ENERGY ACCOUNTS: ARCHITECTURAL REPRESENTATIONS OF ENERGY, CLIMATE, AND THE FUTURE

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Re-Thinking the Box: Net-Zero-Energy-Capable Housing

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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, etc. 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 its affects are, at best, a threat and 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 almost 50% of all CO2 emissions in this country, it would seem a reasonable request, as a society, to both continue to migrate back to inherently more sustainable urban centers AND to require its architectural community to take on a much more intentional role in helping to solve these real and present dangers posed by the built environment. Most European Union nations have approached this issue head-on by incentivizing radically more sustainable modes of dwelling and transportation in urban centers and by redesigning building codes to require all new buildings achieve "Near"-Zero-Energy (NZE) within the next 15 years (starting in 2015, all new buildings in Brussels, the seat of the EU, will be required to meet a NZE standard). The North American consciousness is much slower to act as energy is still relatively cheap, space is more plentiful, the politics are more polarized and the development community is less inspired to see the value of such change. The work of Onion Flats attempts to skirt these issues by first demonstrating that it's possible to eliminate the notion of any "premium" associated with a higher standard of design and sustainability. 'Common sense' need not come at a premium, if approached creatively, and their work continues to offer alternatives to conventional architectural, development and building practice. The ambition of the work of Onion Flats, therefore, is to inspire those involved in the making of the built environment to continue to dream, to think otherwise, to pause long enough to be able to see the value of an experimental, affordable and therefore feasible approach to the design and construction of self-sustaining, provocative and thriving urban communities.

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 14.1. Typical Onion Flats Project: Rag Flats, 2006

AN APPROACH TO ARCHITECTURE

In 1997 Onion Flats (OF) started a small development/design/build collaborative in Philadelphia. The intention of the collaborative has been to integrate seamlessly the process by which their ideas about architecture, the city, and sustainable development go from interpretation to construction to habitation. In order to do so, OF has found it necessary to build and own the work that they design. While this requires a greater degree of liability and responsibility not typically experienced within a contemporary architectural practice, it has also offered them 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. Their projects have been experimental, primarily urban, focused on affordability and in the most general sense "sustainable." Their early projects (see Figure 14.1) took 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 and construction waste management. These approaches to sustainable thinking and building quickly became standard practice within all OF developments. What has more recently become standard in their work is

figure 14.2. Required roof area for 20.5 kWh/sf/year consumption

figure 14.3. Required roofarea for 4.5 kWh/sf/year consumption

a rigorous and intentional focus on radically reducing energy consumption within their projects. Understanding how to radically reduce the amount of energy consumed by buildings, without sacrificing other architectural and urban design related commitments, has required that they re-train themselves in good building science practices, passive solar design principles and mechanical systems engineering. They have also had to re-think the way they construct their buildings by developing, most recently, a holistic and sustainable building system that could be modular, significantly more efficient, higher quality and affordable. Most importantly, they've had to re-consider the metrics by which they gauge the performance of their 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, their most recent work has been framed by the 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 can be referenced. 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 one tries to make sense of this number based on the above question, and takes, 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 1920 sf with an average consumption of 20.5 kWh/sf/yr, this home would consume roughly 3245 kWh/month. If one wanted to "zero-out" that energy consumption with photovoltaics on the roof, one would need approximately 2832 sf of roof space to have this building achieve NZE (see Figure 14.2). This suggests that an urban building, built to code, cannot possibly generate all it needs to survive on it's own site.

Working in reverse if one only had a 16'x40' roof, that 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 that 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 that was originally based on a heating-dominated climate, one that emphasizes super-insulation, airtight and thermal-bridge-free construction, and balanced ventilation, and relies on internal heat gains and passive solar radiation to provide the majority of the 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 2.6 transmission 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. This is the context within which this paper looks to the work of OF. Four projects will briefly be reviewed, all in Philadelphia: 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 as a pre-Certified Passive House, and if built, the largest Passive House project in the country, scheduled for construction in the late Spring of 2015.

figure 14.4. 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.1 In the image provided, the unit identified on the left is a single family Row home and highlighted on the right is one lower duplex unit (see Figure 14.4). The design 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 and pervious parking lot. 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 OF knew at the time. They 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 the roofs were filled with PV, this project would 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 OF's definition of "affordable" construction. Thin Flats was, however, in many ways a "standard" development, or more precisely, the limit of what OF could do with standard approaches to design and construction. After this project, they began to look critically and intentionally for more replicable systems of construction that would increase efficiency at multiple levels, while allowing them to maintain control of larger scaled projects.

