2012

Introducing Better Ideas to an Industry Resistant to Change; Utilizing Approachable Architecture as an Envelope for Serious but Settled Technology

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Introducing Better Ideas to an Industry Resistant to Change; Utilizing Approachable Architecture as an Envelope for Serious but Settled Technology in Residential Construction

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ABSTRACT

This paper is based, in part, upon the involvement of students and their faculty advisors in the biennial Solar Decathlon Project, a student competition that culminated in the construction of energy efficient residential units at Potomac Park in Washington D.C. in September, 2011. These residential structures designed and built by students, represented differing visions of future housing by universities from the United States, China, New Zealand and the Netherlands. All represented engineering and design excellence and reflected each team's vision of a more complete, more holistic approach to the question of what we as a civilization will live in over the next half century. All showcased emerging technologies that could, if utilized, substantially change what we relate to as home.

Of central importance to this discussion is whether and to what extent these technologies will be assimilated by a building industry and the buying public. It is this acceptance, or lack thereof, that will determine what we live in, not the technical wizardry that may be available. Any significant change in what we live in will be driven by market realities. This is a fundamental issue that is frequently overlooked in discussions of this nature. Cutting edge technology is of esoteric interest only unless it has commercial appeal and application. It is axiomatic that what we live in lags behind what can be produced. Much of the present housing stock represents mid twentieth century or older technology The demographics of the United States indicate that what exists as well as what is being built will soon be considered unacceptable for a number of reasons. The question is how can better technology be introduced to an industry and a public resistant to change in this area?

1. INTRODUCTION

Examination of demographic, social and environmental considerations offer insight into what we as a buying public will want to call home in the near future. Our families are growing smaller and natural resources are growing scarcer. There is a greater social consciousness regarding the virtue of ecological considerations and the vice of conspicuous consumption. The economic/social climate that brought us the era of the McMansion is now permanently behind us. Consequently, it would seem safe to say that the era of efficiency in housing is now at hand.

Pitkin and Meyers (2008) found the following demographic trends in a study on housing in the United States:

> Patterns of housing development are poised for dramatic change in the early decades of the 21st century. There are a number of reasons to expect that major trends in U.S. housing markets during the coming half century will differ markedly from those that have dominated recent decades. These include both new

> patterns of demand and ongoing changes in the housing stock, as well as the unique intersection between supply and demand … a body of knowledge has slowly accrued in the subfield known as housing demography and may now be poised for much greater attention given the urgency of impending trends. On the housing demand side, the inevitable aging and retirement of the large Baby Boom generation, the rise and uncertain future of immigration, and on-going changes in the level and distribution of income will affect how many households there will be in the future and their ability to pay for housing. Less quantifiable but potentially of no less impact on demand are trends in preferences especially among the younger generation. On the supply side, the characteristics and location of the stock of existing housing have evolved from what they were a quarter century ago, posing new constraints as well as opportunities for future development, redevelopment, and reuse. And it seems increasingly possible that rising energy costs and climatic events, along with their associated mitigation measures, could lead to new and different patterns and types of development by mid-century if not sooner. (p. 1)

If the aforementioned demographic change is at hand, then the market has been slow to respond. For years, there has been discussion among the intellectual elite about the need for change in how we view what we call home. New housing systems have been introduced that could have revolutionized the industry and created a more efficient residential product for millions of people. Most of those systems have been ignored. Projections of what we would live in, once highly regarded ideas, now seem comical in light of historic retrospect; worthy concepts with no market. It has been argued that the building industry is the problem. Builders are conservative and traditional; set in the ways of the past. The rebuttal to that allegation, however, is that there is little reward for a builder to offer something other than what the consumer is accustomed to and will pay money for.

The construction industry has been grappling with the issue of efficient housing for some time. From the end of the Second World War until the mid 1970s residential construction remained unchanged and relatively inefficient; stick built platform framing, plywood wall sheathing, and single glazed windows were what the industry produced and people bought.

