A Sustainable Housing Response to Hurricane Katrina

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Abstract

This article describes the collaborative experience of the ecoMOD project at the University of Virginia (UVA) and Habitat for Humanity® International as they developed a prototypical ecological, prefabricated, and affordable home for a family along the Gulf Coast of Mississippi after Hurricane Katrina made landfall in August 2005. Since 2004, ecoMOD has created five affordable housing units, four of them in Charlottesville, Virginia. The project is a partnership of the UVA School of Architecture and the School of Engineering and Applied Science. The project's aim is to create well-designed, high-quality homes that minimize living costs and environmental impact.

Introduction

To date, ecologically sustainable homes have been mostly reserved for the wealthy. Yet the health concerns associated with indoor air quality and the financial burden of unnecessarily inflated utility costs point to the need for homes that are both environmentally responsive and affordable for low-income people. With more than 200,000 homes destroyed by hurricanes in 2005 (Cashell and Labonte, 2005), the Gulf Coast is in the midst of a long rebuilding effort. Hurricane Katrina alone is the single most destructive and costliest natural disaster in U.S. history. To address the resulting building crisis, in early 2006 the ecoMOD design/build/evaluate project at the University of Virginia (UVA) expanded its scope to partner with Habitat for Humanity® International (HFHI, or Habitat) in the devastated Gulf Coast region of Mississippi. Originally focused exclusively on housing for central Virginia, the ecoMOD project accepted an invitation to provide a home for Habitat's Operation Home Delivery program with Habitat for Humanity of Greater Charlottesville (HFHGC). HFHGC sent five conventional panelized homes to Habitat for Humanity of the Mississippi Gulf Coast (HFHMGC), and the ecoMOD2 team designed and built one of these. HFHGC shipped ecoMOD2, the preHAB house, as a flat-pack panelized home using an innovative super-insulated

steel and foam panel system instead of a conventional wood stud frame. They installed the preHAB house in an established neighborhood in Gautier, Mississippi, for a family displaced by Hurricane Katrina (see exhibit 1). The site is a 1960s affordable housing subdivision just north of the area flooded by the initial deluge of Hurricane Katrina. Although several houses in the subdivision were significantly damaged, the part of Gautier that was essentially "erased" is 2 miles south—directly on the coast. Installing this particular house provided an opportunity for the design team to test and investigate contemporary design, environmentally responsible strategies, and prefabricated construction within the constraints and mission of HFHI.

Prefabrication can be a cost-effective method of construction, and highly energy-efficient homes have lower utility costs, making sustainability and prefabrication an ideal combination for affordable housing (USGBC, 2007). Currently, however, prefabricated homes are seldom designed for energy efficiency, and most environmentally sustainable homes are expensive to build. The design team used prefabrication to test the cost-effective strategy and raised money to subsidize material and equipment donations. To align with HFHI's mission,[1] local and university volunteers completed all the labor. In addition, the team is currently evaluating the home's energy efficiency through monitoring systems and monthly energy savings models. The 1,087-square-foot, three-bedroom home was built for approximately $65 per square foot.

Exhibit 1

The ecoMOD2, preHAB House in Gautier, Mississippi

Student rendering of ecoMOD2, the preHAB house, which is an affordable, ecologically sound, prefabricated home constructed in Gautier, Mississippi.

[1] "Habitat for Humanity International is a nonprofit, ecumenical Christian housing ministry. HFHI seeks to eliminate poverty housing and homelessness from the world, and to make decent shelter a matter of conscience and action" (HFHI, 2008). According to Habitat for Humanity, the organization strives to produce decent housing nationally and internationally; in the United States, the price of a typical Habitat house averages $60,000 (after subsidies). HFHI operates out of Americus, Georgia.

Ultimately, the research team noted two major observations about the ability to translate the ecoMOD2 project into other similar situations. First and foremost, a region responding to a natural disaster and housing crisis is a good testing ground for alternative methods of providing housing, but working in such areas requires much patience and flexibility. Secondly, the idea of sustainable, prefabricated housing is compatible with the mission of HFHI; however, making this idea a reality on a widespread basis will require retraining Habitat staff and volunteers.

Educational Objectives

Of the several possible ways to simultaneously address social equity and sustainability in a university design program, the two most common are design/build projects, which offer a direct response to a specific community need, and speculative design research projects, which seek to have a broader (albeit more abstract) effect. This research team aimed to blend the best of these worlds to achieve results that are both tangible and forward thinking. The project, which is embedded within the university's curriculum, is intended to create well-built homes that cost less to live in, minimize damage to the environment, and appreciate in value.

