Pump-Up the Volume

Passive House, Mass Production and Multi-Family

Can HOUSING save the planet?

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INTRODUCTION

“Affordable” Housing is an oxymoron. “Net-Zero-Energy” Housing is, for most, illusive and impenetrable. “Modular” Housing conjures images of cheap doublewides and trailer parks. “Housing” itself carries it’s own baggage in need of constant qualification: Subsidized Housing, Market-Rate Housing, Student Housing, Senior Housing, Co-Housing, Suburban Housing, Urban Housing…..? With such variety in scale, program, social and economic strata, what possible common denominator would allow us to discuss, if not rethink, the standards by which we envision the design and construction of “housing” in this country, and for that matter, why would we?

Given the not-quite universally accepted knowledge that climate change is real; that it’s affects are, at best, a threat, at worst, catastrophic; that it is man-made and therefore solvable; and the less commonly known fact that the making and operating of buildings account for 45% of all Green House Gas emissions in this country (Energy Information Administration 2012), it would seem a reasonable request, as a society, for buildings to take on a much more intentional role in helping to solve this real and present danger. It would also make sense that as a society we would continue to migrate back to urban centers which we all know are inherently more sustainable environments for living. Most European Union countries have approached this issue head-on by significantly increasing urban density, decreasing the value of the car in favor of more sustainable modes of transportation and, with the help of a 30 year old proven building standard initiated in Germany known as *Passive House (Passivhaus)* (Passivhaus Institute 2014), are redesigning their building codes (EPBD 2014, ECEEE 2014, Passive House US 2014) to require all new buildings to achieve “Net (or Nearly)-Zero-Energy” by 2030. Passive House is a “fabric first”, super-insulated and air-tight approach to the design and construction of buildings which is based on rigid metric standards and meant to reduce energy consumption in any type of building by 70-90% of typical construction. With such radical reduction in energy consumption, these buildings claim to be capable of readily generating the remainder of the energy they need to survive with equally reduced on-site renewable energy generation. We are much slower to act in this country because energy is still cheap, space is more plentiful and our politics are more polarized. The work of Onion Flats, a Philadelphia-based development/design/build company simply attempts to skirt these issues by asking “If it doesn’t cost more to build to this higher design and sustainability standard, why wouldn’t we?”

This paper looks at several projects completed, under construction and in development by Onion Flats. Their 15 year evolving practice and interest in the design and construction of sustainable, urban communities proposes a rigorous yet common sense approach to “affordable” housing which gets better with scale, makes more sense in cities, is inspiring to live in, might help save the planet and will leave politicians, developers, builders, architects, academics and students alike asking, “Why would we do any less?!!!!

Figure 1, Typical Onion Flats Project: Rag Flats, 2006

AN

APPROACH TO ARCHITECTURE

In 1997 my brother and I started a small development/design/build collaborative called Onion Flats. The intention of the collaborative is to integrate seamlessly the process by which our ideas about architecture, the city, and sustainable development go from interpretation to construction to habitation. In other words, we have always found it necessary to *build* the work that we designed, and in most cases, own it as well. While this has required a greater degree of liability and responsibility, it has also offered a space of freedom and opportunity to "play", to explore ideas about the city, community and high-performance building in a very direct and productive manner. Our projects have been experimental, primarily urban, focused on affordability and in the most general sense "sustainable". "Sustainable" or "green" has always been descriptive enough to capture the kind of work that we did. Our projects (e.g., Figure 1) have taken on a broad range of efforts related to sustainability such as storm water management, water conservation, indoor air quality efficient lighting/heating/cooling systems and recycled materials, waste and buildings. All of these issues remain central to the communities we design today but they're issues that are now built into our DNA and frankly require less work. Dual flush toilets, low-flow fixtures, LED lighting, no VOC paints and sealants, high-efficiency heating and cooling systems, locally sourced and recycled products, near-zero-waste recycling centers for construction materials…..these are all standard products and services that are readily available to the design and construction industry currently and are affordable. We have honed in, therefore, on a facet of housing and community development which requires the most creativity, thinking and innovation: *Energy*. Understanding how to radically reduce the amount of energy consumed by buildings, without sacrificing other architectural and urban design related commitments, has required that we re-train ourselves in good building science practices, passive solar design principles and mechanical systems engineering. We've had to also re-think the way we construct our buildings, imagining a holistic and *sustainable building system* that could be modular, significantly more efficient, higher quality and affordable. Most importantly, we've had to re-consider the *metric* by which we can gauge the performance of our buildings. "Net-Zero-Energy-Capable" housing, developed in a dense urban environment (with limited solar generation potential) and constructed at a cost equal to conventional construction, if accomplished, might help raise the standards of what is possible in any form of housing in this county. And so, our most recent work is framed by the following question: *"Can urban housing, affordably, generate all that it needs to survive?"*

Answering this question first requires a baseline metric between *energy* and *housing* that we can reference. Data on energy consumption within a typical American home, cross-referenced to the energy consumption guidelines within the residential building code provides us a baseline average metric of ***20.5 kWh/sf/year*** of "site" energy consumption per home. If we try to make sense of this number based on the above question, and we take, for purposes of discussion, a typical, urban Row home in Philadelphia, one that is 16'-0" wide x 40'-0" long, three stories tall, and therefore, a total 1920sf with an average consumption of 20.5 kWh/sf/yr, this home would consume roughly ***3245 kWh/month***. If you wanted to "zero-out" that energy consumption with photovoltaics on your roof, you would need approximately 2832 sf of roof space to have this building achieve NZE (Figure 2).

This means that an urban building, built to code, cannot possibly generate all it needs to survive on it's own site.

Figure 2, Required roof area for 20.5 kWh/sf/year consumption

Figure 3, Required roof area for 4.5 kWh/sf/year consumption

Working in reverse if you only had a 16'x40' roof, how much energy can that roof generate? 615sf of roof space can generate about 6.15kW of electricity and that would require the home to consume only ***4.5 kWh/sf/yr*** of electricity, a ***78% reduction*** in consumption. This is an important metric if one is serious in asking the difficult question of how urban housing could even begin to support a Net-Zero-Energy-Capable initiative. Curiously, this ***roof metric*** is precisely the metric which defines a *Passive House*.