Allen and Thallen (2011) making note of this stated the following:

> In the beginning, American builders adapted imported European building methods to their more severe climate, but later, they invented an entirely new system that was flexible, and used materials more efficiently, and was easier to construct. This new system, the wood light frame, has been the predominant system of residential construction for over 150 years and remains so today, even as creative builders experiment with new systems. (p. 32)

This building system produces what the buying public relates to as housing. The vast majority of housing designs found in contemporary America utilize this system. As noted above, there have been many attempts to bring new concepts in housing technology to the buying public. The late 1960s brought us Buckminster Fuller's Geodesic Dome. For many it was believed to be the future of housing. More recently, Building systems such as "Rammed Earth", "Straw Bale Wall" and homes built partially below grade are being suggested as housing alternatives. As in the case of the Geodesic Dome, these systems will have their advocates but will ultimately be relegated to the role of historic novelty; much as Dr. Fullers design is today. Those experiments, however efficient, are incapable of producing what the market considers to be an acceptable product. They are functional and inexpensive to produce but more novel than the market will consider

2. THE ERA OF COMPONENT BASED IMPROVEMENT

Economic and social conditions in post-World War II America allowed the construction industry to produce housing that worked just well enough. Fuel was inexpensive, vacant land adjacent to cities was plentiful, families were growing and environmental concerns were yet to become an issue of any significance. As long as these variables were in place there was no call for a better residential product. The energy crises of the 1970s brought a dramatic, if incomplete, change in how residential buildings were conceptualized and built.

Wulfinghoff (2000) points out this historic change in how we began to view how energy conservation affected how we live:

> The Big Bang that started the modern era of energy conservation was the ‘energy crisis’ that erupted in 1973 … the supply of energy was no longer viewed as something that was always ahead of demand. Instead, the supply of energy, although still vast, was now viewed as lagging behind demand. Previously, energy efficiency had been a technical aspect of designing equipment, systems and buildings. In 1973, efficiency metamorphosed into ‘energy conservation,’ which emerged as a distinct field of interest, rather than continuing to be a subsidiary engineering issue. (p.4)

That period was what this author refers to as the era of component based improvement; an improvement in construction systems without an overall vision. Wall sheathings like plywood or asphalt impregnated fiber board that had been the standard of the industry since the late 1940’s gave way to extruded foam products that had a much higher resistance to heat transfer than their predecessors. House wraps like Tyvek replaced roofing felt paper as a product to apply over wall sheathing. Thermo pane windows, better sealants and 2x6 exterior walls were more of the component-based thinking that was done in place of a more comprehensive approach. At bottom, all of these systems were still wedded to the stick built or platform framed house with its inherent limitations: high cost of construction, limited capacity for insulation and limited structural rigidity.

3. THE SIPS PANEL AS AN ALTERNATIVE FOR CONVENTIONAL CONSTRUCTION

Structural Insulated Panels (SIPs) are made of two layers of Oriented Stranded Board (OSB) which is a material made of recycled wood products with a foam core for insulation. (Figure 1)

The Structural Insulated Panel Association stated the following:

> The structural insulated panel (SIP) has emerged as a unique alternative building technology for building envelope construction. It provides efficient solutions to such concerns as energy efficiency and dwindling natural resources. SIP technology is not new. It was used in residential construction as early as 1952 when Alden B. Dow, son of the founder of the Dow Chemical Company, began designing SIP homes. The first of these was built in Midland Michigan that year, using foam-core SIPs for exterior walls, interior partitions and roofs. They are still occupied today. (p. 1) (Figure 2)

