Improved Specifications for Federally Procured Ruggedized Manufactured Homes for Disaster Relief in Hot/Humid Climates

Stephanie Thomas-Rees, Research Architect
Subrato Chandra, Program Director
Stephen Barkazsi, Senior Research Engineer
Dave Chasar, Senior Research Engineer
Carlos Colon, Senior Research Engineer

Florida Solar Energy Center
Cocoa, FL

ABSTRACT

Before reconstruction can begin after a natural disaster, temporary housing is essential to stabilization of a community. The offsite, rapid construction, and the ability to transport (and relocate) are two advantages of the ruggedized manufactured home. Two improved specifications, *EnergyStar* (*ES*) and the *Building America Structural Insulated Panel* (*BASIP*) manufactured home, are suggested in this paper that enhance the energy efficiency, sustainability, and indoor air quality and provide back up power, without compromising human health, safety or comfort. The energy performance of the *ES* and *BASIP* manufactured homes are compared to the base case or currently specified ruggedized manufactured home using the FSEC developed ENERGYGAUGE® USA (Version 2.5.6) software. The specifications presented in this paper allow for better quality construction and includes renewable energy. This not only reduces utility bills during regular operations but provides electricity and hot water for essential functions during power outages associated with reconstruction following a natural disaster.

INTRODUCTION

Hurricane Katrina caused major devastation to parishes, communities and entire cities requiring accommodations of mass quantities and extreme urgency. The Federal Emergency Management Agency (FEMA) responded to the temporary housing needs by procuring over 100,000 travel trailers and over 25,000 ruggedized manufactured homes. However, finding the proper location and the costs associated with constructing, transporting, installing, maintaining and operating these temporary housing accommodations has become controversial. Local governments denied installments within flood zones (which are where most of the destruction and devastation occurred and where the temporary housing was needed) and local citizens brought opposition citing that they feared these "FEMA Cities" would increase crime rates and lower their property values. Critics believe that dispersing the money they spent per home, directly to each of the victims they provided accommodations to, is a better use of taxpayer dollars than purchasing these units for temporary and often, one time only, use. While the temporary housing program is antiquated, it is what the law allows.

FEMA procured manufactured homes are used to accommodate victims of natural disasters. As hurricanes are predicted to intensify and increase in numbers, more temporary structures will be needed. When Hurricane Katrina struck the shores of Louisiana, Mississippi and Alabama last year, 25,000 manufactured homes and 100,000 travel trailers were ordered (and built) to help accommodate the thousands of victims who could not find and/or afford safe housing while their homes were being repaired or in some cases, rebuilt completely. By extrapolating information from recent articles, the costs associated with recent manufactured home and travel trailer purchases amounts to approximately 2.9 billion dollars. Each travel trailer costs about $10,000. Each manufactured home costs about $76,800 per dwelling, which includes purchase, transportation, installation, maintenance, cleaning and disposal. However, these figures do not include energy costs and environmental impacts, associated with the manufactured homes that are currently used.

Continued to be scrutinized for temporary home expenditures, FEMA is complying with what law allows. The Stafford Act limits the amount of money FEMA can grant directly to an individual at $26,200[1]. While this may seem like adequate funds to support a household for a period of 18 months, some times, as experienced during Hurricane Katrina, safe housing accommodations are not available because an entire community has been devastated. The program for providing ruggedized manufactured homes was developed in the 70's and although

[1] http://www.fema.gov/library/stafact.shtm#sec408

antiquated, the program or procurement specifications warrant improvement.

Manufactured homes, utility expenses, maintenance, etc. are provided at no cost to the victims until they can move back into their existing homes or find other permanent housing. The manufactured homes are typically provided for a period of not more than 18 months. Once the 18 month period has expired, the manufactured homes are vacated and immediately transported to a staging area for future reuse or sale through the GAS website (http://gsaauctions.gov/gsaauctions/gsaauctions). If displaced residents can not find affordable housing, extensions are granted by FEMA. Most recently, the Punta Gorda, FL village has extended the remaining occupants' stay until September 2006, totaling a 24 month housing period for these residents. In Florida there are 4,160 manufactured homes or trailers still occupied by storm victims, down from a 2004 peak of more than 17,000. There were 551 families at one time in the Punta Gorda village that opened in November 2004 (see photo of typical FEMA temporary community, the one pictured in Figure 1 is in Arcadia, FL).[1]

high energy use. Poor indoor air quality can induce medical complications in occupants with asthma or other chronic illnesses and with energy costs on the rise, procurement specifications necessitate energy efficient solutions without compensating human comfort or safety.

If FEMA's current procurement process is to remain standard procedure, this report recommends two specifications for consideration. The *EnergyStar* Ruggedized Manufactured Home *(ES)* and the *Building America Structural Insulated Panel* Manufactured Home *(BASIP)* specifications, included in this report, provide improved temporary shelter accommodations suitable for multiple moves, and have capabilities to provide power for essential loads during extended power outages. Not only are the tangible benefits associated with energy cost savings the justification for this report, but indoor air quality plays and increasingly demanding role amongst occupants with sensitivities to asthma and other environmental related health conditions. Also included in this report are energy cost comparisons and analysis.

Figure 1. FEMA City, Arcadia, FL
Photo Credit: FEMA

The procurement process that FEMA initiates when manufactured home orders are needed, start with FEMA requesting quotes from manufactured home builders to build the homes in accordance with HUD Manufacturing Housing Standards, also known as Title 24 (Chasar, et al. 2004). The manufactured homes specified to these standards, developed in the 70's, are often constructed to the minimum standards, resulting in large energy use compared to their site built equivalents. The specifications recently used in hot and humid climates (i.e. areas where Hurricane Katrina struck) have the potential for indoor air quality and high maintenance concerns, in addition to

The *ES* manufactured home specification is modeled from the Energy Star guidelines for manufactured homes (MHRA 2003). An ENERGY STAR labeled manufactured home must be at least 30% more energy efficient in its heating, cooling and water heating than a comparable home built to the 1993 Model Energy Code (MEC) (Chasar, et al 2004)[2].