Passive House is a German building standard which it's founder, Dr. Wolfgang Feist, developed in the 1980s after being inspired by the super-insulated home experiments taking place in North America in the

1970s. It is, therefore, a standard which was originally based on a heating-dominated climate, one which emphasizes super-insulation, airtight and thermal-bridge-free construction, balanced ventilation and relies on internal heat gains and passive solar radiation to provide the majority of heating needs for the home. Technically, there are really only three requirements that, if followed, make a Passive House:

- A maximum of ***4.75 kbtu/sf/yr*** for heating/cooling (about ONE TENTH of what a typical home uses).
- A virtually airtight building which must measure no more than ***.6 ACH50*** (which is about TEN times as tight as the code requires), combined with required mechanical ventilation through an ERV or an HRV.
- A maximum Specific Primary Energy Demand of ***38 kBTU/sf/yr*** of "source" energy (not site).

Total allowable consumption of ***38 kBTU/sf/yr*** of "source" energy converted to Kilowatt Hours is ***4.5kWh/sf/yr*** of "site" energy (assuming a 2.5 multiplier), perfectly aligning with the *roof metric* mentioned above. Theoretically, this means that Passive House and urban housing are ideal collaborators in an effort to explore how urban housing can generate all that it needs to survive. And so, while I know our housing projects are more than the sum of their electrons, this is the context within which I'd like to begin to introduce our work. Four projects will briefly be reviewed: FIRST: Thin Flats, a nine unit multifamily, LEED PLATINUM project in Northern Liberties; SECOND: Belfield Townhomes, a three unit, subsidized housing project, and Pennsylvania's FIRST Certified Passive House project, completed in 2012; THIRD: Stables Townhomes, a 27 unit market rate townhome project currently under construction with Phase One complete, and a pre-Certified Passive House. FOURTH: Ridge Flats, a 146 unit mixed-use project, designed to be the largest Passive House project in the country, scheduled for construction in the late Spring of 2014.

Figure 4, Thin Flats, 2008, first LEED Platinum duplexes in the USA

MEASURING UP

Thin Flats is comprised of eight duplexes and one single-family row home (Vivian 2011, Flannery 2011, Vivian 2010, Fernandex 2009). The one on the left (Figure 4) is the Row home and highlighted on the right is one lower duplex. We had a reasonably good thermal envelop with R38 walls and a .32 U value for windows, with a broad range of sustainable practices, such as an intensive green roof, solar thermal hot water, radiant heating, rainwater cisterns, pervious parking lot, etc. The blower door tests for the duplex unit measured *4.8ACH50* and the single-family home measured *2.1ACH50*, more than twice as tight as the duplex. With 24 months of measured data, and the duplex unit averaging ***9 kWh/sf/yr*** and the single family home averaging ***7 kWh/sf/yr***, the larger single family home used almost HALF the energy that it was projected to use and ONE THIRD of the energy of the Reference “Code Home”, while the duplex unit used 20% less than was projected and over 60% less than the Reference “Code Home”. By all accounts, this project was a success from a performance perspective, with what we knew at the time. We had never heard of Passive House in 2004-2006, and while the project is a resounding success from the projected performance goals of a LEED Platinum building, these units are still using 36-50% more energy than a Passive House, which also means that even if we filled the roofs with PV, this project would probably not be able to achieve Net-Zero-Energy. This is not a critique of the project or of the LEED building standard, but an important context through which to understand the rigorous performance criteria of a Passive House. And at ***$144.00/sf*** Hard construction costs, these higher-end, market-rate condos, with custom detailing, finishes and fixtures, still fit within our definition of “affordable” construction, but Thin Flats was also, in many ways a “standard” development, or more precisely, the limit of what we could do with standard approaches to design and construction. After this project, we began to look critically and intentionally for more replicable systems of construction that would increase efficiency at multiple levels, while allowing us to still maintain control of larger scaled projects.

BELFIELD TOWNHOMES


Figure 5 Belfield Townhomes: Left: Front porches with green walls; Right: Image from above

In 2010, we were approached by the Philadelphia Office of Housing and Community Development (OHCD) to determine if we could salvage an affordable housing development in the Logan section of the City that OHCD had been working unsuccessfully on for several years with a local Non-Profit CDC. Prior designs were inefficient and had come in over budget. The funding, which was earmarked for the project through the Philadelphia Redevelopment Authority (PRA) and HUD, was imminently at risk of being returned to HUD due to inaction. We were told that the project, once designed and permitted, had to be built in no more than SIX months. We were asked not simply to design the project for the CDC but to act as co-developer and take full responsibility for the logistical, financial and technical success of the project. The requirements were simple: design and build three much-needed homes for this community that would house large, formerly homeless, families, with a handicap accessible ground floor, within the budget and timeframe allotted. This project (Figure 5) would be the first new construction to take place in this community within the last 50 years. There were no "green" or "sustainable" requirements specified for the project. We reviewed the site, the former design, program requirements, budget and schedule and determined that this project, while risky, offered us the opportunity to experiment with several ideas regarding affordability, high-performance building technology and alternative construction techniques we had been developing conceptually for years. This project would be a "first" for us in several ways:

- it would be our first subsidized housing project
- it would be our first project constructed in a modular factory
- it would be our first attempt (and the State of Pennsylvania's) at the rigorous ***Passive House*** building standard, and with that, a Net-Zero-Energy-Capable prototype of "affordable", subsidized housing.

At first we didn't even tell the CDC or PRA that we would be designing the project to the Passive House standard. Since we were co-developers and being asked to be fully liable for bridge financing, design and construction of the project within the schedule and budget allowed, it was, in effect our risk to take. The budget (which averaged ***$130sf*** for Hard Construction costs) seemed reasonable, however untested. We had designed and built some of the first LEED Platinum projects in the country, become Certified Passive House Consultants several years prior and while convinced of the common sense and rigorous building science principles behind Passive House thinking and building, we would be effectively going out on multiple experimental limbs to make the project a success (Torres-Moskovitz 2013).

