Performance Optimization & Development of a Home Modular Delivery System

Lisa D. Iulo[1], Aaron Wertman[2], Bruce Quigley[3]

[1] Associate Professor of Architecture, Stuckeman School, The Pennsylvania State University, 426 Stuckeman Family Building, University Park, PA 16802; email:ldi1@psu.edu
[2] M.Arch student, Stuckeman School, Pennsylvania State University, 105C Stuckeman Family Building, University Park, PA 16802; email: acw5101@psu.edu
[3] Deputy Executive Director, Union County Housing Authority, Industrial Blvd. Lewisburg, PA; email: b.quigley@unioncountyhousingauthority.org

ABSTRACT

The objective of this research is to expand affordable home energy performance by developing an optimized modular delivery system, a Kit-of-Parts (KoP), applicable for infill development of new homes and for retrofitting existing homes. This innovative system of components is projected to result in homes that surpass Energy-Star performance for energy-efficiency, have improved indoor air quality, and provide realistic options for aging-in-place. Most notably it will provide a way to deliver high quality, well-designed, small affordable housing projects on a broad scale with a specific aim of revitalizing existing communities. This paper will present precedents, urban analysis and potential solutions for the modular home delivery system, KoP. KoP includes a carefully considered and flexible modular system for new and retrofit homes that can accommodate contextual adaptation to multiple infill sites and program needs. Modular construction can effectively achieve the level of quality control requisite for healthy and energy efficient homes. Multiple KoP modules can be combined and configured for the delivery of new houses and small housing projects on a variety of site conditions. Modular augmentation cores, that include well-integrated mechanical and plumbing systems, will also be advanced. These cores can be employed to save, update, transform and retrofit existing residences, especially in adapting homes for the accessible single floor living desirable for aging-in-place. Another benefit of the KoP is the potential for densification and revitalization of existing towns.

INTRODUCTION

> *"For Pennsylvania's economy to thrive, it needs a housing market that meets the needs of low- to moderate-income residents. Those needs are far from being met and are increasing along with the demand for housing by the Marcellus Shale gas industry,"* State Sen. Eugene Yaw, R-Loyalsock Township (Thompson, 2011).

Recent estimates project that population increases and loss of housing due to demolition will translate into a need for about 1.5 million additional new housing units in the U.S. each year (McWilliams, 2013). Existing towns are an obvious choice for investing in housing to address this growing need. The walk-able, mixed-use character of existing communities make them inherently sustainable, and the benefits of redevelopment are obvious - a vibrant small town has the potential to be a very desirable place to live. Cost-effective new infill housing and retrofitting of existing homes hold promise for revitalizing existing towns by addressing housing options that will allow aging residents to remain in their community.

The project described herein endeavors to expand affordable home energy performance by developing an optimized modular delivery system, a Kit-of-Parts (KoP), applicable for infill development of new homes and for retrofitting existing homes. This coordinated system of components will result in homes that surpass Energy-Star performance for energy-efficiency, have improved indoor air quality, and provide realistic options for aging-in-place. Most notably it will provide a way to deliver high quality, well-designed, small affordable housing projects on a broad scale.

KoP differs from most modular housing approaches in that it is not intended, marketed or presented as complete houses, buildings or groups of homes. Rather, the KoP is envisioned as a process built around a set of detailed components. These “parts” represent a UL listed product that would be specified much like doors or windows, benefiting from the strengths of the modular industry, but requiring the sensitivity of a qualified architect.

PROJECT OBJECTIVES

The home modular delivery system, KoP, is intended as the core building blocks for realizing infill housing on a broad scale. This standard geometric template will conform to the common constraints typical of infill development in small towns, modest houses, and efficient modular construction. Application would not be universal, but if planned properly it could be reasonably ubiquitous (Quigley and Iulo, 2012). KoP fabrication documents will meet tight manufacturing standards and tolerances; designed to a level of coordination unprecedented in the design of individual affordable houses. Customization for each project design would occur during site adaption for individual application of the modular components and through the integration of local materials. Investment in the development of these fabrication-ready building modules will allow for the high up-front costs of integrative design to be spread over many small projects. Previous studies suggest that local modular plants can build to the high-standards required for the KoP. This facilitates integration of local materials and methods and takes advantage of existing relationships.