BELFIELD TOWNHOMES

In 2010, OF was approached by the Philadelphia Office of Housing and Community Development (OHCD) to determine if they could salvage an affordable housing development, located in the Logan section of the City, on which OHCD had been working unsuccessfully 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. OF was told that the project, once designed and permitted, had to be built in no more than three months. They 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 would be the first new construction to take place in this community within the last 50 years. The budget averaged $130sf for Hard Construction costs. There were no "green" or "sustainable" requirements specified for the project. This project would be a "first" for OF in several ways. It would be their first subsidized housing project, their first project constructed in a modular factory and their first attempt at a Certified Passive House. The homes are simply and efficiently organized, 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

figure 14.5. Belfield Townhomes: Left: Front porches with green walls; Right: Image from above

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 provide shading 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 Planning Package (PHPP), enable these houses to achieve Net-Zero-Energy-Capability.[2]

Also, essential to the experiment, was challenging the standards by which architects, urban planners and Municipal Housing Authorities conceptualize "subsidized/social/affordable housing". OF saw an opportunity to define "social" housing as the best rather than the cheapest, fastest and often most ill-conceived forms of housing. They were interested in testing whether it was possible to narrow the gap (or maybe even eliminate it) between "market rate" and "subsidized" housing; exploring whether subsidized housing could also be inspiring, filled with light and life, high-quality, high-performance, long-lasting and healthy materials and systems (see Figure 14.6); whether it could equally have the ability to encourage its inhabitants to be conscious-of and care-for their environment. Most importantly, it was an experiment to see if it could all be done within the budgets that Federal and Municipal subsidies typically support. They 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. They 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.

SUSTAINABLE BUILDING SYSTEM

An "affordable", high-performance, building system that could be replicable at large scales drew OF to modular construction (see Figure 14.7). Scale is critical to the success of any manufacturing process, and repetition is key to efficiency and affordability.

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. More simply stated, the benefits of scale, as they relate to affordability in both modular construction and Passive "Housing" design, are perfectly aligned.

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 (see Figure 14.8). The materials were also inexpensive and readily available. In order to simplify the detailing of the air-barrier layer, they placed it on the outside of the framing and had it double as the moisture barrier, they then placed continuous layers of polyisoscianurate rigid foam board on the exterior of the framing. Triple pane windows sit flush to the exterior air barrier making air sealing between them and the wood framing extremely simple and as "fool-proof" as possible. Beyond this exterior insulation layer on the walls, a vented but closed rain-screen system finished with a mix of metal panel, concrete board and brick was employed.

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. Several experiments were performed during the energy-modeling phase of the project in which the team 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 one of the most important lessons the team learned during the project and has helped to further hone