Figure 6, Belfield Townhomes: Kitchen/Living Area

Also, essential to the experiment, was challenging the *standards* by which architects, urban planners and Municipal Housing Authorities conceptualize "subsidized/social/affordable housing". We saw an opportunity to define "social" housing as the best rather than the cheapest, fastest and often ill-conceived forms of housing. Was it possible to narrow the gap (or maybe even eliminate it) between "market rate" and "subsidized" housing? Should there be a difference? Could subsidized housing also be inspiring, filled with light, life, high-quality, high-performance, long-lasting and healthy materials and systems? Could it equally have the ability to encourage its inhabitants to be conscious-of and care-for one's environment? Most importantly, could it all be done within the budgets that Federal and Municipal subsidies typically support? We saw the potential for this project to demonstrate not only a new standard of *performance* but also *design* of housing in general for the City if not the country. We saw the potential to demonstrate with this project, not a prototypical *building* as much as a prototypical ***system of building*** that was replicable, scalable and capable of enabling any building to radically reduce it's energy consumption and then generate the remainder of the energy that it needed to survive, particularly in urban environments. We saw the opportunity to demonstrate how one the oldest forms of urban housing, the "row house", could still remain relevant and, in fact, an essential partner in addressing issues of climate change, social inequity and urban blight (James 2012).

The homes are simply and efficiently organized (Figure 6), with a handicap-accessible ground floor living, kitchen, bathroom and bedroom. The second and third floors have three more bedrooms, two bathrooms and one office. The buildings are set back from the sidewalk, to match the adjacent neighbors and create planters and a front porch for community engagement. The orientation of the building follows the urban grid in this part of the city, which is not ideally oriented for maximum southern exposure, however, shading devices on the South/West face of the buildings appropriately shade in the summer and allow for maximum heat gain in the winter. A 5Kw photovoltaic array on each home maximizes the area that each roof offers and is designed to, as defined through the Passive House energy modeling software, enable these houses to achieve Net-Zero-Energy.

SUSTAINABLE BUILDING SYSTEM

An "affordable", high-performance, building system that could be replicable at large scales drew us to modular construction (Figure 6). We had been exploring the benefits of modular construction for several years. Even though the modular industry has been primarily geared in the United States toward the single-family suburban home market, the repetitive and cellular nature of typical urban housing typologies is actually more ideally suited to a modular and manufactured system of construction. *Scale* is critical to the success of any manufacturing process, and *repetition* is key to efficiency and affordability. It's easier for a manufacturing plant to build a large volume of the repetitive cells that define a large building than it is to build a large volume of small individual buildings. Similarly, *scale* matters when designing a Passive House. It is easier to design affordable Passive *HOUSING* than it is to design an affordable Passive *HOUSE*. Large multifamily buildings have smaller surface-to-volume ratios than single-family detached homes, and therefore inherently have less opportunity for heat loss, making large buildings, purely from a building physics perspective, more efficient. After having already determined that the *roof metric* for energy *production*

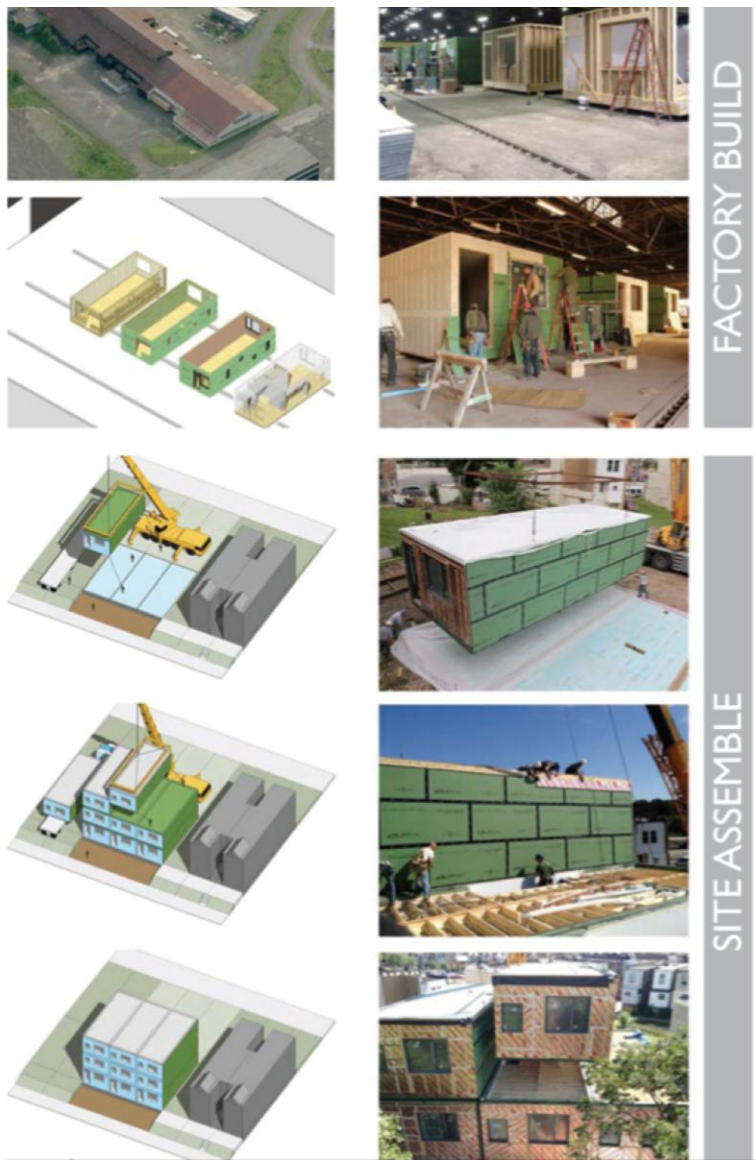

Figure 6, Process of modular from the factory to site assembly capacity with typical urban housing typologies aligns well with the Passive House *metric* for energy *consumption*, i.e. that urban housing and the Passive House standard are good bedfellows, we've come to the same conclusion about Passive House and modular construction.