The normal cycle of the project includes an academic year for design and construction, followed by an academic year of evaluation. For ecoMOD2, however, it was necessary to significantly reduce the cycle to 14 weeks for design, overlapping with approximately 6 broken-up weeks for the UVA students to construct the home and several intermittent weeks for Habitat volunteers in Mississippi to complete the home. The goal of the design phase is to foster integrated and interdisciplinary collaboration throughout. The process is iterative and multifaceted. To mimic factory production, each ecoMOD prototype is fabricated at a decommissioned airfield hangar owned by UVA and shipped either as modules or panels to its final destination. Because of the great distance between Virginia and Mississippi, the team decided to ship panels rather than modules. The evaluation phase is built on emerging strategies and protocols for the analysis of a completed building. Each evaluation process may include analysis into the environmental impact of the systems and materials, energy performance, affordability, human comfort, constructability, and thoughtful placement within a community.

Interdisciplinary Process

The ecoMOD Project is multidisciplinary and involves undergraduate and graduate students from various programs in the UVA School of Architecture and School of Engineering and Applied Science. The participants are required to synthesize complex information and effectively collaborate to make decisions. The collaboration is simultaneously intradisciplinary and interdisciplinary, which makes the challenge that much more difficult. Students and faculty are forced to learn each other's language and to collectively reach conclusions. Often, solutions that are obvious for one discipline are not as clear to others. By strategically bringing so many disciplines together, the end results are typically richer and more thoroughly studied. By definition, the design was not from the mind of a single person but was the coordinated effort of many.

During the project, the students learn sustainable design and environmental principles—and then immediately apply them. They apply these principles with a real budget, site, and client. And to

take this learning approach a step further, the faculty analyzes and monitors the home throughout the project. This kind of critical feedback loop is unusual in architecture and engineering education (and the professional world) and is what distinguishes this project from many others.

All the ecoMOD design teams use "decision webs" to facilitate the decisionmaking process. The webs are a graphic device to help track thought processes and recognize the complex array of issues affected by each decision. The ecoMOD2 design team did not always agree, and decisions occasionally became compromises. Yet they were constantly aware of the potential danger of watering down good ideas by choosing the strategy that most people could agree on. Finding just the right balance between productive collaboration and "design by committee" is a continuous concern for all ecoMOD projects.

The ecoMOD2 team also works with outside advisors, which, depending on the project, might include architects, engineers, contractors, fabricators, subcontractors, prefabrication experts, landscape architects, affordable housing developers, housing counselors, planners, historic preservationists, environmental scientists, building department officials, business people, and sustainability experts on daylighting, material selection, indoor air quality, energy efficiency, and renewable energy.

Educating the Public

The ecoMOD2 team designed the preHAB home in Gautier with an emphasis on natural ventilation, thermal efficiency, and cost-savings strategies for materials, including the use of reclaimed materials from buildings destroyed in the hurricane. Team members also designed it to meet the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED)™ for Homes standard (USGBC, 2007); however, the $3,000 cost of participating in the pilot phase of the project, together with the scheduling of the design and construction, kept the team from registering the project with the USGBC. LEED for Homes is partly based on the nationally recognized LEED for New Construction standard, which has become the most widely adopted green building program in the United States. One of the two housing units at ecoMOD3, completed in Charlottesville, Virginia, after ecoMOD2, is registered with LEED for Homes, with the goal of achieving a gold- or platinum-level certification in 2008. Because LEED for Homes has now ended its pilot phase, the cost of registration and certification has decreased significantly.

Through the use of sustainable design, materials, and technologies, this home will educate homeowners, builders, and architects in the region and provide support for developing sustainable goods and services by increasing the market for these products. By designing to demonstrate adaptable and hurricane-resilient housing using precautionary principles, this demonstration effort can potentially mitigate the creation of building debris and the complete loss of habitation in future disaster recoveries. As part of an effort to communicate the potential of the design, the regional media featured ecoMOD2 three times on local Gulf Coast television stations, at least once in a local newspaper, and a few times on Gulf Coast websites. An exhibit of Gulf Coast rebuilding efforts that traveled throughout the region featured ecoMOD2. The project also was shown in New York City.

"Sweat Equity"

Part of Habitat's mission is to find future residents who are willing to put "sweat equity" into building their own homes. Typically HFHI affiliates use conventional wood framing or stick-built strategies with a large and often inexperienced volunteer workforce. Future homeowners and other short-term volunteers show up for "build days" to assemble materials that are already prepared for them by full-time Habitat staff or volunteers. The volunteer-based construction process not only leads to the completion of a home, but it is also an essential part of Habitat's mission to raise money and public awareness. HFHI officials see the value in the dramatic scene of a crowd of volunteers hammering walls together to energize the community and maximize fundraising. The future homeowners are usually required to put some "sweat equity" into their home or another home, and, although they purchase the home, the price is significantly lower than its actual cost or appraised value.

