Low Energy Architecture / Low Energy Living:

Strategies for passive design at the urban and building scales

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ABSTRACT: Low energy architecture must be addressed in the context of low energy living; it must be addressed at the scale of urban/town fabric as well as that of individual buildings. Although limited guidelines addressing energy efficient rehabilitation of existing homes and town fabric exist, none of the resources address these issues from the point of view that can have the most impact, the occupant's. This paper presents a replicable process for low-energy architecture and living that takes into account occupant patterns as a design factor in passive design at the urban and building scales.
Keywords: low-energy, renovation, retrofit, planning, passive design, occupant

INTRODUCTION

This paper addresses low energy architecture through occupant interaction and the understanding of occupant patterns at the urban and building scales. Specifically, the paper addresses 1) the use and reuse of existing infrastructure; 2) establishment or expansion of walk-able uses on a community scale with the intention of reducing car trips 3) the adaptation of existing homes to contemporary use, in the interest of proposing strategies for energy-efficient, passive low energy renovation and retrofit of existing, sometimes historic, buildings in existing town centers. These opportunities are illustrated through the presentation of a case study for the renovation and retrofit of a semi-attached, historic row house in Carlisle, Pennsylvania. The analysis of the existing town fabric and infrastructure will illustrate the benefits of the historic development patterns of the downtown area as an inherently sustainable community. Design strategies for the use, reuse and expansion of existing infrastructure and community fabric will be discussed. Finally, an 1841 row home will be presented as an evolving model for passive low-energy design to include the reuse of existing spaces to meet the live/work needs of the occupants and the modification of the existing building envelope and systems to achieve a higher-performing, more energy efficient, and environmentally responsible building. The intension of this study and precedent is to illustrate a flexible, occupant-driven process that can be adapted to fit other homes within existing towns.

BACKGROUND

Low Energy Living On the fringes of the Northeast Corridor traditional towns are undervalued. They may provide regional and civic identity for residents of surrounding areas but rarely are they the commercial, institutional or residential centers that they once were. The formerly healthy mixed-use town centers are now under-used and considered to be less desirable than surrounding suburbs or rural areas. When businesses and institutions moved to remote (car based) venues, towns had less market appeal. Their fabric, in many cases, doesn't adequately support autos (at least one car for every adult) and their (often very well made) buildings are not easily and efficiently adapted to contemporary uses. The reinvigoration of such towns represents not just an excellent opportunity for low-energy living but a satisfying alternative to the homogenous development that has often emerged nearby. Such transformation will likely require active support from myriad sources but it is clear that considered, contentious and evolving resident action is requisite. The transformation must be a reawakening of community.

Low Energy Architecture In 2000, single-family attached houses (row houses and townhouses) comprised 5.6 percent of the total U.S. housing inventory, 2% less than their highest inventory in 1940 [1]. Although this market is a small percentage of the overall single-family housing market, it is the majority of the housing type in existing town centers and therefore energy-efficient renovation of these structures, to reinforce community, is essential. Despite the United State's reputation as a "rootless" society, fewer than 12 percent of Americans moved since 2007, the lowest rate since the Census Bureau began tracking this information in 1940 [2].

However the vast majority of the nation's existing housing stock is constructed to standards far below current energy codes. Although some guidelines exist to inform the retrofit [3] or renovation [4] of existing homes to green and energy efficient standards, these guidelines do not generally take owner occupant patterns into account beyond material performance/preference and thermal comfort. Recognizing and designing with occupant patterns in mind provides the opportunity "to position users' behaviour as a key 'active' determinant of energy performance in passive design" [5], not only through adaptive opportunities, but also as a strategy for low-energy design and community building. Strategies for passive low energy design should be considered at multiple scales within the context of the neighbourhood fabric and the building.

