

Commercializing Energy-efficient Affordable Housing: The EcoMOD South Project

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ABSTRACT: This paper addresses some of the recent activities of the ecoMOD project, a research and design / build / evaluate initiative at the University of Virginia School of Architecture and School of Engineering and Applied Science. In 2011, the ecoMOD received a substantial portion of a \$2.45 million grant from a regional economic development funder to work with commercial companies and non-profit organizations in the two most economically deprived areas of Virginia, Southside and Southwestern Virginia. The funding is being used to develop a commercially available version of an ecoMOD home design. Since 2004, ecoMOD has designed, built and evaluated prefabricated affordable homes for affordable housing organizations such as Piedmont Housing Alliance and Habitat for Humanity. This recent grant is intended to commercialize a modular Passive House Standard version of one of the previous designs and help develop the capacity for fabricating sophisticated, high-performance homes in the region. The effort is dubbed 'ecoMOD South' because the affordable housing organizations and fabricators are based in Southside and Southwestern Virginia.

KEYWORDS: Passive House, Modular, Affordable Housing

INTRODUCTION

The ecoMOD Project is a research and design / build / evaluate initiative at the University of Virginia that since 2004 has created a series of highly energy-efficient affordable housing units. In 2009, a sister project, ecoREMOD, was formed, focusing on renovations and deep-energy retrofits. The projects are embedded in UVA's curriculum and structured to maximize the educational opportunities. To date, almost 400 students (and a handful of faculty members) have helped to create a total of nine housing units on six sites. Once occupied, student evaluation teams monitor and evaluate the homes carefully, with the results guiding subsequent designs. The ecoMOD / ecoREMOD project (Quale, 2012 and www.ecomod.virginia.edu) is a partnership of the UVA School of Architecture and School of Engineering and Applied Science. The goal of the project is to provide a valuable educational experience, while demonstrating the environmental and economic potential of prefabrication and renovation. ecoMOD / ecoREMOD teams work directly with affordable housing organizations to ensure sustainable housing is no longer a luxury reserved for the wealthy.

The project teams strive to address the two most important challenges facing the next generation of designers: the significant environmental impact of the building environment, and the growing economic divide between high-income and low-income individuals. In the context of this multi-year project, participants have included architecture, engineering, landscape architecture, historic preservation, planning, business, environmental science, economics and high school vocational education students and faculty. The curriculum and the projects have been recognized nationally and internationally as a model for sustainable architectural and engineering education, and have won over a dozen major awards.

The evaluation phase is structured to monitor and analyze completed housing units. It is essential to the project because it can contribute to building both confidence and humility in students. The evaluation teams typically assess the environmental impact, efficiency, affordability, and occupant satisfaction of each housing unit. The monitoring systems deployed by the engineering teams measure indoor and outdoor air temperature; relative humidity; CO₂ levels; and electricity, gas and water usage.

The University of Virginia Innovation office has registered the copyrights for the designs of the completed homes. Since the beginning, the intent was to allow affordable housing organizations to benefit from the convenience of getting a high-performance home delivered for a reasonable construction cost. By taking the ecoMOD designs into production, our intent is to give affordable housing organizations quick, low-cost and sustainable infill housing options that cost less to operate.

1.0 ecoMOD SOUTH DESIGN PHASE

1.1. Redesigning the Prototype

In the summer of 2011, the Tobacco Indemnification and Community Revitalization Commission of the Commonwealth of Virginia approved a \$2.45 million research and development grant for the University of Virginia's ecoMOD Project and another project (reCOVER – focused on post disaster transitional housing). The grant is to work with modular and structural insulated panel (SIP) manufacturers and non-profit organizations in creating commercially viable manufactured housing. The ecoMOD South research project is currently commercializing one of the project's modular homes with Cardinal Homes, a modular homebuilder in Southside Virginia. The original prototype of the home -- ecoMOD4: the THRU house [Figures 1 and 2] -- was designed and built by students in 2009 for Habitat for Humanity of Greater Charlottesville. The two-story, two bedroom home has just over 1,000 square feet, and is home to a refuge couple from Afghanistan. It has a donated photovoltaic array, which when combined with a well-insulated and carefully air-sealed building envelope, allowed the designers to target zero-net energy. As of the summer of 2012, the home has achieved a few months of net zero living, although not consistently. It is believed that the energy habits of the homeowners, and the fact that the construction budget did not allow for high-performance windows, contributes to the higher than anticipated energy use, which remains substantially lower than a comparably sized conventional home.