Currently most new subsidized housing development focuses on multifamily and larger projects inappropriate for the majority of Pennsylvania’s town fabric and small rural communities. This project recognizes the need for a delivery model that uses resources to deliver high-performance affordable single homes and small projects. Modular construction holds promise for enhancing the quality, energy efficiency, sustainability, and durability of residential construction for new and existing homes. Development of a modular "kit-of-parts" has significant potential for the delivery of homes that are affordable to construct and maintain. Energy-efficiency measures developed and integrated into the KoP will protect financial investment since according to the UNC Center for Community Capital and the Institute for Market Transformation "the more efficient the house, the lower the default risk;" Energy-Star homes are 32% less likely to go into default and for each additional point reduced on the Home Energy Rating System (HERS) index the default rate drops" (UNC, 2013). Towards this end, it is critical that KoP homes perform well below energy code requirements and Energy-Star certification standards (see www.energystar.gov) on the HERS index.

KoP makes use of a well-established and widespread module housing industry in the United States and in Pennsylvania especially. The KoP includes a carefully considered and flexible modular system for new and retrofit homes that can accommodate contextual adaptation to multiple infill sites and program needs. Modular construction can effectively achieve the level of quality control requisite for healthy and energy efficient homes. Multiple KoP modules can be combined and configured for the delivery of new houses and small housing projects on a variety of site conditions. Modular augmentation cores, that include well-integrated mechanical and plumbing systems, will also be developed to a high level of efficiency and integration. Coupled with improvements to building envelopes and careful attention to air quality, these cores can be employed to save, update, transform and retrofit existing residences, especially in adapting homes for the accessible single floor living desirable for aging-in-place. The highly efficient core modules can improve the overall performance of existing homes (Iulo, 2013).

This research explores modular building as a response to multiple apparent and specific needs for housing in Pennsylvania and beyond, including:

1. Modest housing for an aging population – emerging demographics are driving a strong need for high quality, low maintenance housing that is modest in size and cost.
2. The need for the production of healthy, energy efficient housing and retrofit of existing homes.
3. Demand for housing related to the natural gas industry - The rapid expansion of the natural gas industry because of drilling in Marcellus Shale formation is causing unprecedented growth in established towns throughout a region unaccustomed to growth (Thompson, 2011).

CONTEXT

This project is a collaborative effort between the Energy Efficient Housing Research group at Penn State and the Union County Housing Authority. Union County is an ideal location to address the needs summarized above and explore the proposed housing delivery method. The geographic majority of the Commonwealth of Pennsylvania comprises rural communities like Union County. These communities are home to nearly 30% of Pennsylvania's 1.27 million people. On average, rural populations are older than residents of more urban areas. According to The Center for Rural Pennsylvania, "from 2000 to 2030, the number of senior citizens in rural Pennsylvania is projected to increase 58%", resulting in an estimated 25 percent of the total rural population being age 65 or older by 2030. "At that time, there will be more senior citizens than children and youth in rural Pennsylvania" (Center for Rural PA). The population of Union County has steadily grown since 1900, with 8 percent growth realized in the decade since 2000; the current population of 44,947 is projected to grow to 52,280 by 2030 (Center for Rural PA). The county includes sparsely populated agricultural areas, but the majority of the county's population resides in municipalities considered to be "urban" by The Center for Rural Pennsylvania. The densest areas are the boroughs of Lewisburg, a college town with a population of approximately 6,000, and Mifflinburg with a population of +/- 3,500. The Borough of Lewisburg ranks a walk score of 85, "Very Walkable" on www.walkscore.com, with restaurants, groceries, parks, schools, shopping and other amenities within walking distance. Even the small rural borough of New Berlin has churches, a courthouse, two banks, a senior center and fairgrounds within walking distance of the majority of the residents. These community connectivity characteristics are important to the overall livability and sustainability of the towns; specifically they are consistent with principles of Smart Growth, Enterprise Green Communities, and USGBC LEED® Green Building standards, all associated with reducing energy use and environmental impact. Further, according to a National Association of Realtors survey, the majority of Americans favor "walkable, mixed-use neighborhoods" (Martin 2014).