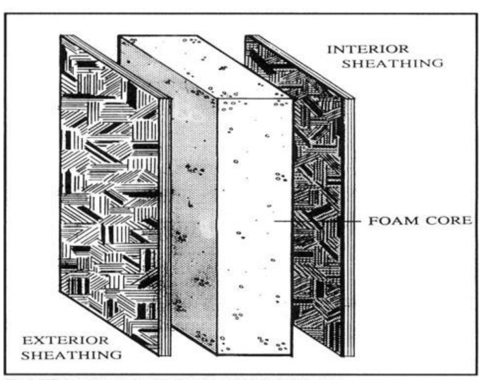


Figure 1: Basic SIPs Construction

The SIP panel technology offered the builder the a way to build a better product. One that was architecturally consistent with what the buying public was accustomed to but was structurally superior, better insulated and less expensive to construct.   The INHome House is the name given to the project fielded by Team Purdue for the Solar Decathlon Competition.   INHome is a reference to the design parameters that define its character and philosophy. It is a single story contemporary ranch: an architectural design common to the Midwest; particularly Indiana.

It is a design that is attractive and approachable and therefore marketable. The common response of those who toured the house was that it felt like home; there was an immediate level of comfort among those who walked through. The In Home House had the look and feel of a commonly produced house but was constructed using the SIPs panels referenced above: a high efficiency wall and roof systems that were anything but common. The walls and roof structure were constructed of SIPs panels rather than conventional stick framing. The SIPs panels, as were utilized on the INHome project, are a cost effective solution to the problem of creating an architecturally desirable home with greater energy efficiency and lower construction costs. The 4" walls carry a resistance to heat transfer (R factor) of 20; the 8" roof had an R factor of 50. This reflects an approximate 30% increase over conventional wall and roof systems depending upon what wall sheathings and insulations are applied. Further, the system as tested was less subject to penetration by outside air. The technology as well as the architecture is non esoteric meaning builders will build with it and buyers will buy it. The SIPs panel system has been thoroughly vetted as a building technology. Having been in use for over sixty years the properties of this system are well known through testing and field use.


Fig. 1: Architect Alden B. Dow first used structural insulated panels in housing in the early 1950s

Figure 2: SIPs Panels Used in 1950s

Shaw (2001) argued in a study by Brock University:

> When it comes to quantifying actual heat loss in different wall systems, the Brock University study provided an excellent opportunity for accurate comparison between SIP and stick construction in the real world. The two structures involved in the study were rental housing units, located immediately adjacent to one another. Both buildings were identical and had similar east-west orientations, ensuring the same exposure to outdoor temperature and wind conditions. Except for brief periods, both houses were occupied throughout the course of the study, which took place over a 12-month period from February 2000 to January 2001. Both units were heated with a natural gas/forced air system. One unit was constructed with 4.5" SIPs while the other used 2x6 studs with batt insulation. Both houses were constructed according to the Ontario Building Code (OBC). The units were built by the same crews, with no one being aware that scientific tests would be conducted afterwards. The study incorporated several test methods to analyze different determinants of energy efficiency: thermographic imaging, hourly temperature readings and air leakage measurement. Furthermore thermographic photographs provided visual confirmation of areas of thermal weakness in the 2x6 wall, where thermal bridging (i.e. conduction) is visible around each stud, along with pockets of air leakage.
>
> This imaging evidence was supported by temperature data recorded hourly by a series of sensors located within the walls of each building. Temperatures recorded in the middle wall and inside the exterior wall surfaces of the stud construction showed the greatest fluctuation, corresponding closely to the variation in outdoor ambient temperatures especially during the cold months of December, January and February. In comparison, the SIP wall sensors recorded higher and significantly more stable temperature in those locations. (p. 2-3) (Figure 3)