In order to test this conclusion, we needed to design not simply a more efficient building but rather a more efficient building ***system***, one that was both radically unique and capable of meeting the thermal bridging, air-tightness, thermal resistance and ventilation criteria of a Passive House, but at the same time, rooted in every day modular framing techniques which could be easily transferred to each building trade on the production line.

Typical 2x6 and 2x12 wood framing was chosen as the base structure and thermal envelop, primarily because it was what the production crew knew best (Figure 7). The materials were also inexpensive and readily available. In order to simplify the detailing of the air-barrier layer we placed it on the outside of the framing and had it double as the moisture barrier. Our triple pane windows would sit flush to the exterior air barrier making air sealing between them and the wood framing extremely simple and as "fool-proof" as possible. In order to achieve the required R-values needed in the roof, floor and walls, we filled the wall/floor cavities with dense-packed cellulose and then clad the envelop beyond the air/moisture barrier layer with two continuous layers of polyisoscianurate rigid foam board, staggering the joints between the layers to insure a tight and thermal-bridge-free skin. Beyond this exterior insulation layer on the walls, we created a vented but closed rain-screen system finished with a mix of metal panel, concrete board and brick.

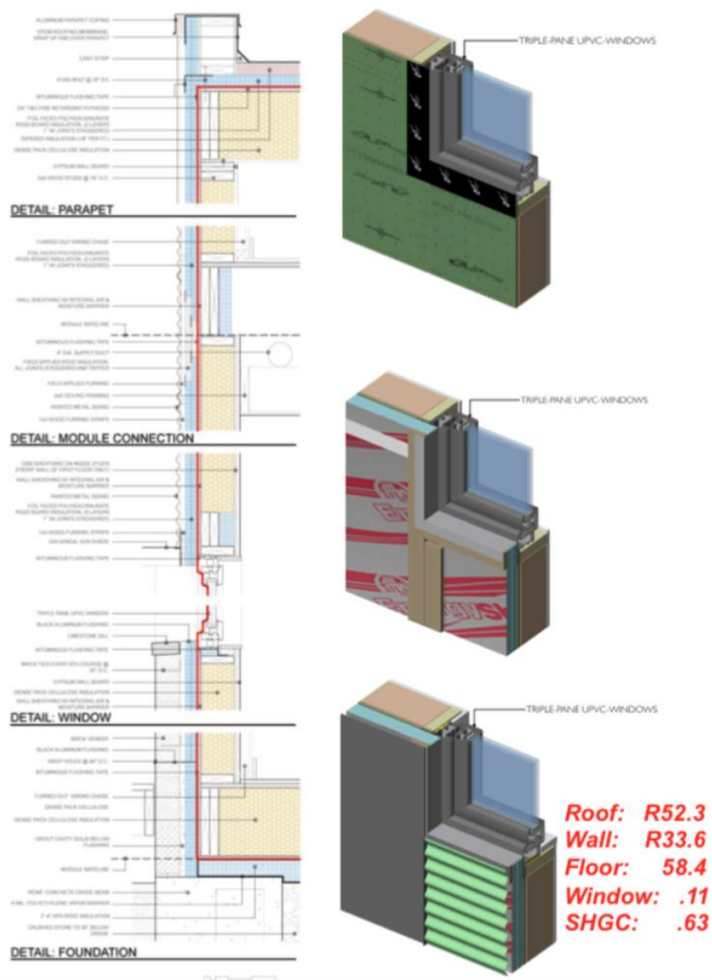

Figure 7, Composition of the Sustainable Building System thermal envelope

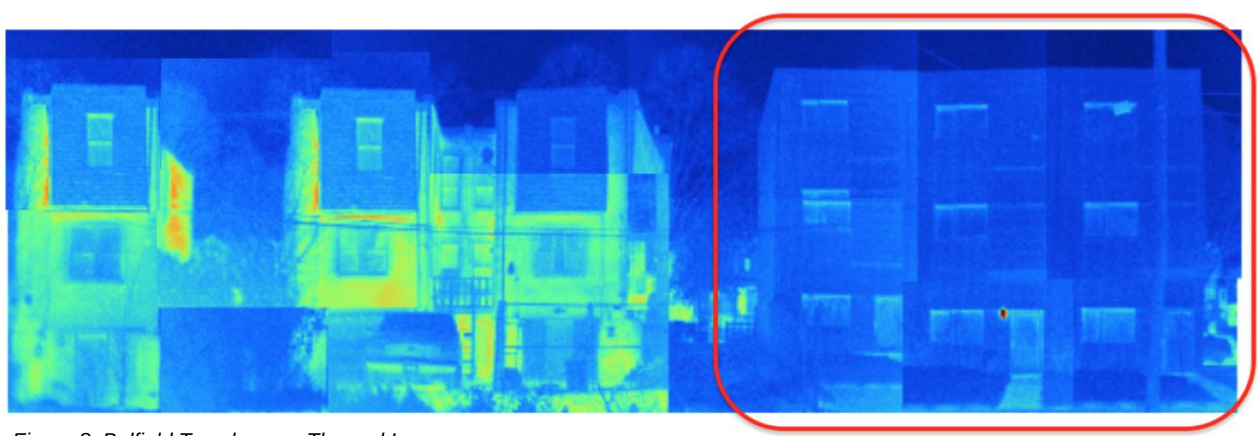

Figure 8: Belfield Townhomes: Thermal Image

There would be no opportunity to perform a pre-drywall blower door test on these houses (often preferred during the construction of a Passive House) because the air-tightness of the individual modules could not effectively be tested until they were installed, with seams sealed, on-site. We had performed several experiments during the energy modeling phase of the project in which we compared the importance of *thermal resistance* (i.e., insulation) versus *air-tightness* in the overall performance of the building's thermal envelope. While both are critical to the performance goals of a Passive House, slight reductions in air-tightness have a significantly larger impact on Specific Primary Energy Demand than similarly slight reductions in the thermal resistance values of the envelop. This is certainly one of the most important lessons learned during this project and has helped to further hone our Sustainable Building System as well as our detailing. Luckily the blower door test measured ***.4ACH50*** for each home, 30% tighter than the .6ACH50 required by the Passive House standard! Thermal imaging provides a visual representation of just how tight the homes really are (Figure 8).