Union County is also representative of other regions of Pennsylvania and throughout the United States in that the cost of housing is a significant burden on a large segment of the population. Between 2005 and 2009, 24% of homeowners and 44% of renters were expending more than 30 percent of their household income for housing; up to 30 percent of total household income is the commonly accepted cap on the amount that Americans should spend on overall housing-related costs, including utilities. Directly related to overall shelter costs are expenses related to home energy. Union County is especially impacted by home energy expenses since the majority of homes are heated using expensive fuel oil or electricity (USA.com). The Home Energy Affordability Gap, developed by Fisher, Sheehan & Colton (FSC), is used to qualify the gap between "affordable" home energy bills and "actual" home energy bills (http://www.homeenergyaffordabilitygap.com). According to the FSC 2012 report (2013), the Home Energy Burden for Union County is 41.9 percent. Those of low to moderate income are most adversely affected. In Pennsylvania, households below 50 percent of the poverty level (which represents 19.9 percent of Union County's households) are expending a "crippling" 36 percent of their household income on utility bills alone (6 percent or less is considered affordable). Even Pennsylvania households with incomes between 185 and 200 percent of the Federal Poverty Level have energy bills that exceed the affordable 6 percent of income (FSC 2013). Younger (under 25) and older (65 or older) households "experience similar housing burden to each other" and a higher overall housing-cost burden than other age groups (Swartz 2008). Exacerbating the problem, findings have shown that as housing prices increase, low-income households are increasingly forced out of higher-quality, higher-priced homes into older lower-quality, less-energy efficient homes (LIFE 2011). These facts point to the importance of energy efficiency considerations in all homes, new or existing.

Finally, although only the tip of a very small finger of Pennsylvania's Marcellus Shale formation extends into Union County, the county is surrounded by actual and potential Marcellus Shale activity on the north, east and along the southern border. Therefore, housing demand related to this energy industry extends into Union County, especially from the north (Lycoming, Tioga and Bradford Counties) where Marcellus shale wells are concentrated.

Union County Housing Authority Energy Efficient Housing Program

The Union County Housing Authority has embarked on a program to address the long-term affordability of their clientele. Pennsylvania's Union County Housing Authority launched the Energy Efficient Housing Program (EEHP) to demonstrate a way to reduce utility costs in order to make homes more affordable and sustainable for "Prime-Time" homebuyers, people age 55 and older living on a modest budget (less than 80% of the area median income). The projects were intended to demonstrate green design and development principles. The four homes, a duplex and retrofit of two existing homes designed and constructed as pilot projects for the EEHP, were recently completed and new homeowners occupy three of the four. An initial assessment shows that these homes are quite successful in meeting goals for a reasonable initial construction cost ($70 - $108 / S.F.) and long-term expenses related to energy performance (duplex = 46 HERS; Retrofits = HERS of 68 and 77 respectively). This pilot project is being monitored by the EEHR group and findings will inform decisions on the KoP development. Development of the KoP builds off of the lessons learned from the design for modular housing and energy efficiency improvements deployed in the Union County EEHP homes.

PREFABRICATION AS A MODEL

A yet unmet goal of the EEHP is its ability to be replicated. Rarely do we see small green affordable housing projects. A significant reason is the size since small projects, like infill houses, cannot bear the soft costs required by a rigorous design process. Nor does one design "fit all." The concept for the modular home delivery system KoP being developed for this research is intended to address that.

Precedent Review

This study began with an analysis of precedents for residential prefabrication. Although there is a long history of prefabrication worldwide, attention was dedicated to post-war U.S. examples of prefabrication where modern construction materials are used. The precedents examined fell into three broad categories: those examined based on spatial configuration and repetition; types of prefabrication; and component construction. Constructability, affordability, sustainability and flexibility of the selected exemplars were studied.