The specification for *BASIP* goes a little further in creating a specification that results in optimal indoor air quality, increased energy savings and also

[2] http://www.fsec.ucf.edu/bldg/baihp/pubs/estar-hudcert/index.htm

provides “free energy”. Table 1 summarizes the window, and surface U values as well as other characteristics.

Table 1. Summary of Construction of the Existing and Proposed Specifications for FEMA Ruggedized Manufactured Homes

Characteristic	Base Home (existing)	Energy Star (proposed	BASIP (proposed)
Floor Insulation	R-19	R-21	R-19
Wall Insulation	R-13	R-13.5	>%-15.4
Ceiling Insulation	R-21	R-18.5 roof deck radiant barrier	>R-23
Roof	Dark Shingle	Light shingle with radiant barrier	White metal raised seam roof
Windows	Single Pane, Metal Frame	Low-E Vinyl; Frame	Low-E Vinyl Framed with storm shutters
Heating System	Electric Resistance Furnace, COP:1	Heat Pump HSPF 7.5	Heat Pump HSPF 7.7
Cooling System	Central Air (Split System) Conditioning SEER13-2 ton	Wall Hung Heat Pump SEER 13-2 ton	Wall Hung Heat Pump SEER 13-1.5 ton
Water Heater	Electric Water Heater 40 gallon capacity	Electric Water Heater 40 gallon capacity	ICS Solar Water Heater with backup 40 gallon electric water heater
Ventilation System	Under floor	Above ceiling in vented attic	Under SIP roof (in conditioned space, unvented attic)
Duct Joints (leakage expressed as CFM25 to out as % of floor area)	Industry Standard – 6% leakage to out	Sealed with mastic – 3% leakage to out	Sealed with mastic (inside thermal envelope) 0% leakage
House air tightness (in terms of ACH50)*	7.5	5.10	4.00
Retractable Awning	N/A	Optional (provides additional square footage/outdoor space)	Optional (provides additional square footage/outdoor space)
On Site Generated Power	N/A	N/A	3.25kW PV system

*Figures from measured data of blower door test of US manufactured housing (Baechler, et al, 2002)

BASE CASE, ENERGY STAR AND BUILDING AMERICA STRUCTURAL INSULATED PANEL MANUFACTURED HOME CHARACTERISTICS

Improving the construction methods and energy efficiency of federally procured ruggedized manufactured homes, used as temporary accommodations, will increase the durability and expand the life expectancy and reusability. The improved specifications and revised roof layout of the *BASIP* will also accommodate a mating of “single wide” units to make a “double wide” and larger unit that would provide a more comfortable environment and a more mainstream approach to typical home floor plans (see end wall elevations as illustrated in Figure 3). This report does not explore floor plan redesign at this time; however it does identify some of the few designs that have evolved since Hurricane Katrina left so many victims homeless.

The base case or currently procured and the proposed *ES* ruggedized manufactured home have overall dimensions of 14’x 60’ (Figure 2). The units specified have 3 bedrooms and 2 baths. The base case and *ES* units have ventilated attics and gabled roof plans (Figure 3). The *BASIP* unit has been lengthened to accommodate a mechanical room and mono-sloped roof (Figures 4 & 5).

The *ES* specification uses an advanced framing method. While the base case uses typical 2x4 stud construction spaced on 16” centers, the advanced framing method uses 2x6 studs spaced on 24” centers. Advanced framing methods may reduce wood use up to 25% and improve wall thermal resistance values from 5 to 10%. It can also decrease labor with fewer pieces going together, therefore saving money[3]. The *BASIP* specification uses structural insulated panel method with integral wire chases for walls and the roof but the floor system uses advanced framing method, locating the plumbing requirements in the "belly", as does the base case and *ES.*

The BASIP specifies a photovoltaic (pv) integrated metal roof system with a skylight and Integrated Collector Storage (ICS) solar hot water system. The elevations illustrate "Bahama" style shutters that provide hurricane protection and solar shading. The end wall elevation (Figure 5) illustrates the inclusion of a retractable awning that also provides solar shading and additional square footage.

ENERGY ANALYSIS USING ENERGYGAUGE®

The proposed specifications and the base case federally procured manufactured home are analyzed using the FSEC developed ENERGYGAUGE® USA (Version 2.5.6) software program. This program predicts building energy consumption using the DOE2 analysis engine with a user friendly front end that develops DOE2 input files and models that are more appropriate for residential building systems (Parker, et. al, 1999).

An analytical model was developed for each of the manufactured home specifications. These models were essentially the same with differences only in the R-values in the various building envelope components, the duct leakage values, the heating and cooling equipment, fenestration properties and the integration of renewable energy sources, i.e. pv and solar hot water heating. The base case and *ES* are similar in geometry but differ in hvac systems engineering and hvac equipment location.

Considering the energy costs alone, these specification recommendations facilitate significant utility demand reductions. During a 12 month period, the latest order of 25,000 FEMA specified ruggedized manufactured homes will consume about 247 GWh, which will cost the Federal Government approximately 24.7 million dollars (at $0.13/kWh). If these units were deployed to other areas like Hawaii, where utility rates are almost 44% higher, the government's electric bill could cost over 35 million dollars. The *ES*, which proposes to improve the energy efficiency by at least 12%, would provide a savings of over 3 million dollars over a 12 month period. The *BASIP*, proposes to improve the efficiency by at least 77% (see Table 2). This equates to about 60.7 GWh of electricity saving approximately 20.2 million dollars.