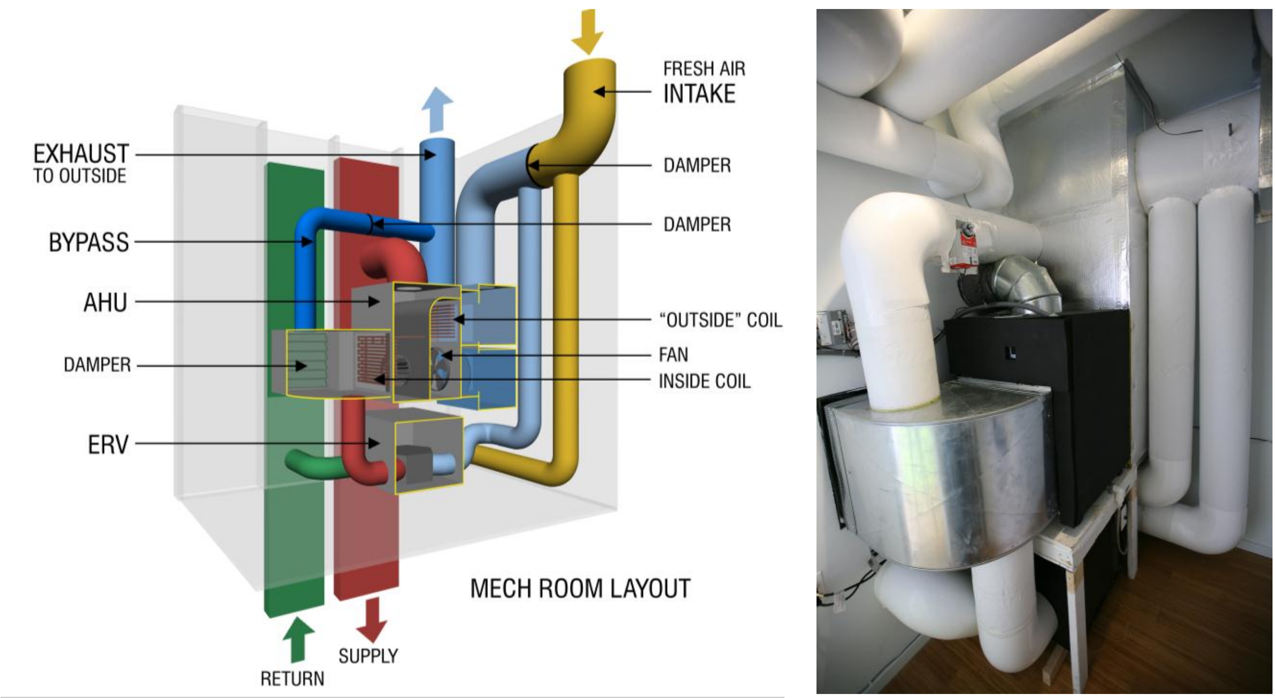

Figure 9: Left: diagram of "coupled" PTAC (AHU) and ERV; Right; as-built

MECHANICAL SYSTEMS

After exploring several options for heating/cooling/ventilation for these three story homes, we were inspired by European low-energy and composite heating/cooling/ventilation/domestic hot water systems (known as "magic boxes" (Holladay 2010), but none were available in the US. Our collaborating mechanical engineer, however, took clues from these sophisticated and inaccessible systems and designed a cost effective and "coupled" air-source heat pump/ventilation system that partially mimicked the magic box, but worked with an off-the-shelf, inexpensive yet highly efficient 9000BTU Packaged Terminal Air Conditioning (PTAC) heat pump unit and an Energy Recovery Ventilator (ERV). We located the mechanical room on the third floor (Figure 9) so that our fresh-air intake and exhaust air ducts would come through the roof. Each town home in the development has its own combined heat pump/ERV unit for heating, cooling and ventilation. We had decided early on that we would only have electric in the houses, no natural gas. Gas would have been another costly service, it would have required venting for several appliances, and therefore, more punctures in the thermal envelop and the potential of heat loss and air leakage, and gas is a non-renewable resource that can't be generated on-site. Domestic hot water is provided by a Heat Pump Water Heater (HPWH) and placed in the laundry room so that it symbiotically works to reduce heat and humidity generated by the condensing dryer and washer.

ENERGY MONITORING

A significant and robust energy, temperature, humidity and CO2 monitoring system is installed in each home within the Belfield project. Every electrical circuit is monitored for energy consumption and the production of the 5Kw PV system covering each home's roof (Figure 10). Temperature sensors are placed in each room in the house, with two CO2/humidity sensors positioned on upper and lower levels. All data is collected through a monitoring hub and managed through a website unique to each home. The monitoring is absolutely essential to understanding not simply how the home performs but how the occupants live within the homes. We realized very quickly with this project that there is no such thing as a "Net-Zero-Energy" building. There are only "Net-Zero-Energy-Capable" buildings, because as we can now clearly see with about 12 months of measured data, the occupants often have desires contrary to the lean performance goals of their homes.

The data, from three identical houses, shows widely ranging energy consumption (Figure 10). Analyzing each circuit we discovered a complicated and fascinating story of occupant behavior, property mis-management and a need for significant education.

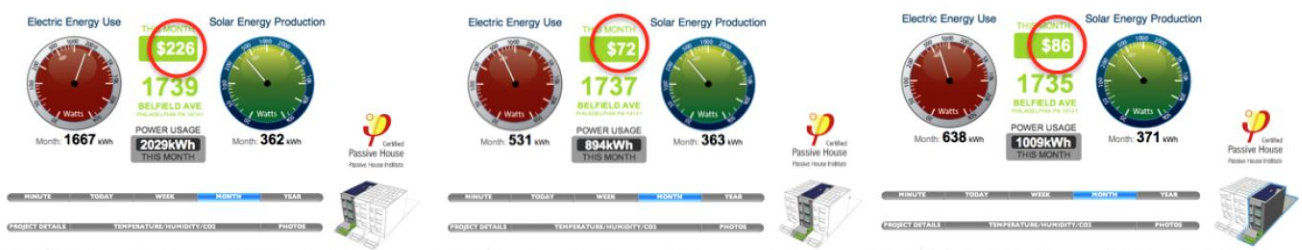

Figure 10: Website portal page of each Belfield Townhome linked to respective and more comprehensive energy monitoring sites for each home