Throughout modern history, the industrialized manufacturing of building materials led to designers speculating about different approaches to the manufacturing of homes. Manufacturing processes associated with wartime aircraft construction, followed by assembly line manufacturing in the automobile industry excited speculation in particular. Certainly the influence of the aircraft industry was still evident in the late 1960s in Architect and educator Paul Rudolph's extruded cylindrical home modules. However mass-production wasn't the only thing underlying design – flexibility in combining the modules allowed for significant customization of the modules to particular site and cultural contexts. The pinwheel parti of Rudolph's site design for Oriental Masonic Gardens in New Haven, Connecticut created a dynamic central community space using similarly shaped and stacked module units. Rudolph also explored modular construction in high-density residential configurations for New York City. Buckminster Fuller's explorations using manufactured kits to "overcome shortcomings in existing homebuilding techniques" include the famous Dymaxion Houses (first developed between 1927 - 1929 and redesigned in 1945. http://en.wikipedia.org/wiki/Dymaxion_house). Of particular interest for this study, however, is the Dymaxion Bathroom. This 1936 ultra-efficient plumbing core encapsulated the sanitary functions of the home into a hygienically sealed module. This bathroom module was constructed from four molded plastic or metal sheets light enough to be carried by two workers and small enough to be used in the retrofit of existing structures. All plumbing and ventilation was centralized in the core. Although the fixtures were arranged "to ease the care of children and seniors," ultimately, the space-capsule aesthetic proved too sterile for mass consumption (http://www.weirduniverse.net/blog/comments/2824/). The radical transformation of housing typology in Rudolph's Oriental Masonic Gardens was also eventually rejected and demolished. Thus showing that the appearance/perception of modular construction must be carefully considered. Carl Koch's Lustron House, a kit of factory-produced "parts that could be assembled in many configurations" is credited with "not perverting conventional image" (Davis, 1995). Koch, according to Davis, anticipated that to be successful factory-produced housing must support the market, considering "a network of financiers, sellers, and maintenance support. Illustrating success in this area, "as recently as 1991 the magazine *Progressive Architecture* sponsored an affordable housing competition based on the Lustron model, intended to awaken the housing profession to the pressing need for housing to demonstrate, yet again, the benefits of mass-production" (IBID, pg. 25-26). Abacus Architects award-winning project for this competition was manufactured in Pennsylvania and showcased on a site in Cleveland, Ohio. The architect has adapted the design of the Progressive Architecture Affordable House Prototype for "different family types and site conditions, including grouped houses with lower level parking built for a Neighborhood CDC on a hillside site in Pittsburgh" (www.abacusarchitects.com).

More recently there is an increased interest in modular construction for achieving modern, affordable and sustainable homes. Allison Arieff and Bryan Burkhart examined architect designed prefabrication for the "homes of the future" in their 2002 book, *PREFAB*. Author Jill Herbers continued this theme in *Prefab* modern (2004). These ideals were brought to public attention by Dwell magazine when they dedicated an issue of the magazine to prefab homes and subsequently challenged architects with designing modern prefabricated homes for $200,000 (Arieff (2005). Modern prefabricated home designs were further promoted on fabprefab, "a web resource dedicated to tracking developments in the market for 'modernist prefab dwellings" (www.fabprefab.com). In 2002 the potential for "sustainable" prefabrication was realized, perhaps inadvertently, with the first DoE Solar Decathlon competition, when collegiate teams constructed their solar home designs on the National Mall. Shortly thereafter, in 2005, Architect Michelle Kaufmann's modular GlideHouse was exhibited in the National Building Museum to showcase the potential for achieving Green Homes. Today, the Santa Monica, California company LivingHomes (http://www.livinghomes.net/homesCommunities.html) has expanded their portfolio to offer LEED certified prefabricated homes designed by well known architects including Ray Kappe, FAIA and the Philadelphia based partnership KieranTimberlake Architects. The C6/CK series LivingHomes are cataloged on the website based on size and price and can be customized by interested homebuyers. The U.S. Department of Housing and Urban Development (HUD) has acknowledged the potential for prefabrication in the facilitation of well-designed affordable housing. According to HUD researcher Carlos Martin, PhD, " the trick is finding that magic tipping point where you can use prefabricated materials, components, systems and modules and still create innovative and site-specific buildings" (Arieff 2013). Several university Design/Build programs have managed to successfully merge modular building conventions with sustainable building practices. Of most interest for this study are Auburn University's DESIGNhabitat Program, specifically the DESIGNhabitat 2 house that addresses site-specific design by marrying room-sized home modules with site-constructed components (Hinson & Norman 2008) and U.VA's various ecoMOD solutions for urban infill, community densification, and renovation of existing homes (Quale 2012). Notable in merging high-performance building strategies with innovation in modular construction is the Philadelphia-based develop-design-build firm Onion Flats. Recent work of Onion Flats utilizes existing housing typologies of row-houses and courtyard apartment blocks while rethinking the construction, spatial layout, and efficient home energy systems, allowing for innovation within an already accepted context while greatly improving the energy-performance of their projects.