The ecoMOD2 team partnered with HFHI and many of its affiliates, including HFHGC and HFHMGC. Through this partnership the team was able to demonstrate for itself and local citizens value-added construction techniques[2] using sustainable and reclaimed materials. The benefit of partnering with HFHI was not only the invaluable education and skills students and volunteers acquired but also the ability to lower overall production costs. The prefabrication occurred more than 900 miles from the final site of the house, so the challenge of responding to onsite issues was a difficult one. Because the team could not permanently oversee construction during the full period, onsite time was valuable; and because site visits were extremely limited, the amount of onsite time became a critical concern.

Guiding Principles and Design Goals

The team strived to create a house that is adjustable to the climate of southern Mississippi. Contained, exterior spaces are an integral element of the design, expanding the apparent size of the house, while simultaneously helping to passively cool it. The team's goal was for the family to be able to turn off the air conditioning during all but the very hottest days of the year—something that is highly unusual today in that part of Mississippi. The house incorporates a photovoltaic solar panel array that provides domestic hot water for laundry, bathing, dishwashing, and cooking and a heat pump/heat recovery system for heating and air conditioning. With the photovoltaic array in place (a "gift" to the family from funding secured by the UVA team) and the air conditioning turned off, the home could possibly operate without electricity from the regional electrical grid. Unfortunately, Mississippi is not a net metering state, so the homeowners will not be able to "bank" any excess capacity for future needs.

The design team followed the strict Habitat requirement to create a three-bedroom home no larger than 1,100 square feet. Although the home is just 1,087 square feet, ecoMOD2 appears to be almost 2,100 square feet because of four distinct spaces—in the form of covered porches and outdoor spaces—brought into the perimeter of the building. Each of these four spaces serves a

[2] *Value-added construction* is a commonly used term referring to design and construction decisions that affect the thermal envelope, energy, and water efficiency of the building. The intent is to limit air leakage and inefficient use of materials.

unique purpose: entry, screened-in outdoor dining, private terrace, and covered storage area to substitute for a garage that Habitat does not typically provide. The south-facing outdoor spaces and the windows on the east and west façades were meant to incorporate shade devices that are able to both protect the home from harsh sunlight and adapt to become hurricane-protection devices. Unfortunately, only some of these screens were installed because new wind-load requirements established after Hurricane Katrina made it difficult for the team to appropriately document the capacity of these elements. All the windows and doors are carefully placed to balance the need for daylight, natural ventilation, and privacy. The single shed roof with the high point facing the north also encourages natural ventilation. The north-facing windows are high on the wall to facilitate stack effect and cross ventilation.

The design can be prefabricated as panels, room-sized modules, or components, or as any combination of all three. The prototype house is built from an innovative steel and foam panel system (ThermaSteel™ Corporation of Radford, Virginia),[3] which is highly insulated and resists hurricane-force winds and mold. The ecoMOD2 team convinced ThermaSteel to sell its leftover panels for a significantly reduced cost—less than wood-stud framing. Typically, ThermaSteel engineers and prefabricates the panels to fit each project. Purchasing the "remainders," however, meant the team had to cut and reassemble the wall panels into the correct configuration for the preHAB design. Because the exterior spaces are partly covered by the roof, it was necessary to ensure the hurricane-proof structural performance of the exposed roof areas, so the ecoMOD2 team had ThermaSteel make custom panels for the roof. All the panels for the house were shipped on a flatbed truck to the empty lot in Gautier.

The design is also intended to demonstrate the potential of prefab for Habitat affiliates. HFHI was already pursuing panelized construction with its "Operation Home Delivery" project, focused on delivering wall panels from around the country to be set up in the hurricane-devastated Gulf Coast region. Unfortunately, the scale of the disaster meant that the process was not very well organized and that some homes that HFHI received could not easily be assembled as intended. The team heard of a few situations in which the prefabricated frame walls and roofs were disassembled so the lumber could be used for other homes.