The *ES* manufactured home would eliminate approximately 23,000 tons of greenhouse gas emissions, equivalent to removing 3,733 passenger cars and light trucks from the highway for one year or saving our reliance on 48,524 barrels of oil. The *BASIP* specification would remove approximately 125,500 tons of greenhouse gas emissions, equivalent to removing 20,367 passenger cars and light trucks from the highway for one year or saving our reliance on 264,771 barrels of oil.[4]

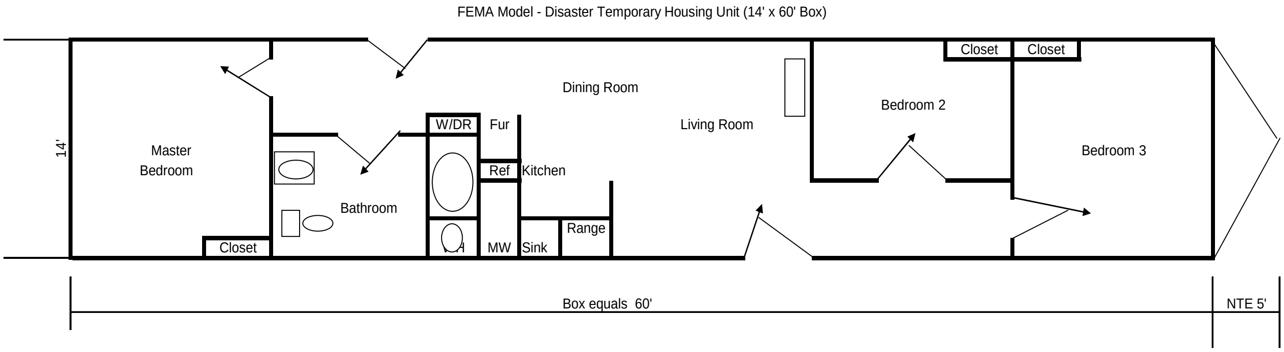
Table 2. Summary of Comparisons of Simulated Savings

End-Use	Base (existing)	Energy Star (proposed)	% Savings Over Base	BASIP (proposed)	% Savings Over Base
Annual Energy Use (kWh)	10,429	8,869	15	*2,549 (6,741 total)	76
Annual Energy Costs ($) @ $0.13/kWh	1,355	1,154	15	332	76
Annual CO2 Output (tons)	6.18	5.06	18	1.15	87
AC	2,328	1,791	23	1,608	31
Heat	1,714	481	72	620	64
Hot Water	2,767	2,652	4	1,391	50
Lighting	1,111	1,111	0	479	57

* Net Energy Usage = Total Energy Usage – PV Produced (see Figure 7 for details)

[3] http://www.energystar.gov/ia/partners/bldrs_lenders _raters/downloads/BuilderGuide3D.pdf

[4] http://www.usctcgateway.net/tool/



WH	Water Heater
BT/S	Bathtub/Shower
W/DR	Washer/Dryer
MW	Microwave
Ref	Refridgerator
Fur	Furnance
NTE	Not To Exceed

Figure 2. Floor Plan for the Base Case (Courtesy of Palm Harbor Homes)

