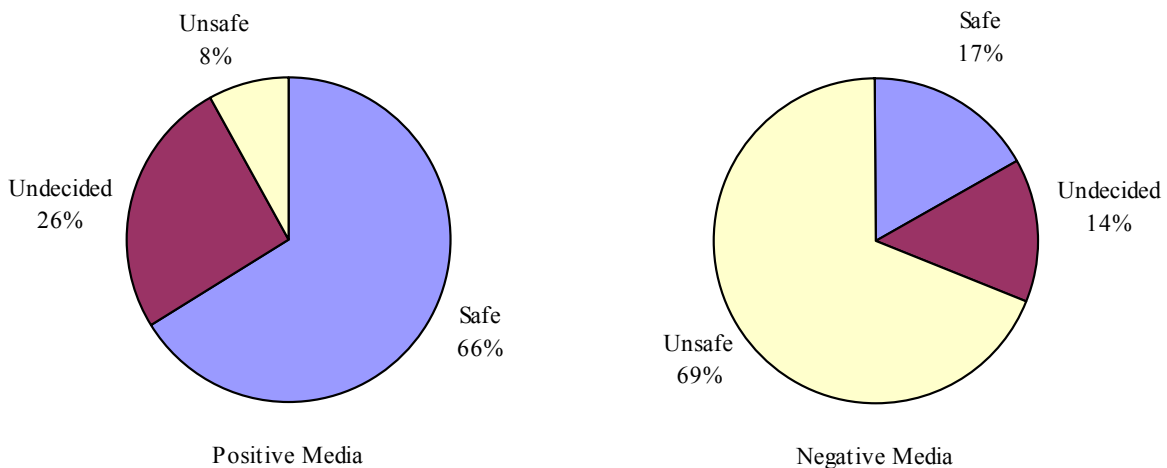


Figure 11. Public perception of post-media exposure groups to manufactured housing.

Affordability

A sample 260m² (2,800ft²) HUD wind zone III manufactured home comprised of 4 modular units approximately 65m² (700ft²) each was found to have a material cost of approximately \$26,100, or \$US 100 per m² (\$9.32/ft²). Material costs for a comparable FBC compliant site-built home in the same 180kmh (110mph) wind zone, costs between \$US 240-325/m² (\$US 22.50-30.00/ft²). Material costs are approximately 60% of the \$US 49,000 wholesale price for the manufactured unit, or, 2-3 times less than materials for comparable site-built homes as a result of material reuse, recycling and volume wholesale purchasing. Although information on labor costs and profit margins remain confidential for competitive reasons, it is assumed that labor is 30% or less of the total cost of the manufactured unit and 4-5 times less than comparable site-built homes. In addition, site-built homes are subject to retail material purchasing, profit mark-ups of subcontractors, and additional builder mark-ups. Manufactured units are often subject to retail sales mark-ups and transportation and site installation costs. On average, HUD wind zone III manufactured homes with furnishings and appliances, have net occupancy cost of between \$US 540-600/m² (\$US 50-55/ft²), or 25%-40% below comparable FBC site-built homes.

CONCLUSIONS

On average, HUD wind zone III manufactured homes have net occupancy costs between \$US 540-600/m² (\$US 50-55/ft²), or 25%-40% below comparable FBC site-built homes. Produced in one-fifth the time and at half the cost of site-built homes, manufactured housing assembled in a controlled, factory environment uses fewer materials and generates 35%-40% less waste than comparable site-built units. Using comparable materials and installation methods as 2002 FBC compliant homes, 1994 HUD wind zone III units are as energy efficient and survivable as site built construction in 180kmh (100mph) wind zones. In spite of this, media exposure was found to have a significant impact on the public perception of manufactured housing safety, quality and value. 66% of survey respondents exposed to positive media bias considered manufactured housing to be safe, compared to 69% who considered manufactured housing to be unsafe following negative media exposure. However, research indicates that post-1994 manufactured housing is a safe, sustainable and affordable option in hot humid climates prone to natural disasters and resource constraints.

REFERENCES

- Division of Motor Vehicles, Department of Highway Safety and Motor Vehicles (2004) Mobile Home Damage Assessments from Hurricanes Charley, Frances, Ivan and Jeanne. Bureau of Mobile Home and RV Construction.
- Draper, M. (2005) Interview. Palm Harbor Homes, Inc.
- Florida State University (2005) 2004 Atlantic Hurricane Season. EXPLORES!
<http://www.met.fsu.edu/explores/tropical.html>. {Accessed: March 2005}.
- Grosskopf, K.R. and D. Cutlip (2005) Site investigation and interview. Jacobsen Homes, Inc.
<http://www.jachomes.com/construction.html>. {Accessed: November 2005}.
- Infoplease™ (2005) U.S. Hurricanes.
<http://www.infoplease.com/ipa/A0001443.html>. {Accessed: March 2005}.
- Jordan, Wayne (2004) Manufactured/Mobile Home Study from Hurricane Charley. Bureau of Mobile Home and RV Construction, Division of Motor Vehicles, Department of Highway Safety and Motor Vehicles (DHSMV).
- Manufactured Housing Institute (2004) Monthly Manufactured Home Shipments.
<http://www.manufacturedhousing.org>. {Accessed: March 2005}.
- Manufactured Housing Institute (2005) Fast Facts.
<http://www.manufacturedhousing.org>. {Accessed: March 2005}.
- National Association of Homebuilders (1993) Residential Construction Waste Management: A Builder's Field Guide. NAHB Research Center.
- Schrader, Dennis (2005) Interview. Jacobsen Homes, Inc.
- Stroh, Robert and Marc Smith (2004) Manufactured Housing and Hurricanes. Affordable Housing ISSUES, Volume XVI, Number 6, The Shimberg Center for Affordable Housing, University of Florida.
- Stroh, Robert and Marc Smith (2004) Structural Damage to Housing from the Hurricanes of 2004. The Shimberg Center for Affordable Housing, University of Florida.
<http://www.myflorida.com/myflorida/governorsoffice/Hurricane/pdfs/structuraldamageanalysis.pdf>.
- U.S. Census Bureau (2003) Annual Value of Private Construction Put in Place. Manufacturing, Mining and Construction Statistics.
<http://www.census.gov/const/C30/private.pdf>. {Accessed: March 2005}.

- U.S. Census Bureau (2003) New Manufactured Homes Placed by State. Manufacturing, Mining and Construction Statistics.
<http://www.census.gov/const/mhs/stplace03.pdf>. {Accessed: March 2005}.
- U.S. Department of Energy (2004) Official Energy Statistics. Energy Information Administration.
<http://www.eia.doe.gov>. {Accessed: December 2005}.
- U.S. Environmental Protection Agency (1998) Characterization of Building-Related Construction and Demolition Debris in the United States. No. 68-W4-0006.
- Uhlik, Felix (1997) Development of an On-Site Waste management System and Recycling Infrastructure for Residential Construction in Florida. Building Construction Industry Advisory Council (BCIAC). State of Florida.
- Williams, Frank (2004) Florida Manufactured Housing Association (FMHA) Report on 2004 Hurricane Season, Hurricane Housing Working Group, Office of the Governor, State of Florida.
http://www.myflorida.com/myflorida/governorsoffice/Hurricane/pdfs/report_2004.pdf. {Accessed: April 2005}.