Limitations of prefabrication

The revitalization and densification of existing towns and community fabric is one goal of the proposition addressed with the KoP. Currently modular manufacturers do not target infill development. As articulated by U.VA ecoMOD professor John Quale:

> *Homeowners are typically restricted to placing their prefab house on a suburban site, where land is cheaper. In addition to cost considerations, most*

> *manufacturers and modular houses are designed for the orientation of wider suburban lots. No major manufactured home company offers models designed for narrower but deeper urban lots with the entry side facing the street. The typical singlewide module for these homes measures 12' to 14' wide by 48' long – a size difficult to transport into many tight urban areas. As a result, families in the affordable housing market are being pushed to the periphery of the city, where they have the added financial burden of being fully dependent on a car.* (Quale 2012, pg. 39.)

The several projects that ecoMOD has completed between 2004 and today demonstrate that modular home design can be dimensioned to be feasible and contextually appropriate for different infill site conditions. Additionally, the addition to ecoMOD3/SEAM house and the schematic designs for ecoMOD XS hold promise for the densification of existing communities by adding small accessory dwelling units to existing building lots (see: http://ecomod.virginia.edu/projects).

The limited use of modular construction as key to a delivery method for publically funded affordable housing projects is another issue that we hope to address with the KoP. The UC EEHP Duplex home was funded primarily through a HOME grant. Two conventional builders and one modular home manufacturer responded to the public call for bids. The low-bid presented by the modular builder was accepted for construction of this phase of the project (the EEHP pilot project included the energy-efficient retrofit of two existing homes; see proceedings from the 1st RBDC conference for lessons learned from the retrofit process). The majority of affordable housing rental projects are funded in part through Low-Income Housing Tax Credits (LIHTC). In *The Architecture of Affordable Housing* author and architect Sam Davis critiques the process imposed by the application process for LIHTC projects, stating:

> *The [developer] must have control of the land on which it intends to build before it can apply for the tax credits. Finding developable property and ensuring its suitability, both technically and politically, takes time, pushing the organization against application deadlines. It is usually at the last minute that the architect is given instructions as to the site and program, and thus the design – the element that will have the greatest effect on the costs and the most lasting effect on the project – is a hasty set of decisions. Although the design can be refined if the application is approved, changes in unit size or mix and in overall costs are not allowed. And since so little of the public review process can be undertaken before the land is optioned and the application submitted, there is an inevitable disjunction between what is contractually required for funding and what may be most desirable for the community. Finally, the deadline for spending the funds once they have been granted is also much shorter than is feasible under the best of circumstances. Since any hitches may jeopardize the financing, the CDC [developer] and the architect must get it right from the onset, without much opportunity to work with the community (Davis 1995, pg. 20).*

Ideally the KoP can address the issues identified by Davis above by providing a building block for schematic design that can be used by the design team for the purposes of site planning and establishing the unit numbers and sizes, basic building massing and general project elements. Further, schematic drawings generated using the KoP can provide visualization tools for community input and "buy-in". Thus the KoP will facilitate upfront planning and allow for refinement later in the process. Additionally, as evidenced by the 2002 rehabilitation and addition to Archer Court in Chicago, Illinois, successful implementation of a kit-of-parts for structural and finishing elements can save construction time and, in turn, labor costs (Schmitz et al 2005, pg. 56).

PREFABRICATION AS A SOLUTION

The precedents discussed above explore some of the ways that the post-war building industry has responded to the need for housing with a mass replicable approach that can be faster and more controlled than site-built construction. However a critique of the assembly line ideals of mass-production is that the resulting houses are uniform and repetitive, lacking the flexibility necessary to adapt to different sites, building types and resident needs. Despite this seeming lack of flexibility, modular home building has become a prominent part of the housing industry. Recognizing a need for flexibility, architects, homebuilders and manufacturers have responded with several variable modular components and panelized systems. These include volumetric modules typical in the modular housing industry, wall and floor panels such as structurally insulated panels (SIPs) and the panelized approach to homes typical in Europe, and structural elements such as the readily customizable truss industry.

Opportunities with Prefabrication

The highly coordinated and integrated system of components envisioned for the KoP includes volumetric modules and element parts that are appropriate in many different configurations for both new construction and retrofit of existing buildings. Based on initial schematic design proposals, components will be selected and refined based on energy-performance criteria. The resulting components can be custom configured based on building requirements, site conditions and local industries, and material availability.