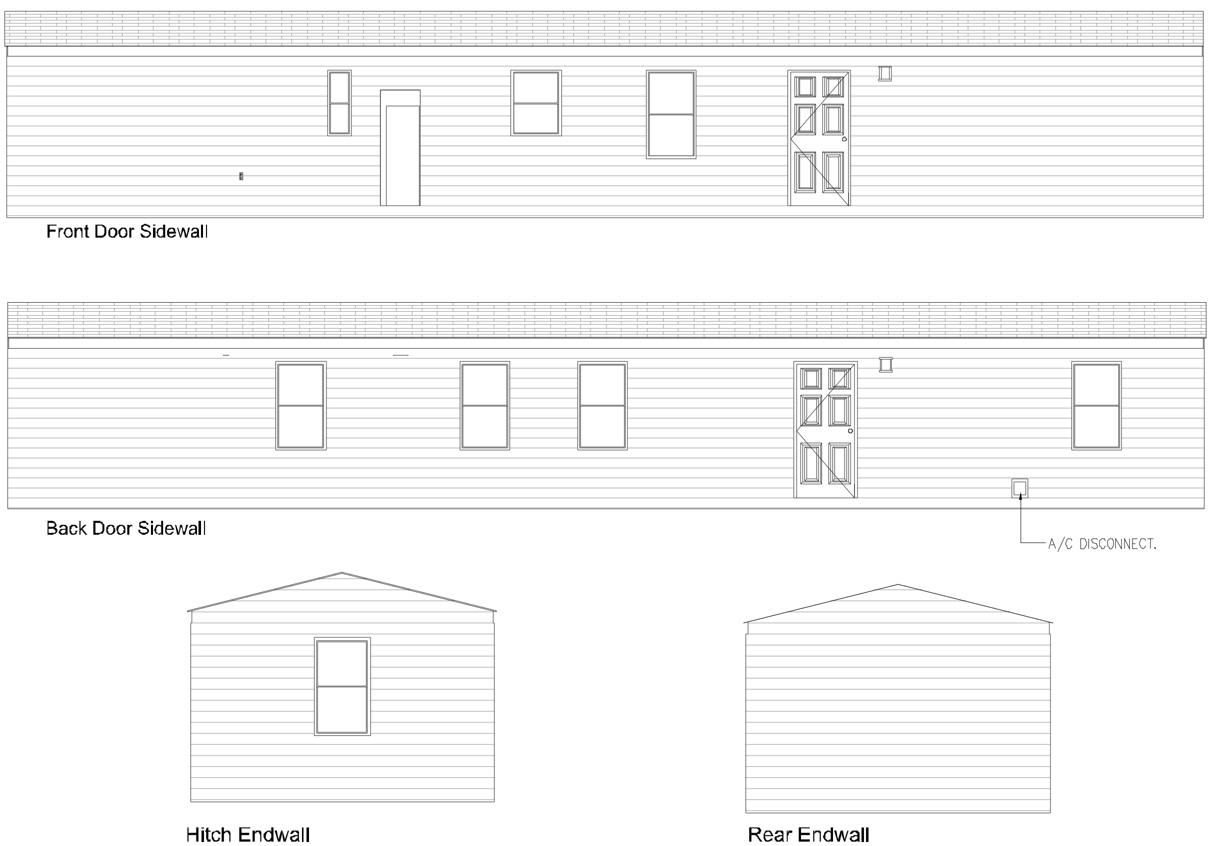


Figure 3. Elevations for the Base Case (Courtesy of Palm Harbor Homes)

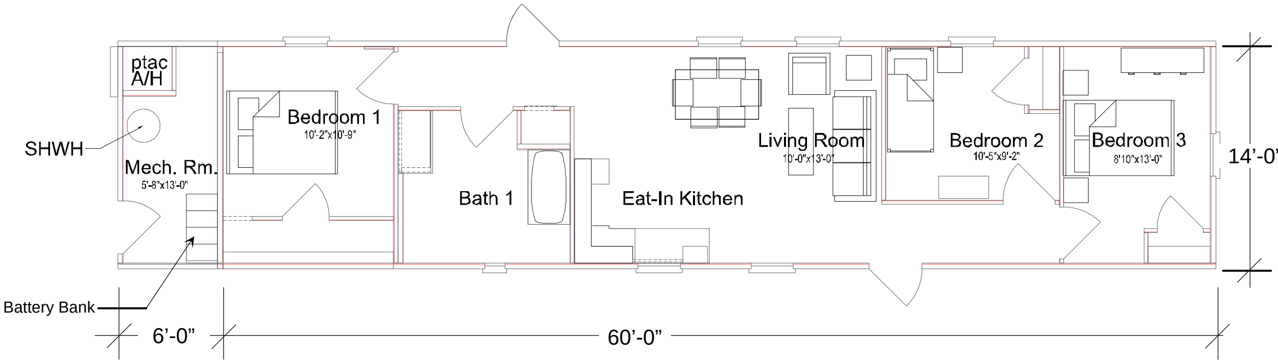


Figure 4. Floor Plan (by Palm Harbor Homes, et al.) for the Energy Star & Building America Structurally Insulated Panel Manufactured Homes