We took a snapshot of one month's energy consumption (February, 2013) which demonstrated monthly electricity bills ranging between $72.00 and $226.00 (Figure 10). We looked at the circuits in the home consuming the most energy and noticed the "Laundry" circuit was recording an average of *104 loads of laundry in 30 days!* We then looked at the HPWH circuit and noticed that the water heater was effectively running in purely electric resistance mode, not Heat Pump mode, most of the month. The heat pump

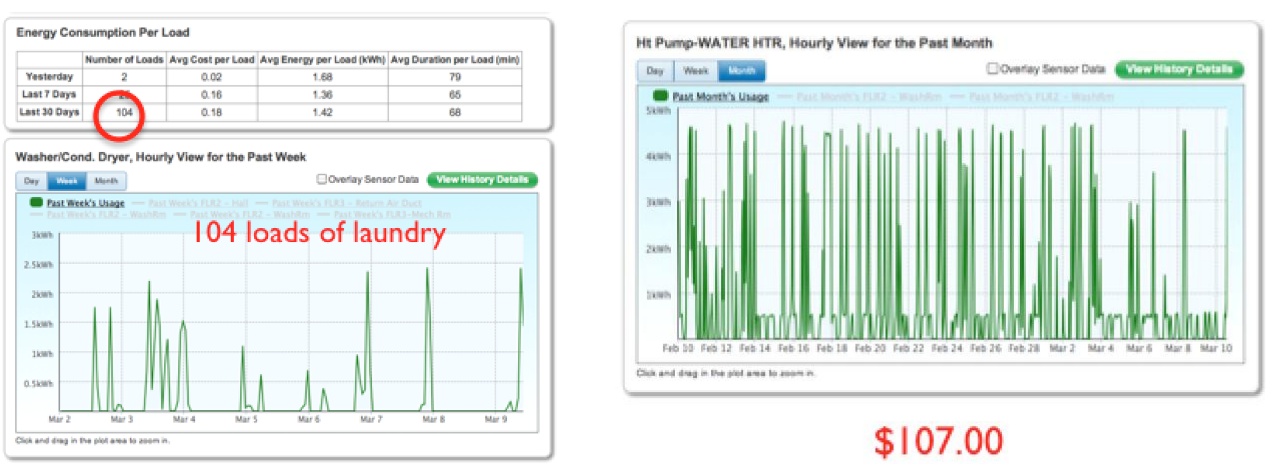

Figure 11: Left: Energy consumption graph for Laundry circuit; Right: Energy consumption graph for HPWH

inside the HPWH has a COP of 2.5, which means essentially that it is 2.5 times more energy efficient than an electric resistance water heater. It turned out that the hot water alone was accounting for *$107.00* of this home's $226.00 utility bill (Figure 10)! It also demonstrates a larger, unexpected issue. We suspect that this one home has been effectively running a small Laundromat, with friends and family coming by to clean their clothes daily. Given that Laundromats are common for most people in this neighborhood and that private washers and dryers are an unaffordable luxury, we completely missed the potential impact that this one social and economic construct would have on the energy demand of these homes. The washer and dryer in this unit running so continuously has also caused other unintended consequences such as significant heat build-up in the home. While this is not problematic in the winter, it contributes considerably to the cooling load and energy consumption in the summer.

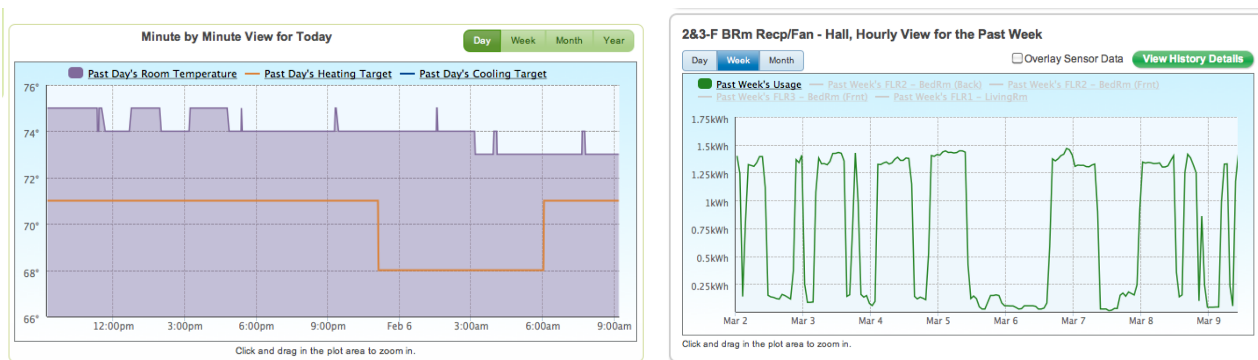

Figure 12: Left: Thermostat set temp relative to Actual room temp; Right: graph indicating significant plug load energy consumption of electric strip heaters

We discovered other significant anomalies between the homes' energy consumptions (Figure 12). In one home, during February and March, the indoor air temperature was consistently being maintained one or two degrees above the set 70 degree thermostat temperature, even though the heat pump rarely turned on. At first we were pleased, thinking that our Passive House was doing exactly what we expected, i.e., maintaining it's indoor air temperature and comfort levels with nothing more than the internal heat loads of people, lighting and appliances. Looking more closely, however, we discovered unusually high plug loads coming from several rooms, which we discovered, upon inspection, was the result of tenants plugging in electric resistance strip heaters throughout the home! This was not because the rooms were cold, but rather simply because they owned them, as they had been accustomed to using them in their prior leaky residences. On several occasions when we'd visit the homes to check on such problems that we were seeing in the monitoring data on-line, we'd arrive to homes in the middle of the winter, with windows and doors open, tenants with shorts and t-shirts on and complaints of variations in temperatures between floors and rooms.