KoP Design Goals

Durability: high-quality long-lasting materials and details that are easily maintained and/or upgraded; favor local regional materials as a means for embracing customization.

Flexibility: flexible and adaptable living space to accommodate changing needs of residents. The focus of the KoP is on providing small homes appropriate for those homebuyers seeking their first home or those looking to downsize, resident demographics that align with those most affected by shelter and home energy costs. Further, small homes better meet changing home demographics in general; throughout the U.S. there are increasingly more individual households. In Union County, 72.9 percent of the households are "without own children," including 34.7 percent married couples without children and 27.6 percent single person households (Center for Rural PA). With regard to this goal, KoP homes are designed to be accessible and the interior spaces meet Universal Design Standards. Each home designed using the KoP includes a space at the entry level that can serve as a bedroom. Modules for adapting existing homes for Aging-in-Place include accessible bathroom and individual bedroom modules.

Scale-ability: Small-scale, scattered site development provides opportunity for the densification and revitalization of existing communities. Towards that end, several approaches are addressed in developing the KoP:

- Densification through ancillary units that can provide income as a rental property or space for a caregiver;
- Renovation of large, older homes as a multiple-family dwelling;
- Retrofit of existing homes for energy efficiency and aging in place;

Infill of underutilized sites at a scale appropriate to the developable land and the community including single-family infill (detached or semi-attached), duplex or townhome (attached), and multifamily making it possible to apply the KoP for larger-scale projects and urban applications.

Preliminary thoughts on KoP components

To date the KoP team has explored schematic designs for modular layouts that meet the criteria outlined about. The small home configurations are flexible in their layout and adaptable to different building densities and site conditions.

Hybrid panelized / modular approach

Based on the precedent analysis and successful energy performance of the duplex pilot study, a hybrid panelized / modular approach is used for these preliminary studies. This approach was used in two of U.Va's ecoMod Homes (ecoMOD 1 and 3) and the strategy was successfully employed on the assembly line in a manufacturing plant for the EEHP duplex. Rather than walls being framed on tables and lifted into place, as is typical with modular construction, pre-sized and cut Thermasteel SIP panels were delivered to the manufacturer and attached to the completed floor assembly. Although the use of the SIPs did not greatly affect the production line, considerations for material procurement and schedule had to be taken into account – there were additional fabrication drawings to be approved prior to the SIPs being manufactured and a lead time for arrival – considerations not necessary with framing (especially since most manufacturers buy framing materials at bulk prices and have them in stock).

Analyzing the initial KoP schematic drawings, the following elements of the design were identified for further development as energy-saving components in new housing and for the renovation and retrofit of existing housing stock:

Mechanical & Plumbing Cores: Based on lessons learned from Penn State's previous Solar Decathlon entries, the *MorningStar* and *Natural Fusion* solar homes and a study of InHouse OutHouse, an AIA Housing Knowledge Community project developed by a team from Rice University, the efficiency of centralized mechanical & plumbing cores appropriate for different KoP scenarios are explored. The core has been implemented in modular construction and panelized systems, as well as for retrofitting existing homes. This strategy is used for a variety of reasons including improved energy efficiency, restoration of an existing home, and potentially as an addition to a home for aging-in-place. Although the concept of a core unit is projected as a flexible solution for a variety of home situations, in fact it can be somewhat limiting. Therefore the defined parameters, spatial layout, and impact of the core on the more flexible living spaces of the home are carefully studied. The layout of the bathroom, kitchen and utility spaces take universal design and ADA adaptability into account. The cores are designed to accommodate all plumbing and mechanical needs into the conditioned envelope of the home. Further studies of mechanical and plumbing systems for cost and energy efficiency will be explored as KoP research and development continues.

Stair modules: Overall circulation space in the KoP designs is minimized to maximize living space. Vertical circulation has been efficiently limited to two configurations accommodating a straight stair and a u-shaped “scissor” stair. These configurations are appropriate for connecting floors in single family or multifamily dwellings and can be used for adding code-compliant fire stairs in converting existing homes to multifamily dwellings. The stair modules are studied in plan and section for passive solar benefits, specifically, getting natural light to central living spaces and accommodating natural ventilation.