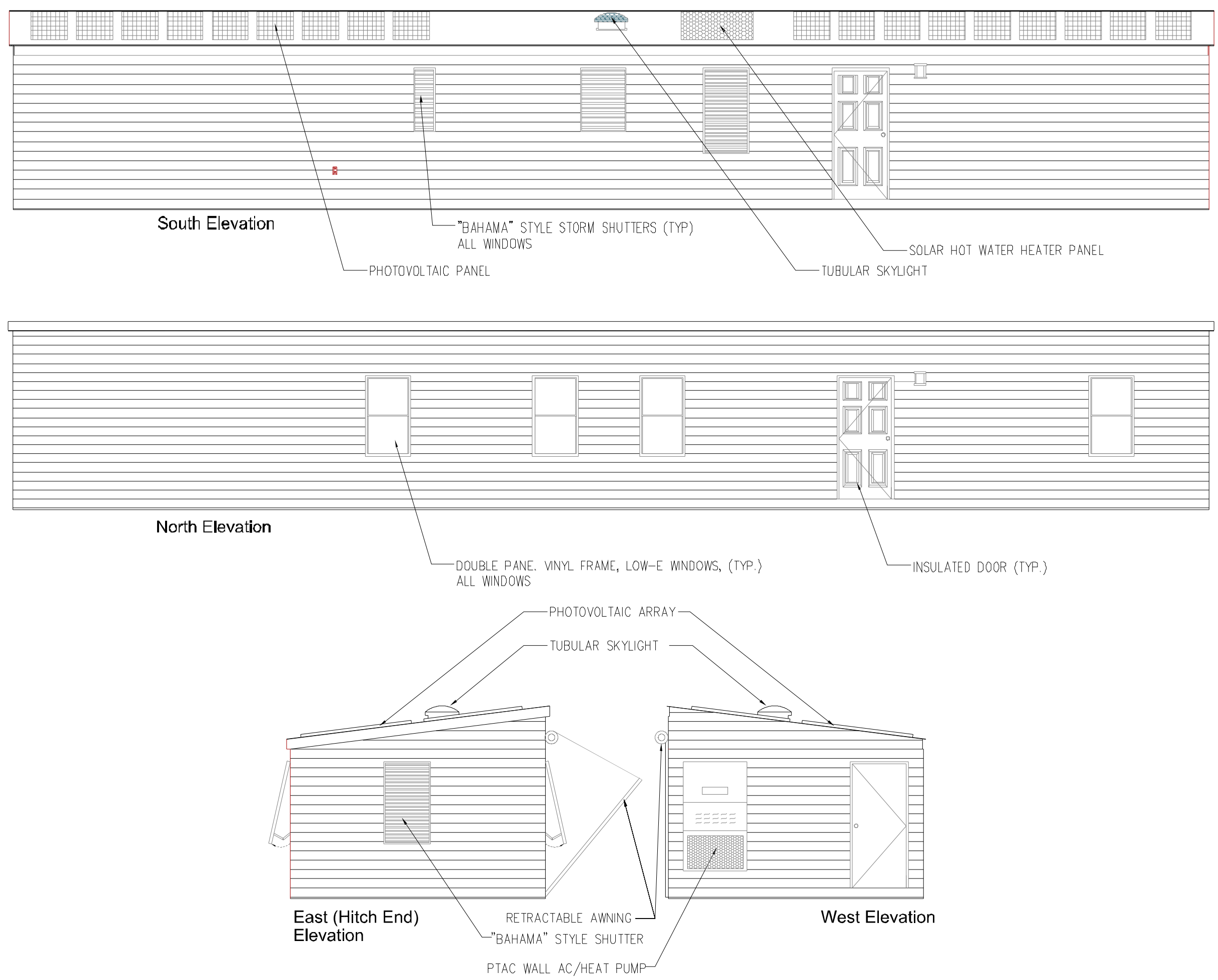


Figure 5. Elevations for the Building America Structurally Insulated Panel Manufactured Home

INTEGRATED PV ARRAY

The *BASIP* specification proposes the integration of a 3.25kW pv array that would generate the peak power requirements. This is especially beneficial when manufactured homes need to be deployed to areas where utilities have not been restored or during times when service is interrupted. EnergyGauge® models the annual energy use and the annual energy produced by the pv array for the home located in New Orleans, LA. Figure 6 illustrates the summary of monthly averages and Figure 7 illustrates the summary of hourly averages. The pv array produces a net energy of 4,192 kWh. Total consumption is 6,630 kWh annually for a net energy use of 2,429 kWh and 77% savings. If the pv array was omitted, the BASIP would produce 37% savings over the base case manufactured home.

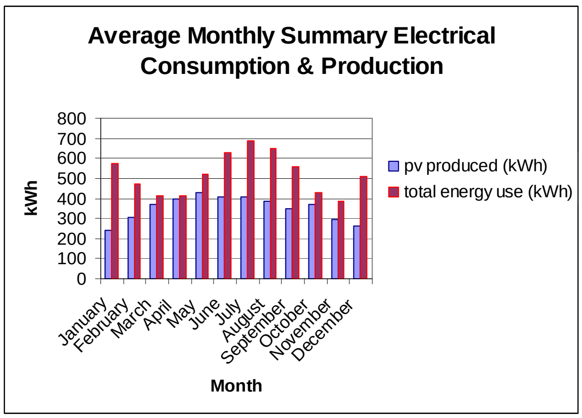


Figure 6. Monthly electrical consumption and production.

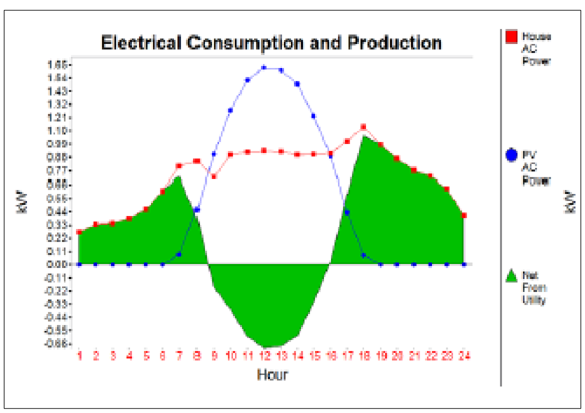


Figure 7. Hourly summary of electrical consumption and production

Figure 8 demonstrates the average hourly electrical uses for the whole year, revealing the hvac and hot water require the largest demand (which is also typical in the base case and *ES* models).

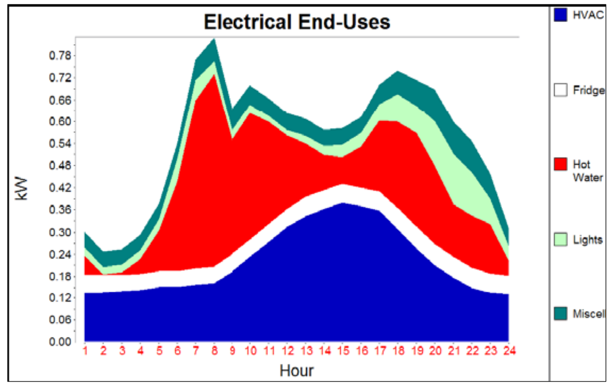


Figure 8. *BASIP* manufactured home electrical end uses.

HVAC

The base case manufactured home as it is constructed today uses a mechanical system that is ducted under the floor of the home (referred to as "in the belly"). The air handling equipment is in the interior of the home and the compressor is set onto a concrete pad once the manufactured home is delivered to the site. This requires coordination and additional personnel to connect the system on site and also almost never involves any commissioning or verification that the system is functioning properly as designed. The *ES* manufactured home models an improved hvac system with higher energy efficiency and improved requirements on duct sealing. It also relocates the ductwork above the ceiling, as does the *BASIP*. However, the *BASIP* creates a conditioned space for the ductwork due to the sip system. The relocation of ductwork above the ceiling eliminates the risk of supply vents being covered with furniture. The *BASIP* uses the plenum above the ceiling and below the sip for return air supply (see Figure 9). This may create an example where innovative technology precedes code development because flame spread ratings and fire code issues may need to be investigated further to ensure code compliance.

The *BASIP* specification proposes a hvac system that is installed onto the home in the factory, allowing the mechanical system to be completely operational upon delivery. The *BASIP* also properly sizes the unit with respect to its characteristics, allowing proper humidity removal and better indoor air quality.