As one might imagine, the performance of these houses has fallen short of their projections. With 12 months of data, while these houses are consuming between 25% and 66% more energy than they were designed to consume, two of the units, using roughly the same energy, ***6-7 kWh/sf/yr***, are still the lowest energy homes we've ever built and roughly 65% more efficient than a typical American home built to code. And while occupant behavior might appear to be an easy target for not meeting the Passive House projections, the primary culprit is actually much more obvious and unfortunate: the Non-profit CDC that owns and operates the properties ***does not charge its tenants for electricity*****!** As such, there is no incentive for tenants to be conscious of their energy consumption. In other words, NO VALUE is placed on energy consumption by the property owners. Even with that significant management flaw, after subtracting the energy generated by the PV on the roofs of the units, they still, on average, require only between ***$32*** and ***$93/month*** to operate all utilities. Armed with this data, we have approached both the owners and tenants of these homes in order to hopefully transform both occupant and management behavior and narrow the gap between human and building performance.

Figure 13: Site Plan of Stables Townhomes

Figure 14: Photo of completed Phase 1 of Stables Townhomes

SCALING UP

The Belfield Townhouses was an important first step in developing an affordable, high-performance, building system that could be replicable at large scales, guided by the Passive House building standard and applicable to both the subsidized and market-rate, urban, multi-family housing industry. We are currently under construction with a 27 unit market-rate townhouse development in the Northern Liberties section of Philadelphia referred to as Stables Townhomes (Figure 13). The project is comprised of three "bars" of 9 four-story, single-family townhomes. Similar to the Belfield Townhomes, we treated each "bar" in the energy modeling software as ***one*** building. The adiabatic party walls between each individual townhome are contained within the thermal envelop of each bar, eliminating the need for any heat loss calculations. For air-tightness purposes, however, again identical to the Belfield Townhomes, we air-sealed between each unit. The "bars" were designed and oriented to capitalize on the almost-perfect Southern exposure of George Street. Floating planters and balconies on the South side of the home both capture and deflect the sun depending on the time of year. We have recently completed the first three units of the George Street "bar" and expect to have all 27 units completed by the end of 2014 (Figure 14).

Figure 15: Photo of completed mechanical system in basement

Stables Townhomes is similarly designed and built in a modular factory with the exact same building system and detailing as Belfield, but simplified and improved. It has the same "coupled" hybrid heating/cooling/ventilation system, but with a slightly larger 12,000BTU heat pump within the PTAC unit to heat and cool the roughly 2400 sf of space (Figure 15). The most significant difference between Belfield and Stables is that Stables has a basement, and Belfield didn't. We chose to make the basement "technically" outside the thermal envelope and therefore had to diligently air-seal and insulate between the first floor and basement levels. All mechanical equipment is located in the basement with exhaust and supply air ducted from an outside wall on the first floor. A slightly altered ducting plan separating "exhaust" from "return" air, insures even air temperature distribution and balanced ventilation on all four floors. The same temperature, humidity, CO2 and electricity monitoring systems are installed in each home with it's own dedicated website.

Figure 16: Photo of blower door test for first completed unit, with measured results

The measured airtightness of the first home came in almost identical to the Belfield homes at ***.49ACH50*** *(Figure 16)*, and once the rest of the block is constructed and tested, Stables will become the 2nd Certified Passive House project in Pennsylvania. Each home has a slightly smaller 4.5kW PV system on each roof, but has the capacity to hold 8.5 kW of PV. With only 4 months of data, currently measuring only ONE home, and with owners who are conscious, diligent and interested in their energy consumption, we project that their annual consumption will be approximately 8244 kWh or ***4.3kWh/sf/year***, which would meet the Specific Primary Energy Demand projections of a Passive House. If the owner chose to place an extra 4kW of PV on this roof, this could conceivably "zero-out" its energy consumption on-site. At a ***$147.00sf*** Hard construction cost for these "market-rate", Net-Zero-Energy-Capable homes with custom finishes, fixtures, appliances, carport and 320sf green-roof garden, we consider this "affordable" housing.