Two components are identified for further development because of their potential for flexible use in different dwelling types and their contextual significance for enhancing community. These are:

Auxiliary units: Room-size modules that can be used for additions or the retrofit of existing homes are proposed. Combined with a mechanical/plumbing core module they can provide accessory dwelling units on an existing lot. How these units meet the ground is of special consideration to assure proper detailing of the modular units and to allow entry to each unit to be fully ADA accessible. The interiors of the units will comply with Universal Design and Visitability standards.

Sun Space: Another element explored for the KoP is an extension of the living space. This module may be contiguous with the residence entry and vertical circulation. Depending on community context this element will be manifest in different ways, as a porch, sunroom or entryway. Orientation and location of this module and its connection to the dwelling unit will vary in order to provide an effective isolated gain space for passive solar benefits. The side porch/entrance seen in Scattered Site Infill Housing, Charleston, SC by the architecture firm Bradford Associates highlights some of the benefits of this component (Davis 1995, pg. 152-156).

A PROCESS, NOT JUST A PRODUCT

The KoP components may hold promise as a construction delivery product aimed at improving the energy efficiency of new housing and for the retrofit and renovation of existing houses. But the product described cannot be separated from the design process. Importantly, a shift in process has to happen for the KoP to be successfully implemented. In a conventional design process, the most time and project fee is dedicated to the construction documentation phase of the project. This shift is facilitated by integrated project delivery (IPD); therefore acceptance of these principles and techniques is necessary (for information on IPD see AIA 2007). Once this occurs, KoP components can be applied as a part of the integrated design process. Since small projects generally cannot absorb the soft costs of a rigorous design process, this cost is spread over many projects. The benefits of a project-specific integrative design process for improving project performance would be "baked" into the individual components, resulting in high performance fabrication for each part. To achieve this result, the development of each component is considerably more involved than architectural design/specification; it must include precise details for means and methods, tolerances, and performance testing – analogous to a UL listing for each component. The KoP components are defined though the parameters of modular construction, a major player in the Pennsylvania housing industry. Rather than every component of the dwelling or building being defined, ultimately dictating the design outcome, the KoP focuses on components that will improve the overall performance of housing. A catalog analogy would be more synonymous with Sweets than Sears. The KoP, as envisioned, provides a valuable role for designers in providing affordable housing, while playing to the strengths of the manufacturing industry. Because KoP establishes the assembly details, the focus of the designer is on the schematic design and construction administration phases of the project. The initial focus of the design professional is on the selection and configuration of KoP components that are most appropriate for the selected site conditions. We imagine that the KoP would simplify project construction documentation by limited the details and calculations necessary. Finally, design expertise centers on the selection of durable, contextually appropriate materials and finishes that will support the local economy. The architect's role is to holistically consider the short- and long-term project goals and efficiently compose the parts in response to the site, client, program, green benchmarking, aesthetic decisions, and community. Allowing the design professional to add maximum value, while limiting time requirements per unit and potentially some professional liability. Ultimately it provides a role for design professionals in small projects where frequently there is none.

CONCLUSIONS

The KoP describes a series of prefabricated interventions that work integrally at three nested scales: 1) core systems; 2) flexible modules for building design; 3) for community enhancement. Individualized contextually appropriate results can be achieved through informed, careful consideration, selection and configuration of KoP elements.

Next step:

Refinement of proof-of-concept will take place over the course of the spring semester. The research team will be looking to industry specialists and stakeholders including representatives of the modular building industry for design advise, pricing and feedback on the practicality and replicability of the concept. Representatives from business will be consulted for real estate advise and strategies for revitalization. The expertise of researchers in HHD and the Penn State Aging and Psycology Lab

(APL) will be consulted on issues related to flexibility and aging-in-place. Two teams of undergraduate engineering students will be engaged to work on this project as their senior capstone requirement. The first will determine appropriate energy performance criteria based on monitoring and assessment of the pilot homes and the second will be developing components of the KoP for optimal energy performance.

ACKNOWLEDGEMENTS

This project is supported by The Pennsylvania Housing Research Center with a generous 2013 Research Grant. Some excerpts included in this paper appear in "Green Infill Housing: envisioning a modular kit of parts." Proceedings of the *ACSA Fall Regional Conference: OFFSITE Theory and Practice of Architectural Production*, Temple University, Philadelphia, PA, September 27-29, 2012.

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