The energy savings from the improved air conditioning and heating demands amount to 25% - 35% and 60% - 65% for the *ES* and *BASIP* respectively over the base case. The *BASIP* can credit this savings so the increased energy efficient rating and the properly sizing of the system. The SIP, in addition to tight ducts, results in tighter construction, less leakage and better indoor air quality.

DOMESTIC HOT WATER

The *BASIP* manufactured home specifies an Integral Collector Storage (ICS) hot water system which saves about 54% energy over the base case and *ES* home (see Figure 10). In the ICS, the hot water storage system is the collector. Cold water flows progressively through the collector where it is heated by the sun. Hot water is drawn from the top, which is the hottest, and replacement water flows into the bottom. This system is simple because pumps and controllers are not required. On demand, cold water from the house flows into the collector and hot water from the collector flows to a standard hot water auxiliary tank within the house (Harrison, et. al, 1997). The benefit to using an ICS system over a drain back system is less mechanical parts and pumps. The *BASIP* unit will have a user's manual and diagrams installed at the water heating system (located in the mechanical room, see Figure 3) that indicate freeze protection procedures during the months of December, January and February, as well as during transportation and relocation. Another benefit of using an ICS system is the availability of hot water during power outages.

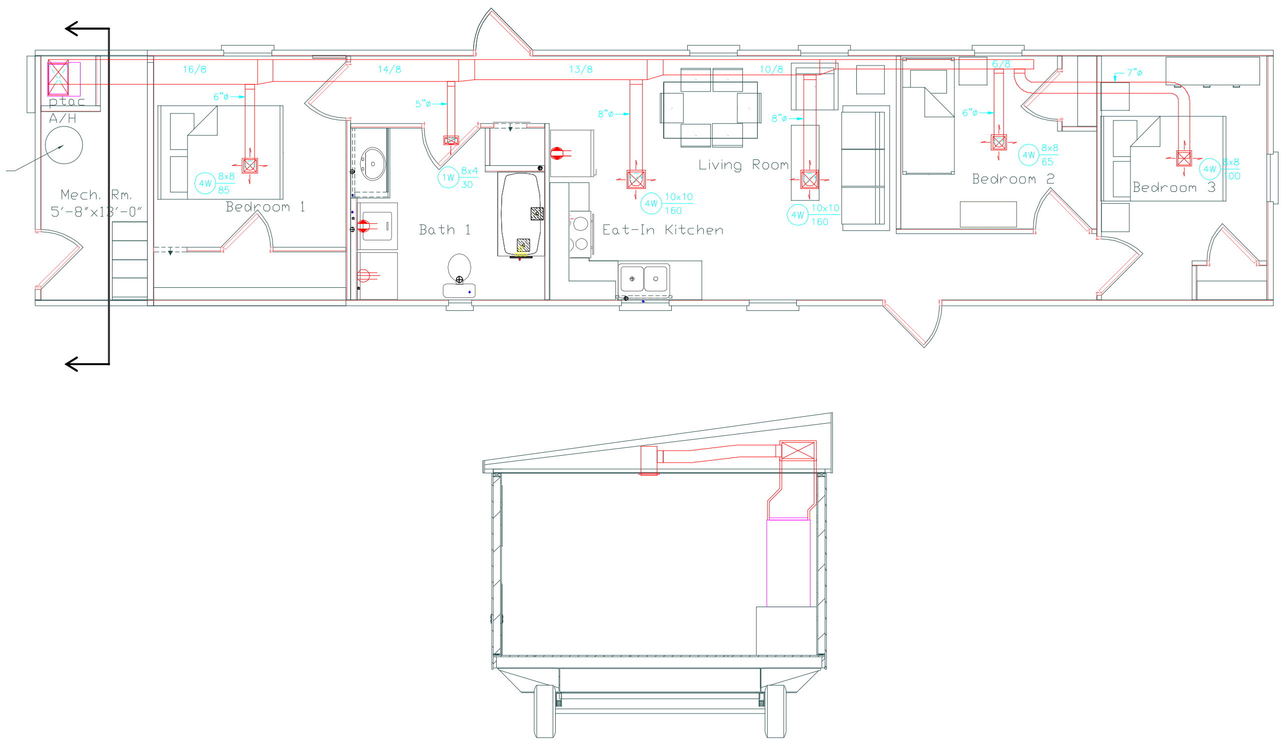


Figure 9. *BASIP* cross section and HVAC layout.