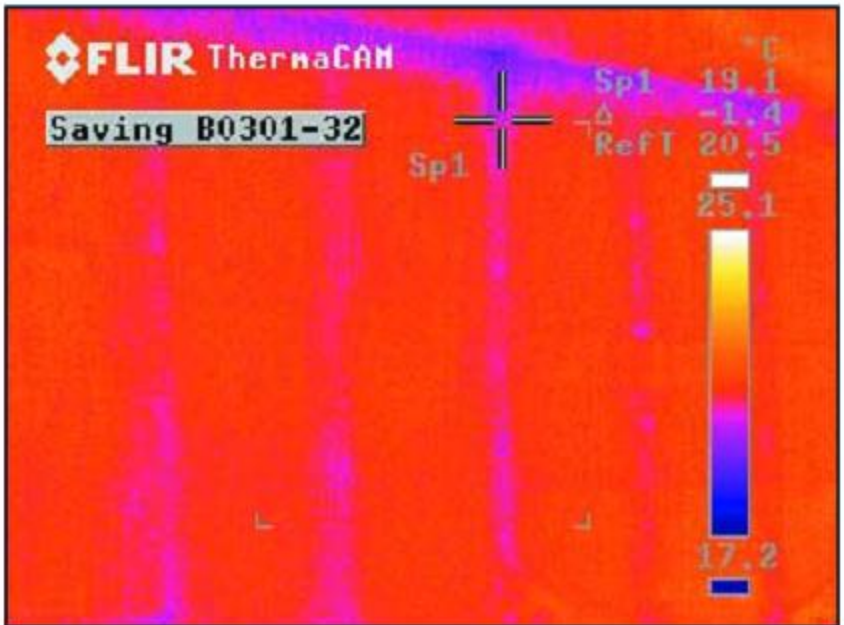


Figure 1a: Thermal photography of stud and batt wall
This thermal photograph of a stud wall reveals multiple points where heat can escape – primarily along studs themselves.

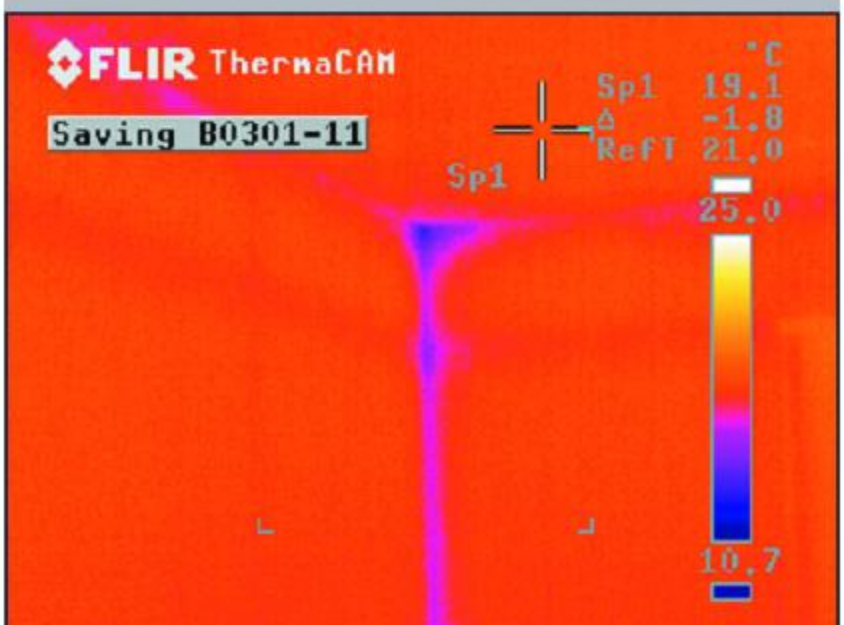


Figure 1b: Thermal photography of SIP wall
The SIP wall allows for minimal heat loss along the wall surface. The only heat loss evidenced here occurs in the corner area.