SCALES OF INTERVENTION

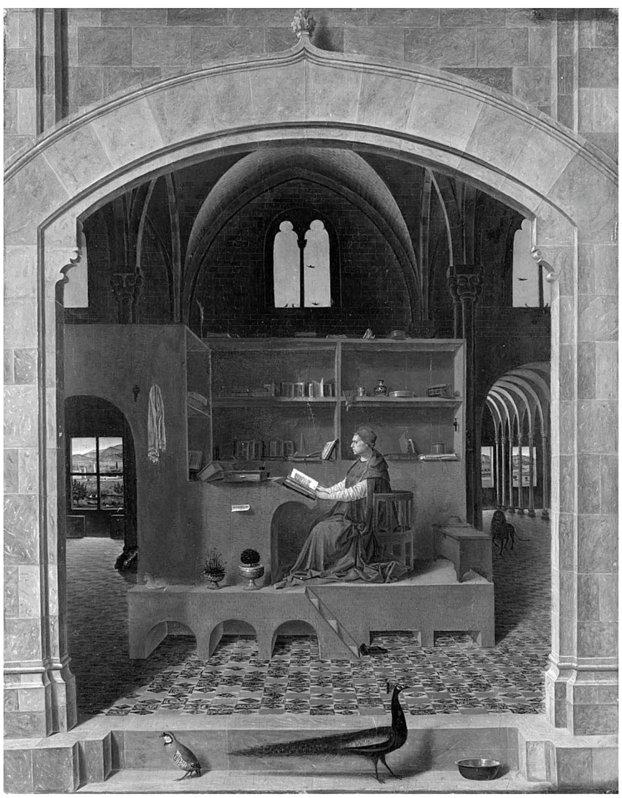

Figure 1: St Jerome in His Study, ANTONELLO da Messina, about 1475. © The National Gallery, London.

The layers of St. Jerome in his Study (Antonello, about 1475) illustrate the multiple scales of consideration necessary for a low energy approach (refer to Fig. 1). The inserted workspace provides privacy, functions for its specific use, and controls the space around it. This work "pod" organizes the space around it into zones, implying different uses and connections with the surroundings. The enclosing building envelope monitors thermal performance, daylight and natural ventilation. The occupant remains connected to the outdoors with visual connections to the sky and the ground. Ultimately the building shell nests within the context, the peacock symbolizing a garden oasis and the windows framing the urban environment – neighbours and adjacent buildings. The occupant, central to the image, controls his work while simultaneously interacting with the environment.

CASE STUDY

251 South Pitt Street is being renovated for an adult couple with no children at home. It is important to the occupants that their residence meets the basic tenets of responsible low-energy community living. Further, both desired a degree of character and authenticity. They concluded that their basic goals could best be met by efficiently occupying an existing house in a walk-able neighbourhood.

Figure 2: Photomontage of Carlisle Square. photos by A. Hyde.

The home is located in Carlisle, Pennsylvania (40º12' 9" N77º11' 42"W). Big by Pennsylvania standards, the town is the county seat of Cumberland County. Carlisle has character; the old courthouse even has marks from artillery shells fired by confederate soldiers around the time of the battle of Gettysburg. Carlisle benefits from multiple amenities within easy walking distance, including stores, community resources, two universities and a law school, governmental and judicial buildings, diverse employment opportunities, parks and recreational facilities, and productive agricultural land (Fig. 2).

Likewise, the house has integrity. Built in 1841, it is solid brick with satisfying proportions and high quality detailing and materials that would be difficult and expensive to replicate today (Fig. 3). At 2,78 square feet the home is too large for the occupants needs, and not well insulated, but the traditional layout supports the separation of space by use, time of day, or comfort requirements. The orientation also provides opportunity for passive solar improvements (Fig. 4).

Figure 3: 251 South Pitt Street, Carlisle Pennsylvania.

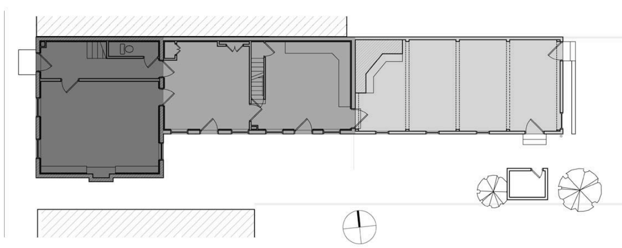

Figure 4: Plan of 251 South Pitt Street illustrating existing conditions and building orientation.

Implementation Scale 1: Use and Reuse of Existing Infrastructure and the Expansion of Walk-able Uses The occupants are fully committed to town living. They primarily walk or bike, keeping one (hybrid) car for limited-use. Further, they are dedicated to improving community through their actions, serving on a board that recently brought a permanent farmers market to downtown and supporting local food-production through home gardening and subscribing to community supported agriculture (CSA). The couple collocated their office and residence. The positive impact is obvious - no commute, efficient use of the extra space, one mortgage, one utility bill – and the day and night activity of the live/work mix of uses benefits the community by providing "eyes on the street" and expanding walk-able amenities.