Figures 1 and 2: Exterior and interior views of ecoMOD4: the THRU house. Source: Scott Smith Photography

The research team has collaborated with Cardinal, as well as Southside Outreach from South Boston in Southside and People Incorporated from Abingdon in Southwestern Virginia to create a four-bedroom version of the design. The housing organizations, the modular homebuilder and the SIPs manufacturer receive the majority of the funding for materials, new technology and training.

As of this writing, the units are being fabricated, and the design and build phases will be complete in the spring of 2013. Two identical versions of the home will be built to Passive House standard (PH) and placed in two different cities (South Boston and Abingdon) – with slightly different climates. The South Boston PH home will be rented by low-income individuals in a city with a moderate / humid climate. The Abingdon home will be purchased by low-income homeowners in a city located in the foothills of the Appalachian mountains, which has a slightly more extreme climate. A third house will be constructed to look exactly the same from the outside, but the insulation, air barrier and mechanical systems have been redesigned to go

no further than meet the energy requirements of the standard building code. This “code unit” will be located next door to the PH home in South Boston. The research team will monitor the performance of all the units, and also assess the return on investment of the added cost to achieve Passive House standard.

The current grant-funded effort is not as directly integrated into curriculum as the previous design / build / evaluate efforts, although current students have contributed to some aspects of the work, including the development of the monitoring system and eventually the analysis of the data. The majority of the work has been completed by a team of former students acting as paid research assistants, three of whom have previous experience with the project.

Over a year and a half, the ecoMOD South research team adapted the ecoMOD4 design to become a four-bedroom, 1,800 square foot home [Figure 3]. In addition to the redesign process, the team critiqued the materials used in the prototype, and spent many months researching material choices, construction details, landscape design strategies, Passive House modeling, and created simulations of energy use, daylighting and thermal bridging. The effort is led by the ecoMOD Project Director, who works with three other faculty members with expertise in engineering, landscape architecture and building simulation. A PH certified consultant manages the PH modeling process, and a PH certified engineer designed the mechanical system.



Figures 3: Exterior view of ecoMOD South homes shown on the South Boston, VA site. Source: ecoMOD South Team

The design process took longer than originally anticipated. With the schematic design already in place, the team assumed a relatively straightforward process to add a third bedroom (a fourth was later added), adjust the design of the building envelope to respond to the Passive House standards, and work closely with Cardinal Homes to understand their process. All the partners agreed on the goals of achieving high performance housing on a limited budget, but not surprisingly, the difficulty was in finding a shared understanding of the meaning of ‘high performance’ and ‘limited budget.’ In the end, the team was pleased it had the opportunity to extend the grant period to ensure we could come up with the best possible project within the budget available.

The collaboration with Southside Outreach and People Incorporated was productive. The most significant challenge the research team faced working with these two well-experienced affordable housing non-profits is the fact that they are quite different from each other. Southside Outreach consists of two full time staff and a community board. Given their limited size and resources, they have been able to have a significant impact on the communities they serve. In addition to developing new affordable housing, they also repair and renovate housing, and offer educational programs to help clients learn how to prepare themselves for homeownership. They work in six counties in Southside, and have been in existence for 17 years.

By contrast, People Inc. is one of the largest community action agencies in the nation. Almost 50 years old, it currently counts 12 counties in Southwestern and Northern Virginia as primary service areas, with an additional 11 counties in Southwestern Virginia as secondary areas. Affordable housing is just one of their interests. The organization has over 200 staff members, and runs a wide variety of programs. Examples include efforts to support elder care, child daycare, preschool and head start programs, after school

programs, tutoring, community development, business development and financing, consumer loans, weatherization and repairs of homes, transitional housing, Section 8 housing, health care, dental care, court appointed special advocates, domestic violence support programs, drop out prevention programs, and workforce development programs of various types.

For Southside Outreach, the ecoMOD South initiative is an important project and consumes a significant percentage of staff time. For People Inc, ecoMOD South is just one of many housing initiatives that they are working on. The Southside Outreach staff, and the housing team at People Inc. know each other well, and have even partnered on a project in the past. Yet, the research team worked with the two organizations in very different ways. The team made sure to understand not only the differences in administrative processes, but also the unique interests and preferences of each organization. The two PH homes will be exactly the same for the two organizations, but the methods of financing the community partner's portion of funding, and individual size and configuration preferences led to a unique working process for both.