Figure 3: Thermographic Comparison

It is instructive to note that the Brock study, as cited above, gives some unintended advantage to the conventional wall system; the conventional wall as tested is of 2x6 construction. (Figure 4) Were it a more even comparison, the conventional wall system would have been limited to the same dimensional parameters as the SIP wall of 4.5” as would be found in most conventional construction. It can be established then that the SIP construction wall and roof panels are more resistant to heat transfer and wind penetration than conventional construction methods as well as being easily integrated into conventional architectural designs. Further, because they form what are referred to as stressed skin panels; a rigid foam insulation sandwiched between two structural panels, they have greater structural rigidity than a conventional framed wall.

The Structural Insulated Panel Association (1997) has demonstrated:

> SIPs are capable of sustaining loads typically imposed on walls, floors, roofs and other load-bearing elements. They are essentially stressed-skin panels. The cores of rigid plastic foam provide shear strength, and the exterior skins of structural materials provide tensile and compressive strength. A panel’s structural composition can be compared to an I-beam. The panel skins are analogous to the flanges of an I-beam while the foam core is comparable to the web. The complete assembly, with exterior and interior faces properly laminated to the foam core, allows for a system that is structurally superior to conventional stud frame structures … A load-bearing wall has superior axial load bearing capacity; i.e., strength to support vertical loads from the roof or floor above…A conventional framed wall is designed to support these vertical loads only through its studs. The exterior sheathing, if plywood, provides no contribution because it must have gaps between the sheets and is not continuous. Other forms of sheathing are also discounted for the same reason. (p. 7)

Finally, SIPs panels are considerably less expensive than conventional framing. The SIPs panels are made of recycled materials in a factory environment. Consequently, the cost of production is low compared to site construction of a stick built project. “A recent study . . . showed that utilizing SIPs reduced installation time by 130 labor hours. When compared to RSMeans labor hours for a conventionally framed home, this labor requirement is equivalent to time savings of approximately 55 percent.” (BASF, p.2)

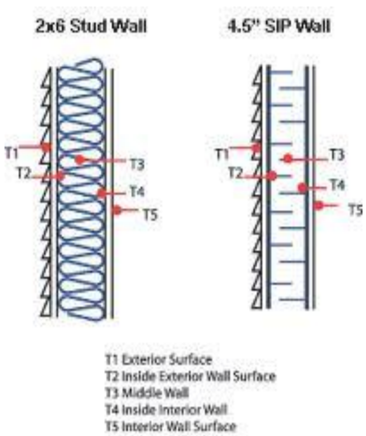
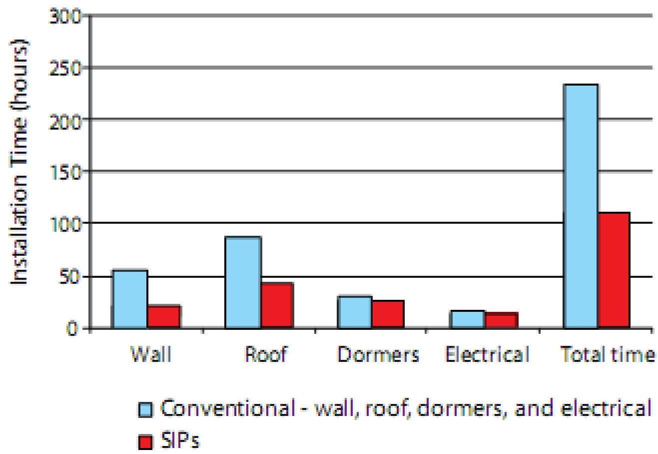


Figure 4: Comparative Cross Section

The SIPs wall or roof panel is made of less expensive materials in a repetitive process that requires less skilled labor in the factory as well as on site, have greater insulation value and are structurally superior to conventional framing techniques. Also, the finished wall or roof panel is of a higher quality than that which is built on site: being built in a factory environment the components are not subject to the uncertainties of the construction field. A factory made wall is built in a frame or jig consequently it is always square, something that cannot be said regarding stick built walls.