figure14.6. Belfield Townhomes: Kitchen/Living Area

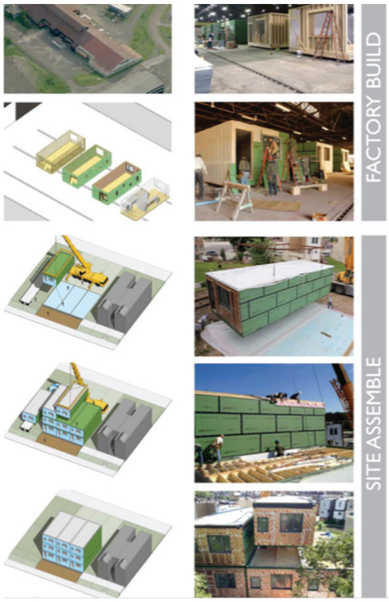

figure 14.7. Process of modular from the factory to site assembly

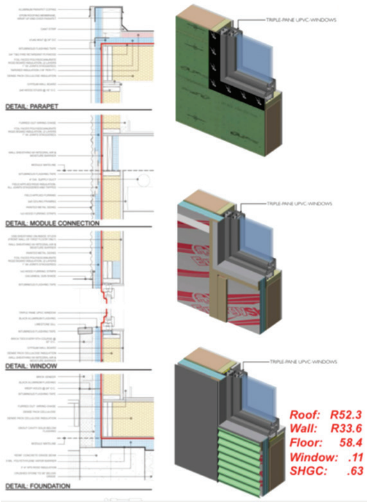

figure 14.8. Composition of the Sustainable Building System thermal envelope

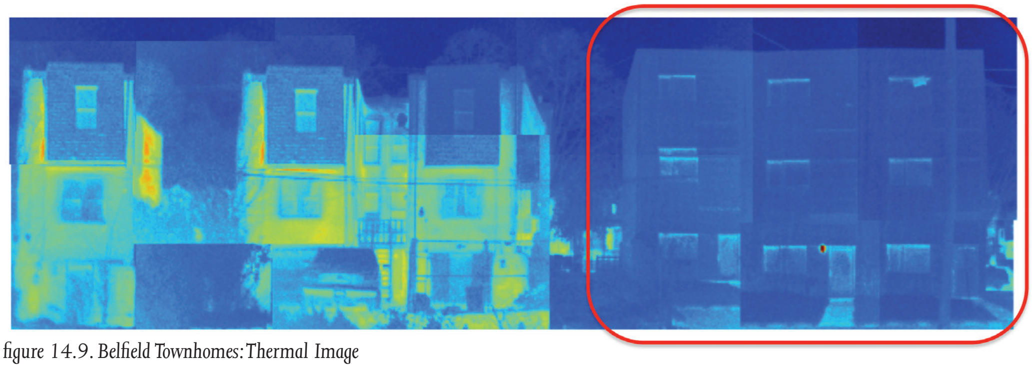

figure 14.9. Belfield Townhomes: Thermal Image

their Sustainable Building System as well as their 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 (see Figure 14.9).

MECHANICAL SYSTEMS

After exploring several options for heating/cooling/ventilation for these three story homes, OF's collaborating mechanical engineer designed a cost effective and "coupled" air-source heat pump/ventilation system using an off-the-shelf, inexpensive yet efficient 9000BTU Packaged Terminal Air Conditioning (PTAC) heat pump unit and an Energy Recovery Ventilator (ERV). 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.

The mechanical room was located on the third floor (see Figure 14.10) so that fresh-air intake and exhaust air ducts would come through the roof. It was decided early on that the homes would be "all-electric", 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 envelope and the potential of heat loss and air leakage. Gas is also a non-renewable resource that can't be generated on-site and would contradict the intention of the project as Net-Zero-Energy-Capable.

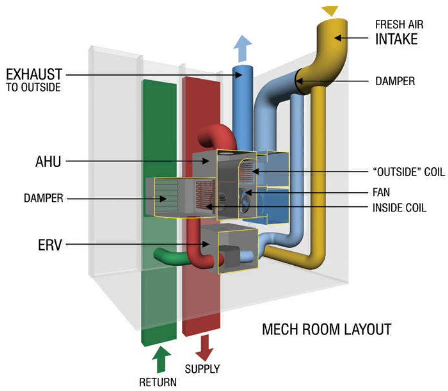

figure 14.10 Fresh-air intake and exhaust air duct

ENERGY MONITORING

A significant and robust energy, temperature, humidity and CO2 monitoring system was 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 (see Figure 14.5). 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. The team 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 one clearly sees with 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 (see Figure 14.11). Analyzing each circuit the team discovered a complicated and fascinating story of occupant behavior, property mis-management and a need for significant education.

A snapshot was taken of one month's energy consumption (February, 2013), which demonstrated monthly electricity bills ranging between $72.00 and $226.00 (see Figure 14.11). The circuits in the homes consuming the most were the "Laundry" circuits. In one home it was recording an average of 104 loads of laundry in 30 days! The HPWH circuit demonstrated that the water heater was effectively running in purely electric resistance mode, not Heat Pump mode, most of the month. The heat pump inside the HPWH has a COP of 2.5, which means that it is 2.5 times more energy efficient than an electric resistance water heater.

The hot water alone was accounting for $107.00 of this home's $226.00 utility bill (see Figure 14.12). This also demonstrates a larger, unexpected issue. The team suspects 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. The team did not account for 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.

Other significant anomalies were discovered between the homes' energy consumptions. 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

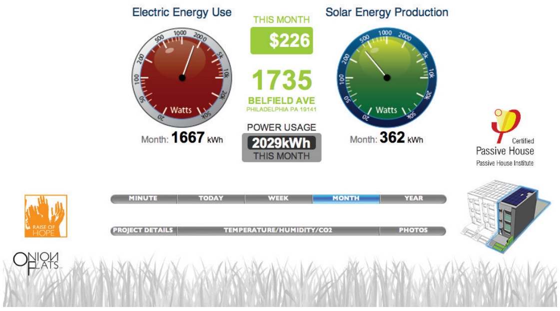

figure 14.11.

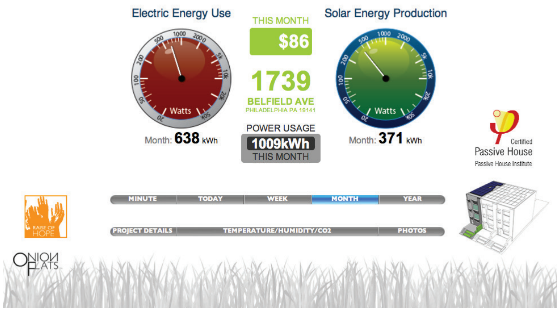

figure 14.12.