From the beginning, the team sought certification under the Passive House standard, while remaining limited to an affordable housing budget. Early PH simulations led the team to add a fourth bedroom because it meant a better ratio of exterior surface to interior volume, without necessitating a major design change. Over time, the ecoMOD South research team, working with the PH consultant, researched a wide variety of insulation and air sealing ideas, glazing specifications, technologies and materials. A particularly difficult challenge was testing the PH design variations on both sites. Fairly often, a small change to a detail or material selection meant the design would fail to achieve PH certification in one site but not the other. This issue was complicated by the fact that while the designs were identical, the sites are not, and orientation of the buildings on the two sites are also quite different.

The portion of the grant funding available for construction allowed the housing organizations to exceed their typical budget compared to a similarly sized home. The total cost of modular production of the PH units is about \$105/SF, with the code unit coming in about \$65/SF. This does not include site and landscape costs, which vary considerably due to radically different topographic and site conditions. The Abingdon PH home is infill housing in a somewhat dense urban context on a very steep lot, with a much more expensive foundation and little opportunity for landscape development. The PH and code home in South Boston are being placed on a mostly flat empty lot, with 13 more adjacent lots that may someday be filled by other ecoMOD designs. Across the street from these homes, there are six two-story apartment buildings (approximately eight units per building) that are owned by the same non-profit partner, Southside Outreach. (An ecoREMODO team recently completed a schematic design for energy upgrades and aesthetic improvements to these buildings. The ideas are being handed over to a professional architecture / engineering firm from the South Boston area.)

These per square foot costs, while higher than similarly sized affordable housing in Southside and Southwestern Virginia, are in line with the affordable housing market in Central Virginia and the Richmond area. They are also below the cost of similar affordable housing in most of Northern Virginia near Washington DC. Therefore the homes are unlikely to be duplicated by these partners as PH homes, but there is clearly a market to sell them as PH units to housing organizations in other parts of the state, as well as to market-rate homebuyers throughout the state and region. The ecoMOD Project, recognizing its inability to achieve a PH design that can be replicated for these two partners in their primary services areas, offered a design studio and engineering seminar in the fall of 2012 to design lower cost, one-story, Energy Star rated homes that will meet the necessary budget for future affordable housing development in South Boston and Abingdon. Cardinal Homes will be able to sell both the ecoMOD South PH and non-PH design, as well as these one-story home designs, called ecoMOD RANCH because they are a reinterpretation of the standard American ranch house.

For the UVA research team and the staff of Cardinal Homes [Figure 4], the experience has been an important educational opportunity for both sides. The ecoMOD South team had to learn about the normal process of designing, engineering and building a home with Cardinal Homes (each modular homebuilder is somewhat different), and the Cardinal staff was exposed to innovative building materials they had not previously procured, and learned how to build a modular home to meet PH standards. Early in the collaborative process, it became clear the expectations on both sides did not align with each other. Cardinal was used to operating as a for-profit company that provides a service to a client with specific interests. The ecoMOD team was expecting a collaborative research lab experience, while Cardinal was looking for clear cut direction from the UVA team. Once this misalignment of expectations was identified, both sides were able to adjust and find process that worked for both sides.



Figure 4: Cardinal Homes staff members discussing the ecoMOD South project. Source: John Quale

The first serious attempt at cost estimating the project was an important moment. The team discovered that the construction budget was not sufficient. Initially the team was planning on creating four homes – two units built as an attached duplex for each of the non-profit partners. The budget for the grant, created several months before, was not based upon actual construction costs for these homes, but on what seemed to be a reasonable request given the scope of work. Since the estimate was roughly 30% over budget, the team suggested simply eliminating one of the homes. The site that People Inc. had selected in Abingdon was proving to be too narrow for the two-unit duplex, and changing to a single family detached home also made more sense in that urban context. Southside Outreach was willing to change to two single family homes, and actually would have preferred that from the beginning. An upside of this significant change is that it helped to clarify the research questions. Rather than dealing with the ambiguity of townhomes, which at that stage were assumed to have SIPs construction in one home and a double wood stud wall in the other, the research team was pleased to have clarity of two PH houses of exactly the same construction on two separate sites, as well as a home that looks the same, but is only built to standard building cost right next door to one of them. The variables have been reduced and clarified, and the evaluation of the performance of the homes will more clearly document the advantages and disadvantages of the Passive House standard for affordable housing in the mid-Atlantic region.

1.2. ecoMOD Decision Analysis Tool (DAT)

One of the most difficult challenges of working collaboratively is making decisions. Among the individuals involved in this complex project, there are a wide variety of backgrounds, priorities and responsibilities. This topic has been a difficult challenge since the founding of the ecoMOD project in 2004. The very first ecoMOD team struggled with this issue, and developed a decision making process that involved a research database, and the use of spider diagrams to allow the team to visualize their priorities. This process helped the team to ensure that all relevant research on any individual decision was being discussed, and also helped them to set priorities when it came to selecting design strategies, building materials and technologies. These diagrams became known as “Decision Webs” among the ecoMOD teams over the years. The points of the webs were organized into six major categories: Energy, Environmental, Social, Financial, Aesthetic, and Technical. As a system of graphic representation, Decision Webs allowed for the quick appraisal of several components at once, and provided a concise statement of values to be handed to the community partner, or to the next design team if the project was stretching across semesters.