walls. When conventionally built frame walls are built in the field the method of squaring them so that they are plumb when they are raised is accomplished by measuring them corner-to-corner until the same measurement is found, tacking them temporarily and then cutting in a diagonal brace to keep the wall square. This process is fraught with the possibility of human error or simply by a lack of diligence: how square the wall is before it is sway braced is often a matter of how cold or windy it is on that day as well as the diligence and expertise of the crew. None of these problem variables exist in the SIPs building system. (Figure 5)

Chart for Actual Installed Time Comparison (hours)



Component	SIP-Built	2"x4" Stick-Built
Wall	24.8	78.12
Roof	50.8	117.48
Dormer	31.33	41.87
Electrical	18.76	21.11
Total Labor Hours	125.69	258.58

Breakdown of labor requirements

Component	SIP-Built	2"x4" Stick-Built
Wall	\$1,372 (\$0.97/ ft²)	\$3,331 (\$2.37/ft²)
Roof	\$2,816 (\$1.63/ft²)	\$4,498 (\$2.60/ft²)
Dormer	\$1,735 (\$2.86/ft²)	\$1,765 (\$2.91/ft²)
Electrical	\$870	\$979
Total Labor Cost	\$6,793	\$10,573

Breakdown of labor costs

Figure 5: Labor Hours for Each System

4. The Advent of High Performance HVAC and Air Filtration Systems

Having considered the envelope of the residential structure, the means of heating, cooling and air filtration are to be considered. Other than the envelope, few areas of housing technology have evolved or have the capacity for potential conservation as how we heat and cool our homes. Every dwelling requires a means of heating and cooling and an accurate means of controlling those systems. Heating and cooling represent the greatest energy demand present in a dwelling and therefore represent the area of greatest potential change in the consideration of the future of energy efficient housing. (Figure 6)

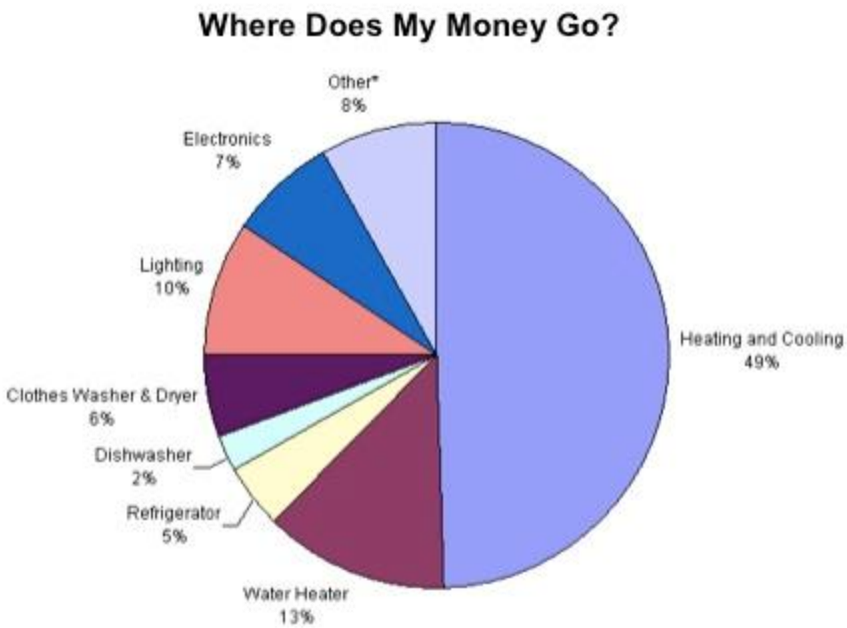


Figure 6: Energy Use in a Typical Home

It is in this area of how we heat and cool our dwellings that the future can be distinguished from the past. The most recent residential HVAC systems use a fraction of the energy required by what was considered high efficiency systems that are still on the market. Better controls for those systems help to use those systems more wisely. But not all that is to be is necessarily new. Geothermal heating and cooling as well as passive solar and convection based ventilation play a role in how we will heat and cool our dwellings. All of these are antique ideas; used in well-designed housing long before they were given the names by which we now refer to them. They now serve as parts of the new "organic" thinking on the subject of how we heat and cool our dwellings.