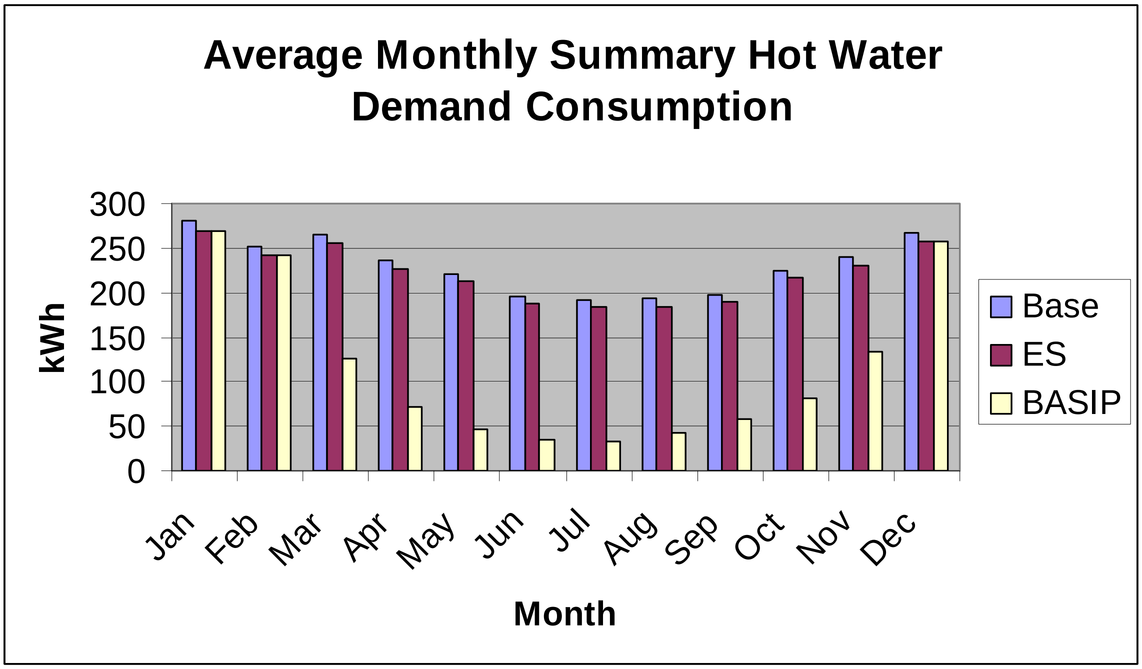


Figure 10. Hot water electrical demand comparisons.

PELIMINARY ECONOMICS

Early in the research of this report, incremental cost estimates were generated for the *ES* manufactured home of about $900. However, due to the proposed wall mount hvac system, third party mechanical system installation costs are omitted (and for each relocation). These charges are estimated at $700 per move. Table 4 estimates incremental costs per component and assumes two moves. This results in a net savings of approximately $854 over the base case, including other proposed upgrades. The proposed *BASIP* manufactured home specifications have incremental costs associated with the skylight, pv, solar hot water system, high efficiency hvac system and sip construction. The pv array is a large incremental cost in the *BASIP* manufactured home specification. Systems can generally costs about $10K per kW of pv array. This would amount to approximately $32.5k for the specified *BASIP* system. Optimistically and with bulk pricing for many of these systems purchased, the array could be procured as low as $6 per kW or about $20k (the figured used in Table 3). Another large incremental costing component is the ICS hot water system. This is estimated at a $2,300 up charge from the typical electric water heaters, which cost about $200. The other incremental costs in Table 4 are likely much higher than would be actually realized due to the experimental nature of the proposal. With these caveats understood, Table 4 illustrates the incremental costs, energy savings and simple payback periods for each specification. The life cycle costs will be determined at a later date if the scope of this project warrants such investigation. Note that the savings and paybacks will vary in accordance with the home's location in respect to the utility rates.

Table 3. Incremental Costs Comparisons and Savings

	Incremental Cost	Incremental Cost ($/ft^2)	Electric Rate ($)	Energy Savings (kWh/day)	Annual Energy Savings ($)	Simple Payback (yrs)
ES Home	($854)	($1.04)	$0.13/kwh	$4.27	$201	-
BASIP Home	$27,301	$29.55	$0.13/kwh	$21.59	$1,023	27

Table 4. Component/Incremental Cost Estimates for ES & BASIP

	ES Home Component	*ES* Home Component Cost Increment	*BASIP* Home Component	*BASIP* Home Component Cost Increment
HVAC (equipment)	Wall hung AC/HP, SEER 13	$101	Wall hung AC/HP, SEER 13	$101
HVAC Labor (based on 2 moves)	Negative cost due to equipment attached to unit	($1,400)	Negative cost due to equipment attached to unit	($1,400)
Framing	Advanced framing, less material, less labor	$0	Sip (walls & roof) ±$3.25 square foot	$2000
Windows	Vinyl frame, dbl. pane, low-e	$400	Vinyl frame, dbl. pane, low-e	$400
Roof	Light colored asphalt shingle	$0	White, raised seam, metal roof	$2,200
Floor Plan	N/A	N/A	Lengthened floor plan	$700
Jump Duct	Jump duct for return air from wall hung at end of unit	$45	n/a	n/a
Retractable awning	Optional	N/A	12'w x 10'd	$300
Bahama shutters	N/A	N/A	See figure 4	$400
Skylight	N/A	N/A	(1) skylight 18sq.ft.	$200
Solar Hot Water	N/A	N/A	ICS w/aux. elec. tank	$2400
PV system	N/A	N/A	3.25kW array	$20,000
Total Incremental Cost		**($854)**		**$27,301**

CONCLUSIONS

Through various programs that the federal government has initiated, the search for more affordable, energy efficient and sustainable temporary housing is taking a more aggressive stance in the building environment. When FSEC was tasked by DOE to develop a proposal for improved specifications for FEMA, we sought input from various industry partners to discuss different ways to improve the current FEMA specifications. This included manufactured home building personnel, material manufacturers, building science researchers and others. FEMA personnel was contacted on numerous occasions but declined to comment. These discussions along with several published reports formed the basis for the proposed recommendations in this report. One such published report was a site visit conducted by a member of the Building America Industrialized Housing Partnership and others affiliated with manufactured housing industry in September of 2004. The report discloses possible moisture-related problem areas and made recommendations for manufactured homes built for FEMA and destined for Hurricane Charley victims. The largest problem areas were the vapor barrier placement, duct leakage and oversized hvac systems (Chasar, et. al. 2004). In July of 2000 the first HUD-Code home made of structural insulated panels (SIPS) was tested, instrumented and monitored for energy efficiency (Baechler, et al., 2002). The results of this experiment provided the premise from which the *BASIP* was developed.