One of the unexpected benefits of using paid research assistants to help run the ecoMOD South project (rather than students in design studios and engineering seminars) is the further development of decisions webs into a much more sophisticated database and ultimately a web-based tool that can be shared with others. The ecoMOD South research team has developed an online database system to collect information on construction materials, partner surveys, design strategies and equipment, as well as a web interface that

can generate diagrams to use in discussions. The tool, known as the Decision Analysis Tool and nicknamed DAT, is a graphical system which represents information, major categories, sub-categories, and scoring data in a terse radar graph format [Figure 5].

The driving goal for the development of the Decision Analysis Tool is to accumulate research on sustainable building components, and display this information in a freely accessed way. Comparable tools include the Pharos project, organized by the Healthy Building Network, which aims to increase product transparency by providing a score according to several “impact categories” to explain information to consumers, and ARUP’s SPeAR diagram, a propriety application used by ARUP consultants clarify sustainability priorities with a variety of clients. Besides the unique graphic interface that the team has developed, the DAT differs from these precedents in two major ways. First, it is a system that can be applied to any decision or situation. Already it has been used to assess the values of the different partners in the ecoMOD South project, and to evaluate complex components such as wall systems.



Figure 5: DAT diagram showing a possible wall system for ecoMOD South. Source: ecoMOD South Team

The first live use of DAT outside of ecoMOD South was for a summit of political leaders, real estate developers, engineers, state regulators, environmentalists and academics to discuss stormwater guidelines in the state of Virginia. The UVA School of Architecture’s Institute for Environmental Negotiation facilitated the summit, and used DAT in several open sessions to help the audience articulate priorities on this topic, and project the ‘votes’ for these various priorities live on a screen. The DAT diagrams helped these leaders get an immediate understanding of where they might find common ground, while also testing the versatility of the system to convey real-time survey data in a large group setting. This flexibility accounts for the second distinguishing factor: DAT is conceived to be freely-accessible without a fee. We intend to continue to build an expanding database so it could be used more broadly, but also to develop the tool so that anyone can develop their own categories and relevant sub-categories, and then define priorities.

The ecoMOD team anticipates that the tool will benefit the partners already involved in the project by providing a way to understand and record complex design decisions, while continuing to grow as a resource for sustainable construction product information and designed building components. For example, modular builder Cardinal Homes will have access to this sustainable research database, and will also have an interface for visualizing their own private research and development decisions. Southside Outreach and People Inc. will have a way to convey their goals for sustainability to interested parties and get access to design information to help develop other projects. As the database and interface grow, the targeted market could widen to include affordable housing organizations across the region, and the sustainable building community as a whole.

2.0 ecoMOD SOUTH BUILD PHASE

After months of research, design, collaborative decision-making, cost estimating and material procurement, the ecoMOD South project finally went into production in late December 2012. As of this writing, construction is not complete, but work is progressing quickly [Figure 6] – both on the modules under construction in Cardinal’s manufacturing facility, but also on the two sites, where foundations and site work are underway. Minor problems have arisen – mostly related to a couple building materials that had been selected but were mistakenly replaced with choices that are typically used by Cardinal. The communication of the desired choices has now been more thoroughly distributed to the appropriate Cardinal staff, and the ecoMOD South team has remained flexible.