5. The Bio Wall; the Future of Air Filtration

As mentioned earlier in this paper, the building industry's response to the oil shock of 1973 was a piecemeal approach to technological change; component based development in building products rather than a comprehensive vision. That development saw improvements in the windows, weather stripping and caulking. Buildings became less drafty but the result of less air from the outside made our homes more toxic. The exchange of outside air may have been bad for heating and cooling efficiency but was beneficial for our health. Our component-based development had made a dwelling less drafty but in so doing deprived the inhabitants of the outside air exchange that allowed dust, volatile organic compounds (VOCs) and other air borne contaminants to be removed from the inside environment. This dynamic is reflected in a comment made by an architect from that time who when asked how we were to address the issue of harmful gasses and dust that would be trapped in our better sealed homes responded by offering that we should open the windows. While this man's answer seemed a bit flippant, it reflected the lack of a coordinated overall thinking about how to address the problem of living in the sealed containers that our dwellings had become. To address this issue, the INHome project featured an air filtration process that is a culmination in development of new and old technologies; an approach that is aesthetically pleasing as well as effective. It is literally an organic air filtration system contained in an enclosure that forms an air return for the HVAC system; effectively pulling stale air across an enclosure of living organisms for purification. This system is referred to as the Bio Wall. (Figure 7)

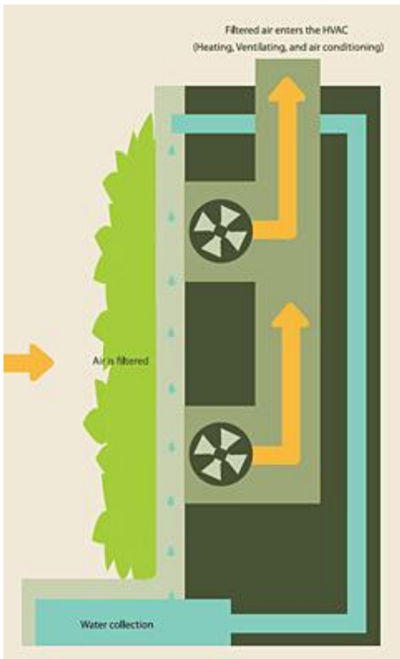


Figure 7: Bio Wall Illustration

The Bio Wall is a holistic approach to air filtration that brings the dwellings inhabitants into relationship with the dwelling involving living organisms to remove contaminants from the inside environment. Research on using plants to regenerate breathable air was a product of early planning for space exploration that has been adopted for use in residential and commercial buildings. This approach to air filtration represents a true marriage of the old and the new and exists at the intersection of what was and what is to come.

The Bio Wall as designed and built into the INHome project served as an aesthetic focal point of the home; an oasis of green with circulating water. This exercise in simple technology is attractive as well as functional. It is this dynamic; a simple but effective technology with aesthetic appeal that resonates with the desires of those who are investing in a home. The Bio Wall is, in the view of this author, a microcosm of the INHome philosophy; a more practical vision what housing will look like in coming years: simple to construct from recycled materials, well insulated, modest in size but nonetheless comfortable to live in and architecturally approachable. (Figure 8)

Figure 8: The Bio Wall on Display

6. CONCLUSIONS

We live in a market economy, consumers must want a particular product; it cannot be forced upon them no matter how good it may be in a technical or environmental sense. It is these elements of practical appeal and architectural approachability that is at the heart of the issue; what we will live in will be determined by what we want, can afford and will best serve our needs. Architectural considerations must serve as an approachable envelope for serious but settled technology. Since change must come from the demands of the buying public our task is twofold: to design products that resemble what the public relates to as housing and to educate the public about the benefits of the new technologies.

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