The FEMA procured manufactured homes are currently constructed in accordance with the Housing and Urban Development's manufactured housing standards (the HUD code). While there are many examples of high quality and cost effective manufactured homes, the FEMA minimum standard homes can consume more energy than their site built comparatives and use materials and mechanical systems that can potentially contribute to poor indoor quality and low durability. Two improved specifications are presented in this report to enhance energy efficiency, sustainability, indoor air quality and provide back up power, without compensating human health, safety or comfort, for high performance ruggedized temporary housing.

Imagine the headlines revised from "The Land of 10,770 Empty FEMA Trailers"[5] (Figure 11), to "10,770 Zero Energy Trailers Provide Power for Small Community". If these units had been built with the *BASIP* specifications, they could generate enough power to provide basic power necessities of a small parish. With more and more headlines like "FEMA Homes Stranded in NC"[6], "Thousands Still Waiting for FEMA Trailers"[7]; how does FEMA justify the process for temporary housing? Placing manufactured homes into communities affected by natural disasters, such as Hurricane Katrina has met enormous resistance by neighboring communities, as well as, local officials. "The NIMBY (not in my backyard) effect goes beyond the Big Easy itself: Half of Louisiana's parishes have banned new trailer parks"[8]. The Punta Gorda FEMA Park (largest-ever trailer park) has received accusations about drug dealing, domestic abuse, theft and vandalism. Despite those concerns, some believe extraordinary events require extraordinary cooperation.

Figure 11. More than 10,000 trailers were sitting at the airport in Hope, AR (AP Photo by Danny Johnston)

The proposed specifications still need further investigation with regards to code exceptions and/or exemptions and fire resistance compliance due to innovative technologies that have evolved since the development and implementation of the HUD Code. Space planning and overall layout should also be examined further. While this report does not explore floor plan redesign at this time, it does identify a few designs that have evolved since Hurricane Katrina left so many victims homeless. Hurricane Katrina brought about many design charettes and discussions by architects, developers, politicians and manufactured housing executives. We can even look historically at measures taken after the San Francisco earthquake of 1906 left thousands homeless and over 5,600 "temporary cottages" were built (see Figure 12).

Figure 12. 1906 San Francisco earthquake cottage. Photo credit: Will Elder, National Park Service

The consensus is that affordable, temporary housing needs to take on a new shape and mission. The U.S Department of Energy's Office of Energy Efficiency and Renewable Energy Department's annual Solar Decathlon, a competition to design, build, and operate the most attractive and energy-efficient solar-powered home, displays examples every year of self sufficient innovative homes, that have been transported to the Mall in Washington D.C. Regardless, Hurricane Katrina has proved that a new process and strategy is in need, one that is healthy, sustainable, and reusable and before an energy crisis hits home again, and one that is energy efficient and responsible.

REFERENCES

1. Code of Federal Regulations Housing and Urban Development [HUD], Manufactured Home Construction and Safety Standards, 24, Part 3280, US Government Printing Office, 1999.
2. Baechler, M.; Lubliner, M; Gordon, A (2002). "Pushing the Envelope: A Case Study of Building the First Manufactured Home Using Structural Insulated Panels" Proceedings of ACEEE 2002 Summer Study, American Council for an Energy Efficiency Economy, Pacific Grove, CA.
3. Chasar, D., Moyer, N., McIlvaine, J., Beal, D. and Chandra, S., "Energy Star Manufactured Homes: The Plant Certification Process," Proceedings of ACEEE 2004 Summer Study, American Council for an Energy Efficient Economy, Washington, DC, August 2004.
4. Harrison, J., Tiedeman, T. "Solar Water Heating Options in Florida", Florida Solar Energy

---

[5]http://www.latimes.com/news/printedition/asection/la-na-trailers10feb10,0,4926000,print.story?coll=la-news-a_section

[6]http://www.newsobserver.com/102/story/411776.html

[7]http://www.msnbc.msn.com/id/10399646/from/RL.5

[8]http://www.cbsnews.com/stories/2005/12/29/earlyshow/main1169004.shtml

Center, Cocoa, FL, FSEC-EN-9, May 1997
5. McGinley, W. M., “Study of Innovative Manufactured Housing Envelope Materials”, Final Report to the Florida Solar Energy Center, Under the Building America Industrialized Housing Partnership, April 2002.
6. Moyer, N., Beal, D., Chasar, D., McIlvaine, J., Withers, C., and Chandra, S., “Moisture Problems in Manufactured Housing: Probable Causes and Cures,” Proceedings of ASHRAE Conference IAQ2001, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, August 2001.
7. Parker, D. et al, 1999. "Energy Gauge® USA: A Residential Building Energy Simulation Design Tool", Proceedings of Building Simulation ’99. International Building Performance Simulation Association, Organizing Committee for the 6th International IBPSA Conference, Department of Architecture Texas A&M University, TX.

ACKNOWLEDGEMENT

This work is sponsored, in large part, by the US Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Building Technologies Program under cooperative agreement number DE-FC26-99GO10478. This support does not constitute an endorsement by DOE of the views expressed in this report.

The authors appreciate the encouragement and support from Bert Kessler (Palm Harbor Homes), Bill Wachtler (Structural Insulated Panel Association), Bill Chaleff (Chaleff & Rogers, Architects), Janet McIlvaine (Florida Solar Energy Center), Danny Parker (Florida Solar Energy Center), Eric Martin (Florida Solar Energy Center), Dennis Stroer (Calcs Plus), Michael Lubliner (Washington State University), Michael Baechler (Pacific Northwest National Laboratory), Mike Dalton (Polyfoam), Ron Sparkman (Barvista Homes), John Michael (ATEX Distributing).