Implementation Scale 2: Building Envelope Any renovation or retrofit project should begin with a home energy audit that will provide existing energy performance information as well as specific strategies for energy conservation. Recommendations for water efficiency, financing opportunities for energy-efficient upgrades, and quick efficiency improvements that can be easily achieved by the owner may also be outlined in the home audit report. Based on the audit information appropriate retrofit measures can be identified to reduce air infiltration and improve energy-efficiency of the existing home. Since 251 South Pitt Street was newly purchased, retrofit of the project - improving the performance of the existing thermal envelope - could be substantially completed prior to move-in. The audit confirmed moderate to severe air leakage at the attic and attic junctures (wall tops, electrical boxes, recessed lights), basement band joist, and attic stairwell. An overall goal of a 30% reduction in air infiltration for the original house was established as a realizable (although significantly lower than recommended) target for the home.

Recommendations were made to inspect the exterior brick walls and seal any leaks, to add insulation to the basement, attic and crawl space, to insulate the floors between levels, and to replace the drafty front door and sidelights. Existing fenestration patterns, overhangs, and opportunities for shading, were analyzed and improved as needed. In order to maintain the character of the original brick structure, alternative methods for improving energy performance were explored for insulating the walls by isolating the different uses through implementing zones and "pods".

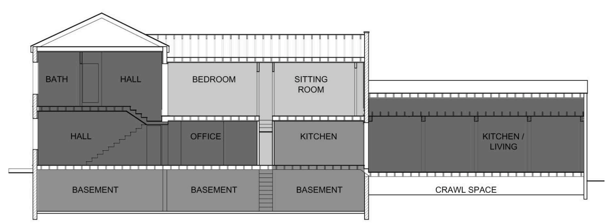

Figure 5: Schematic diagram of proposed Zones.

Implementation Scale 3: Zones Four zones were identified according to function and time of use (day/night; work/home; public/private). Offices on the first floor would be active during weekday business hours, while the downstairs kitchen/ pantry, second floor sitting room and sleeping suite were to be used during winter evenings and overnight. Thermal separation between zones allow for more specialized control of temperature and comfort according to which spaces are in use and what types of activities are happening in each zone (Fig. 5).

Figure 6: Rear Addition renderings. © OPA, Harrisburg.

The rear addition (constructed in the 1980's), a separate zone both mechanically and spatially, was identified as an opportunity for idealized passive solar strategies for lighting and climate control. The space will serve as the primary living and dining area for flexible morning, evening, and weekend use. A major goal of this project was to achieve overall efficiency without separating the occupants from the outdoors. The renovations to the back addition play a large role in connecting the interior with the rear garden (to the east) and an outdoor room defined by a trellis (to the south). The trellis shades the windows from solar gain in the summer, supporting seasonal foliage and a row of deciduous fruit trees in the rear garden. The upgrade of a large existing fireplace and the addition of mass, by replacing part of the floor with a concrete slab and reconstructing the south wall with a partial-height Trombe wall, will allow the space to be primarily passively heated. Eliminating the dropped ceiling to follow the north to south slope of the existing roof allows for operable clerestory windows high in the lot-line wall of the north façade. These additional windows (in combination with doors and operable windows to the south) improve ventilation in the space and eliminate the need for mechanical cooling (refer to Fig. 6). Reversible ceiling fans augment circulation throughout the year, improving occupant comfort.

Implementation Scale 4: Pods and Mini-systems

"What is needed are many more small rooms – some need not be larger than alcoves – to conform to the range and variety of [leisure] activities in the modern home [6]."

After the building envelope has been retrofitted and the zones implemented through minor renovation, thermally isolated "pods" can be added to further separate zones, by use, within the existing structure. In addition to allowing more specialized control over the temperature in each zone, separating the house into "pods" will keep heat from accumulating on the second floor. Mini-systems, optimized according to occupant use patterns, will augment the existing mechanical systems and provide time-of-use comfort. Systems include dehumidification and clean burning efficient stoves that provide both comfort and character (Fig. 7).

Figure 7: Efficient stove supplementing hot water heating system in "pod".