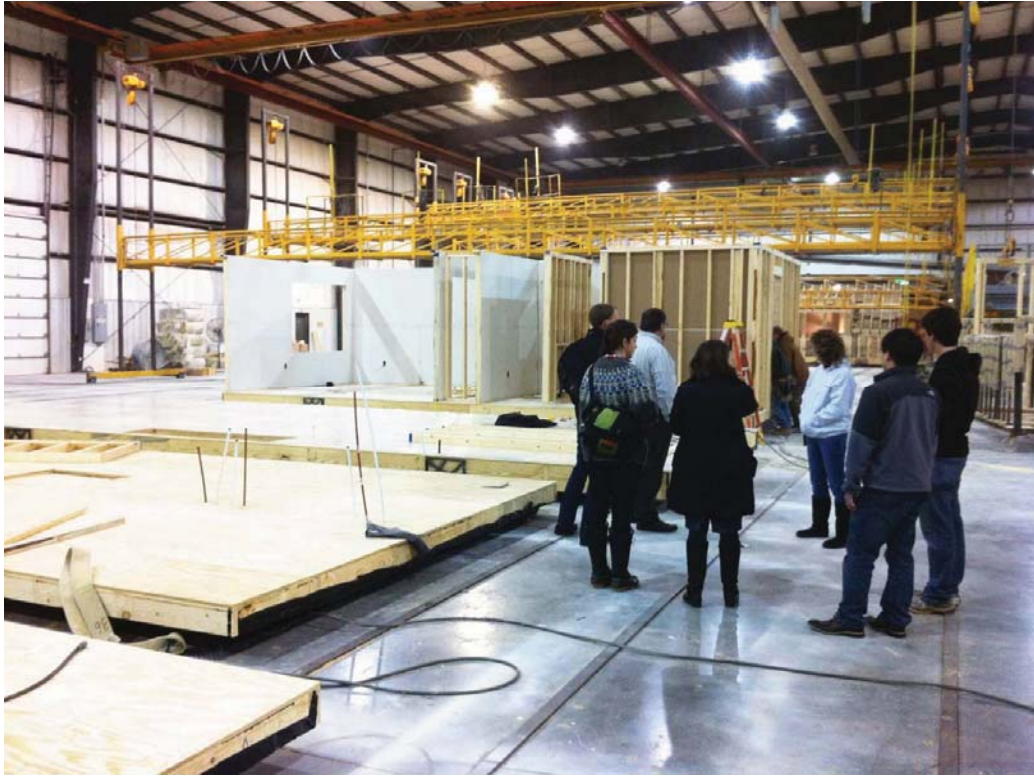


Figure 6: The ecoMOD South code unit under construction at Cardinal Homes in January 2013. Source: John Quale

There has been one major problem in the construction phase so far, related to the delivery of the structural insulated panels (SIPs). One of the partners in the grant is a SIPs manufacturer based in Southside. This company is the recipient of a very substantial portion of the grant funding to acquire sophisticated digital fabrication equipment to allow them to use CAD / CAM technology for routing SIPs panels. After a long delay in the final assembly of this large system in their facility, the company was forced to meet the ecoMOD South deadline and assemble the SIPs for the project using conventional tools. The SIPs were delivered to Cardinal, but were deemed to be below the quality standard required for an efficient building envelope for a PH standard home. Rather than wait for the company to get their new equipment working, or switching to a double stud wall construction method, Cardinal recommended asking another SIPs manufacturer to build replacement SIPs. Unfortunately, the company is based in Georgia rather than Virginia, but they were able to produce excellent quality panels in a very short time. The three homes will be on their foundations by the end of March, and ready for occupation soon after.

CONCLUSION

Besides the exciting opportunity to deliver high quality homes for three affordable housing clients, the most important aspect of this project will be the results from the monitoring and post occupancy evaluations. The ecoMOD engineering team has assembled an affordable, wireless monitoring system that will gather data about local weather; indoor air temperature, humidity and quality; energy use; and building envelope heat flow with sensors in all three homes, including sensors inside the wall and roof sections of the homes. The team will also monitor a recently completed home designed and built by Southside Outreach for comparison.

One of the most interesting questions is whether it makes financial sense to build PH standard housing for affordable housing organizations in the kind of mixed climate found in the Mid-Atlantic region. PH as a formal standard has emerged from Germany and other parts of northern Europe where heat and humidity are less of an issue. Passive House Institute of the U.S. (PHIUS) is in the midst of a process of recalibrating the standard to the wide range of climates in the U.S. – a process that is likely to take several years to perfect. This project has the opportunity to contribute data for analysis to assist PHIUS with this process, but could also be an important precedent to allow affordable housing organizations, modular homebuilders

and individual market-rate homeowners to understand the possible return on investment for PH standard homes in this region. We have already proven that the additional costs associated with high performance windows, doors and other components of the building envelope that achieve PH standard put the price for these homes beyond the amount considered to be accessible for affordable housing organizations in the southern part of Virginia. Yet, the ecoMOD South project has the potential to create economic development with the sale of homes to market rate homebuyers and affordable housing organizations in other parts of the state and the region. The larger question of return on investment is the next important question to answer. In addition, the ecoMOD team intends to assess the overall life cycle impact of the PH homes, comparing them to the code unit, and to a conventional home. While the grant funding will officially end with the occupation of the homes, the longer term relationships with the partners will continue to evolve, and the research questions will likely take at least two or three years to deliver preliminary answers.

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