The goal of the preHAB design is to take this strategy one step further by developing a home that can be prefabricated in various ways. With this project we imagine future disaster relief efforts in which HFHI affiliates from across the United States could enlist their volunteers to build house panels, modules, or components without taking too much time or money away from the local Habitat affiliates' own local building efforts. The perception among Habitat officials is that prefab construction conflicts with HFHI's local volunteer labor strategies. Yet, with a carefully designed prefab house system, HFHI affiliates from across the country could also contribute to very worthy relief efforts outside their own area. By offering a range of opportunities based on level of involvement, this prototype house strategy could include the efforts of smaller HFHI affiliates that do not

[3] ThermaSteel Corporation builds thermal steel panels that are ENERGY STAR® compliant and made from recyclable materials. The panels comply with the Department of Energy's Model Energy Code and have passed Florida's Hurricane Test Lab. The panels contain framing, insulation, sheathing, and vapor barrier and they can be premolded (ThermaSteel Corporation, 2008).

have the resources to ship a complete home to a disaster area. For instance, in the context of Hurricane Katrina, HFHI affiliates in the states adjoining Mississippi and Louisiana could contribute modules. HFHI affiliates within 500 miles could produce wall and roof panels, and others could ship smaller and simpler components.

After setting the walls and roof of the house (see exhibit 2), HFHMGC, with assistance from a Habitat group from Connecticut, completed the interior and exterior finishes. Unexpected complications with the construction, together with a skilled labor shortage in the region (plumbers and electricians, in particular), delayed the completion of the house, which was not finished until the summer of 2007 (see exhibit 3). The local affiliate received a lot of interest in the house from potential residents, and, near the end of the summer of 2007, HFHMGC selected a family. The birth of a new child in the family competed for the funds they were trying to save for the 1-year insurance escrow they needed to close on the purchase of the house. Eventually the family moved in during the summer of 2008.

Exhibit 2

Construction of the preHAB House in Gautier, Mississippi

Students begin to set up the modular panels of the preHAB house in Gautier, Mississippi.

Exhibit 3

Partners Construct Panelized Home in Gautier, Mississippi

The interdisciplinary university team partnered with Habitat for Humanity International to construct this 1,087-square-foot panelized home, which was completed in Gautier, Mississippi, during the summer of 2007.

Evaluation Process

Although many residential projects claim to be environmentally responsible, few attempt to carefully analyze the environmental impact or efficiency of the final product. The ecoMOD project is structured to monitor and analyze each completed prototypical housing unit. The evaluation phase of the project is essential, because, as an educational project, the goal is to build both confidence and humility in students. The ecoMOD evaluation teams typically assess the environmental impact, efficiency, affordability, occupant's satisfaction, and production readiness of each housing unit. The monitoring systems designed by the ecoMOD engineering teams measure indoor and outdoor air temperature; relative humidity; carbon dioxide levels; and electricity, gas, and water usage (see exhibit 4).

Given the distance between UVA and the site in Mississippi, together with the lack of funding to support travel, the evaluation phase for ecoMOD2 has been cut back and is limited to post-occupancy evaluations, a brief material assessment, and partial building monitoring during the first year of occupation. The monitoring includes electrical, gas, and water usage to analyze energy efficiency and measure cost-effectiveness. The team will compare this information to its digital design simulations that predicted those outcomes. Information gathered will help in developing future houses and in communicating the benefits of careful design and construction to future potential homeowners.

Exhibit 4

Prefabricated House With Energy Monitoring System in Gautier, Mississippi

This prefabricated house in Gautier, Mississippi, includes a digital energy monitoring system that the university engineering team designed. The system collects data to chart electrical, gas, and water usage throughout the year.

Conclusion

The extreme nature of the Hurricane Katrina disaster is the biggest challenge facing the Gulf Coast's rebuilding effort. The National Low Income Housing Coalition[4] estimates that 71 percent of the destroyed units in the affected areas were in the affordable to low- and very low-income household categories. According to the Congressional Budget Office, the recovery process from Hurricane Katrina will take longer than normal because workers associated with the effort have no place to live. According to the Brookings Institution,[5] median house prices in New Orleans have increased since Hurricane Katrina occurred and the limited supply of housing is pushing up ownership and rental prices to the extent that entry-level homeowners and other working families may have difficulty finding affordable housing if and when they return. The commonly held expectation that the city may reach only 60 percent of its pre-Hurricane Katrina population over the next several years is very possible if affordable housing is not available. Clearly in this scenario the Gulf

[4] The National Low Income Housing Coalition, based in Washington, D.C., is an organization whose focus is to create more affordable housing. The data suggested in this document are from NLIHC (2007).

[5] The Brookings Institution, based in Washington, D.C., is a nonprofit public policy organization whose mission is to produce independent, high-quality research to influence and direct democracy, economic and social welfare, and a safe and prosperous international system.

Coast will shrink in its economic capacity, tax revenues, and ability to maintain housing stock that is no longer habitable or is in areas that are truly at grave risk and uninsurable. These data confirm that affordable housing is a necessity and the Gulf Coast is in desperate need.