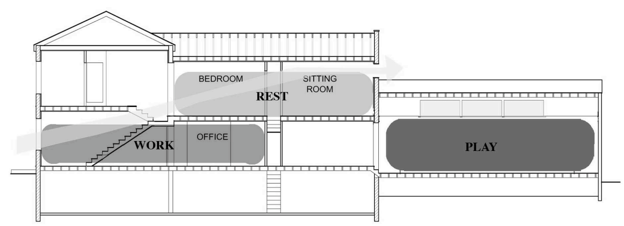

Figure 8: Schematic "Pod" diagram with opportunities for natural ventilation highlighted.

A mini-split air source heat pump could supplement the existing hot-water heating by zone or within "pods". Because of the great opportunity for solar gain along the south wall and roof of the back addition, this space can function independently, providing a solar hot water boost to the whole-house boiler in the future. Controlled connections between zones and pods provide opportunity for natural ventilation and night-time "flushing" (Fig. 8).

STRATEGIES FOR AN OCCUPANT-INFORMED LOW ENERGY APPROACH

The strategies developed for 251 S. Pitt Street can be replicated to achieve passive low-energy living at the urban and building scale. The occupants' decision to purchase an existing home in an established town was a major factor in low energy living. Using existing urban infrastructure and living within walking distance of the town square and neighbourhood resources eliminated the need for a car. Re-allocating the unused front parlour and dining room as commercial office space further reduced car trips and expanded walk-able uses within the community. The reuse of home's infrastructure and management of space minimizes costs for mechanical heating, cooling and ventilating, allowing the home to function passively for most of the year. The overall space assessment and adaptation of existing spaces updated the structure for contemporary patterns, identified opportunities for maximum efficiency, and minimized high-energy consumption heating and cooling systems for small scale individual systems to meet localized, time-of-use demands.

This project demonstrates that energy-efficient, passive low energy living begins with location. Existing town fabric must be cherished and re-established. Approaches for retrofitting of existing homes for maximum energy-efficiency must be balanced with use assessment and identification of existing assets to maintain town fabric and historic character where applicable. This balance is achievable, especially when strategies for managing living spaces or interior "pod" configurations are considered. Most importantly, project coordination and management must be considered, focusing on a long-term plan to achieve maximum efficiency. The plan must recognize and set goals, but must also be flexible enough to transform with changing occupant needs and technology overtime.

Isolating the strategies applied to 251 South Pitt Street may serve as guiding parameters for low energy architecture and low energy living:

- Minimize waste, and reuse or retain existing infrastructure and materials where possible.

- Expand and support local businesses, amenities, and food sources to reduce car trips.

- Study the performance of the existing thermal envelope and identify problem areas. Seal leaks and evaluate window and door performance. Add insulation where possible.
- Evaluate the inherent mass of a building and explore possibilities of using it to store thermal energy. Where little mass exists, consider adding it.

- Identify zones of intensive use by working with occupants to establish how they use space. Establish zones and "pods" of space customized according to time, duration and type of activity.

- Take a two-tier approach to heating and cooling to increase overall performance and meet localized, time-of-use demands.

- Achieve cooling in the summertime by using a minimum of conditioning (by zone) and daily flushing through natural ventilation, concentrating on movement and dehumidification of air to improve the comfort irrespective of the desired temperature which varies from person to person.

- Evaluate the feasibility of adding solar thermal assistance to systems. Consider solar-electric strategies only after optimizing overall efficiency and energy performance.

A long-term goal of the project is to provide a model for occupant informed renovation and retrofit of an existing home. Records of monthly and yearly energy savings will be maintained and compared to prove the value of such a model to other homeowners. Documentation of results will also help to evolve and improve the process over time.

CONCLUSION

The strategies and methods presented provide a needed model for customizing existing housing stock to maximize performance and minimize energy costs through working with the occupant to customize the home and use patterns. It suggests a continuously evolving process for renovation and retrofit of existing homes, but most importantly it provides an alternative to abandoning the resources and advantages of our existing town fabric. This paper suggests a continuously evolving process for renovation and retrofit of existing homes that will allow homeowners to find sustainable ways to reduce their energy bills, while greatly increasing the quality of their communities and living space. The purpose is not to provide a product, but instead to offer occupants a holistic vision specific to each home and a flexible process that will allow them to attain their goals.

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Another example is the U.S. Environmental Protection Agency and U.S. Department of Energy EnergyStar home improvement reference guide, [Online], Available: http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_index [January 2008].

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