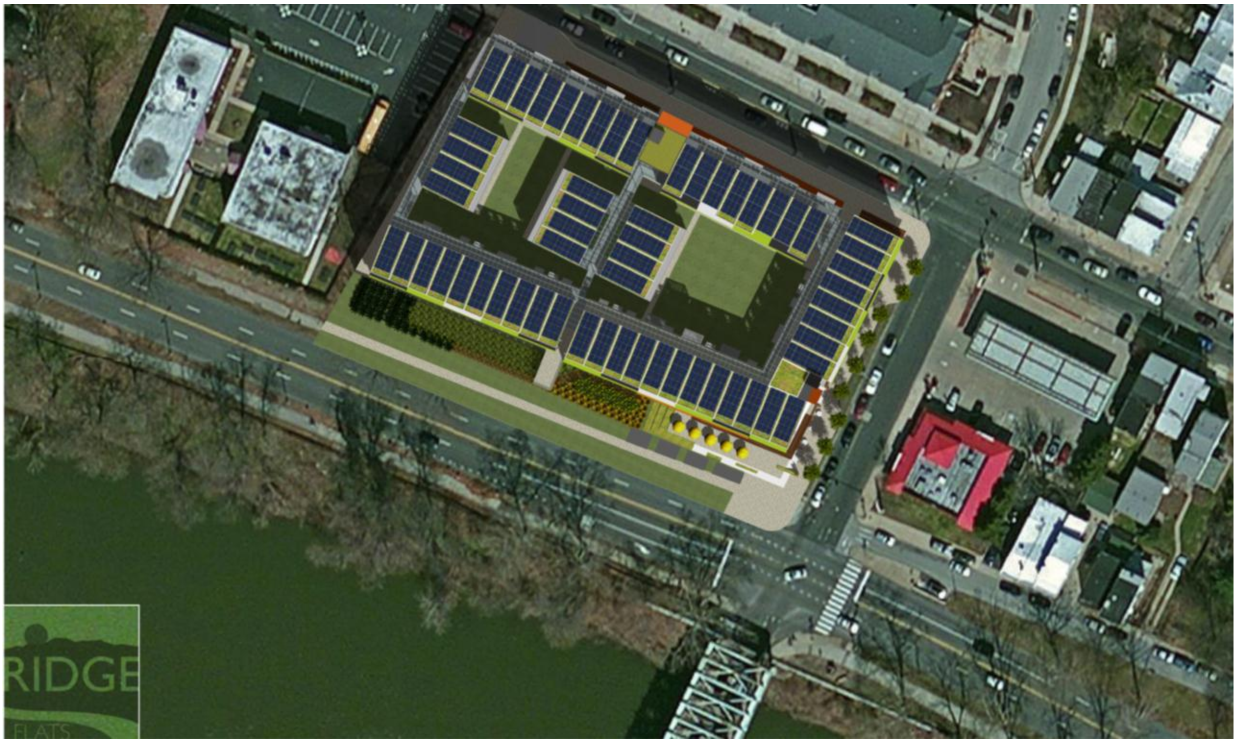

Figure 17: Site Rendering of Ridge Flats

PUMP UP THE VOLUME

While our earlier projects have been small but key experiments in the development of affordable, high-performance design and construction standards for the housing industry, with the ***idea*** of scalability in mind, Ridge Flats, our most recent project, is an experiment in SCALE itself.

Ridge Flats, a 146 unit, mixed use project situated along the Schuylkill River in the East Falls neighborhood of Philadelphia is slated to begin construction in late Spring of 2014 (Figure 17). Once completed, it will be the largest Passive House Certified project in the country. The Philadelphia Redevelopment Authority, which owns the land, put out a competitive RFP to developers for which our proposal was chosen. The neighborhood and City of Philadelphia were inspired by the design and performance goals of the project and saw the potential for it to become a model for future urban development standards. With 100,000sf of four story, wood-framed, residential construction above a one-story non-combustible parking and retail space, Ridge Flats is a model for many types of mixed-use urban housing, including student dormitories, inter-generational housing and co-housing communities (Figure 18). The residential units are 1 and 2 bedroom rentals ranging from 560sf to 937sf, open and spacious, with private outdoor balconies for each unit and a 7000sf communal garden accessed by all units at the second level. The first floor steel and concrete “podium” will be site-built. The residential units will be built in a modular factory, utilizing the same Sustainable Building System developed for our smaller Stables and Belfield projects. Modules will be delivered to the site with finished interiors and exteriors and custom “building gaskets” designed for air and water-sealing between contiguous modules. Limiting the amount of work to be done on-site is key to the affordability, coordination and quality control requirements of the project. The thermal envelope is virtually identical to our earlier projects and demonstrates the replicability of the Sustainable Building System. We are in the process of designing our own hybrid heating/cooling/ventilation/domestic hot water system, as we had done in our earlier projects, but look forward to the day when such combined systems are commercially available in the United States for low-energy multi-family applications. A 266kW photovoltaic roof-top array is designed to provide Ridge Flats with enough electricity production to make it a Net-Zero-Energy-Capable community, and one of the largest in the country (Klayko 2012, Defendorf 2012, Saffron 2011).

Figure 18: Rendering of corner of Kelly Drive and Calumet Streets, Ridge Flats

CONCLUSIONS

"Can HOUSING save the planet?" While this is an intentionally provocative, maybe somewhat naïve question with which to begin and end a paper, it is none-the-less an appropriate description, for better or for worse, of the somewhat naïve and risky work Onion Flats. "Housing", as a noun, most often needs an adjective to frame or activate it in one direction or another. Housing doesn't have to just passively *function*, it can also *perform*. I went to two $10.00 performances in the movie theatre over the last couple of weeks. One left me depressed and lifeless, the other made me laugh and inspired me to look at my environment in a more intentional way when I left the theater. I spent the same $10.00 on the two performances. So, if it doesn't cost anymore to be depressed or inspired, for our Housing to merely *function* rather than *perform*, why wouldn't we chose an inspiring performance?

References:

Arketipo (2010), "Social Housing", Amalie Vivian, Pg. 52-62, December 2010.

Defendorf (2012), Green Building Advisor.com, "Onion Flats' Big Multifamily Passivhaus Plan", Richard Defendorf, January 18, 2012.

ECEEE (2014), "Understanding the Energy Efficiency Directive", http://www.eceee.org/eceee_Maze_guide6EED.pdf

Energy Information Administration (2012). Annual Energy Outlook, with Projections to 2035

Energy Performance in Buildings Directive (EPBD), (2014) http://www.bpie.eu/cost_optimal_methodology.html#.Usn1rRactic

Fernandex (2009), HoCo, "Onion Flats: Thin Flats" case study, by Aurora Fernandex Per, pp 392-401, 2009, Edition: a+t ediciones.

Flannery (2011), Eco-Urban Design, "Thin Flats and Margarido House ", John Flannery, pg. 142-157, 170-177, October 2011.

Holladay (2010), http://www.greenbuildingadvisor.com/blogs/dept/musings/magic-box-your-passivhaus.

Hespel (2011), AMC Lodgement, "Housing, 30 Case Studies", Christophe Hespel, pg. 42-45, November, 2011.

James (2012), Chapter 5: Making More with Modulars: Belfield Townhomes", Mary James, Low Carbon Productions, 2012.

Klayko (2012), The Architect's Newspaper, "Passive Aggressive: Philly firm Onion Flats plans largest net-zero mixed-use development", Branden Klayko, January 19, 2012.

Passive House US (2014) http://www.passivehouse.us/phc2011/2011%20Presentations%20PDF/Lausten,%20Jens%20-%20301%20JL%20PHIUS%20-%20October%202011.pdf.

Passivhaus Institute: http://passiv.de/en/, site visited 1/5/14.

Saffron (2011), The Philadelphia Inquirer, "Changing Skyline: An Energy-Saving Milestone Planned for Philadelphia's Kelly Drive", Inga Saffron, December 11, 2011.

Torres-Moskovitz (2013), The Greenest Home: Superinsulated and Passive House Design, Analysis of Belfield Townhomes, Julie Torres-Moskovitz, Princeton Architectural Press, 2013.

Vivian (2011), Arketipo 49 "Social Housing Case Studies", Amalie Vivian, Pg. 52-63, October 2011.