Initially, inadequate support and infrastructure directly affected the rebuilding efforts. Existing local Habitat affiliates were typically producing two homes per year in this region before the hurricane. Post-Hurricane Katrina homebuilding numbers have increased to an average of 200 homes per year for the Gulf Coast of Mississippi and Louisiana. The initial lack of infrastructure to support such a large rebuilding effort proved to be a very significant challenge. In the end, HFHI assumed many of the responsibilities typically reserved for local affiliates and provided a major influx of cash from its donations. HFHI also combined county-based Habitat affiliates into the more robust regional HFHMGC. When the ecoMOD2 team first arrived in Mississippi less than 6 months after Hurricane Katrina made landfall, both the local Habitat affiliate and the local building department were operating with a small staff and only starting to make headway toward an organized response to the situation. What was a patched-together operation has turned into a much more organized and effective team of Habitat professionals leading their efforts.

The difficulties of taking on the ecoMOD2 preHAB prototype in this context were significant. At the time, HFHI was having difficulty completing conventional wood framing structures like the ones they have built all over the country. Asking them to help build the ecoMOD2 preHAB design required them to adapt to a very different design and a very different type of structure. The collaborative team learned that if ecoMOD participates in another disaster relief effort, it is important to completely solve all issues before shipping to the site so that the onsite construction can be completed on time. In addition, the team should have assumed each phase would take at least twice as long to complete than it would under normal circumstances.

Regarding the design itself, the success will have to be measured—both in terms of the performance of the home and the occupant's satisfaction. The team already knows, however, that if ecoMOD builds again from this design, it should simplify the design somewhat to make sure that any Habitat team can easily complete it. Unfortunately, changes had to be made to the home in the middle of construction because the local Habitat teams did not understand the design intentions. A complete set of construction drawings were available inside the house, but one group misunderstood an exterior open skylight in the outdoor dining area and a bay window in the kitchen and mistakenly removed them both. These elements would have enhanced the livability of the home considerably. In addition, the ecoMOD team should have prepared a clearer list of locally available and acceptable materials to be appended to the construction drawings, to allow for last-minute substitutions. For example, all the ecoMOD teams typically try to avoid PVC/vinyl products, due to the toxic nature of their production and their recycling challenges. But the local Habitat builders ignored the reference to a commonly available aluminum eave and window trim when they found there would be a slight delay in receiving it, and they installed vinyl instead. Also, most of the old growth cypress wood reclaimed (with permission) from destroyed buildings in nearby Bay St. Louis was not assembled into the front entry deck and outdoor dining deck as planned because the local Habitat workers did not have the right equipment. In addition, the local workers left the wood on the ground for an extended period of time—where it turned into a breeding ground for insects. What would have been a beautiful deck of free material had to be replaced with concrete.

Of far less importance, but notable nonetheless, is the unnecessary addition of conventional interior trim at cabinetry edges and door openings. The design team had labored to create simple clean details, but, when leaving town, they failed to put large notes on the trimless details, alerting the local workers that nothing more was required.

In this sense, the completed home is less than what the team intended, but these lessons are important ones. With the projects built in Charlottesville, the teams have complete control over the construction efforts; but, even with ecoMOD1 and ecoMOD3, the final buildings could have been simplified. Recognizing and acknowledging these problems are an important part of refining the ecoMOD design process.

The University of Virginia Patent Foundation has registered the copyrights for the drawings of all the completed homes, including ecoMOD2. The Patent Foundation has also licensed the designs to a modular marketing company to make them available to modular builders, individuals, and affordable housing organizations—although this process is in the early stages. In addition to commercializing the designs, the ecoMOD engineering team intends to commercialize the ecoMOD wireless monitoring system. They plan to make it available to affordable housing organizations and individuals, so others can get easily understandable feedback on their energy and water usage and on the performance of their homes.

By taking the ecoMOD designs into production, we intend to give affordable housing organizations quick, low-cost, and sustainable infill housing options that cost less to operate. Estimates from modular builders show the prototypes can be replicated at a lower cost than standard site-built housing. We do not have clear evidence, however, that the scale of this savings is the same in the context of the heavily subsidized and donation-dependent world of HFHI construction. Further research into this matter is difficult, given the challenges of tracking hard costs with a single Habitat home, but it is an important question for the viability of the preHAB design. In the end, what can be definitively stated is that a team of architecture and engineering students learned a lot about sustainability, prefabrication, and disaster relief housing, HFHI staff and volunteers were exposed to more sustainable methods of design and construction, and a family lives in a home that will cost less to operate than the one next door. Perhaps that is enough for now.

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