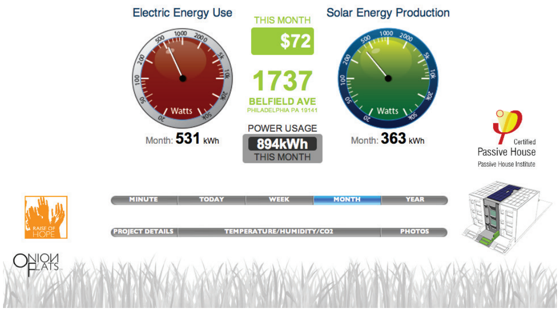

figure 14.13.

figures 14.11-14.13.Website portal page of each Belfield Townhome linked to respective and more comprehensive energy monitoring sites for each home temperature, even though the heat pump rarely turned on (see Figure 14.13). At first the team was pleased, thinking that their Passive House was doing exactly what they 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, they discovered unusually high plug loads coming from several rooms, which they discovered, upon inspection, was the result of electric resistance strip heaters tenants had plugged-in 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 drafty residences. On several occasions when the team would visit the homes to check on problems they were seeing in the monitoring data on-line, they'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 the houses have fallen short of their projections. With 12 months of data, while these houses are consuming between 25% and 66% more energy then they were designed to consume, two of the units, using roughly the same energy, 6-7 kWh/sf/yr (Site energy), are still the lowest energy homes OF has 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, the property owners place NO VALUE on energy consumption. Even with that significant management flaw, after subtracting the energy generated by the PV on the roofs of the units, the homes still, on average, require only between $32 and $93/month to operate all utilities. Armed with this data, OF has 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.

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. Currently under construction with a 27-unit market-rate townhouse, OF's development in the Northern Liberties section of Philadelphia is referred to as Stables Townhomes (see Figure 14.14). The project is comprised of three "bars" of 9 four-story, single-family townhomes. Similar to the Belfield Townhomes, each "bar" was treated 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, the team air-sealed between each unit. The "bars" were designed and oriented to capitalize on the almost-ideal Southern exposure of George Street. Floating planters and balconies on the South side of each

figure 14.14. Site Plan of Stables Townhomes

figure 14.15: Photo of completed Phase 1 of Stables Townhomes

home both capture and deflect the sun depending on the time of year. Three units have recently been completed, and the remaining units expect to be completed by late Spring 2015 (see Figure 14.15).

The Stables Townhomes are 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 larger 18,000BTU heat pump within the PTAC unit to heat and cool the roughly 2400 sf four story home (see Figure 14.16). The most significant difference between Belfield and Stables is that Stables has a basement, and Belfield didn't. The team chose to place the basement "technically" outside the thermal envelope (for modeling purposes) 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 ensures 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.

The measured airtightness of the first home came in almost identical to the Belfield homes at .49ACH50 (see Figure 14.17). Once the rest of the block is constructed and tested, and if it meets the same air-tightness requirements are met, Stables will become the 2nd Certified Passive House project in Pennsylvania. Each home has a slightly smaller 4.5kW PV system on the roof, but has the capacity to hold 8.5 kW of PV. Currently

figure 14.16: Photo of completed mechanical system in basement

figure 14.17: Photo of blower door test for first completed unit, with measured results

measuring only ONE home, and with owners who are conscious, diligent and interested in their energy consumption, their annual net consumption after PV generation was 8916 kWh or 4.7kWh/sf/year with 12 months of data. 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, OF considers this "affordable" housing.

PUMP UP THE VOLUME

While OF's 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, their most recent project, is an experiment in SCALE itself.

Ridge Flats, a 147 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 2015. 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 the OF 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. 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

figure 14.18: Site Rendering of Ridge Flats

figure 14.19: Rendering of corner of Kelly Drive and Calumet Streets, Ridge Flats

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 the smaller Stables and Belfield projects. Modules will be delivered to the site with finished interiors. 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 the earlier projects and demonstrates the replicability of the Sustainable Building System. A de-coupled version of earlier heating/cooling/ventilation systems has been designed for this project, but the team looks forward to the day when such combined systems are commercially available in the United States for low-energy multi-family applications. A 400kW 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 country3.

CONCLUSIONS

The above projects are demonstrations of a scalable, affordable and net-zero-energy-capable approach to housing which could help inform, if not transform, the standards by which housing is conceived, designed and constructed in the United States. It is, however, clear that while the "common-sense" building science principles behind Passive House, especially combined with those inherent in modular construction, will only become "standard" when common-sense itself is actively legislated in the form of building codes and housing policies in this country. If the work of OF demonstrates anything, it is that the financial, scientific and technological barriers to net-zero-energy-capable housing are, relatively speaking, easily traversed. The real "work" involves inspiring and communicating to those responsible for the future of the built environment that radical reduction in energy consumption and CO2 production is actually necessary. In the polarized political and conservative landscape that is the US, this is no small endeavour.

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http://www.passivehouse.us/passiveHouse/PHIUSHome.html

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