Adaptive Reuse: Energy Efficiency and Sustainability Measures

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ABSTRACT

Adaptive reuse offers significant opportunities for energy efficiency and sustainability in the built environment. Design of energy-efficient and high-performance adaptive reuse requires that building performance and simulations tools are used and integrated with the design process. The objectives of this research is to provide building researchers and practitioners with a better understanding of how to effectively conduct adaptive reuse to promote energy conservation and sustainability. A case study of 1315 Peachtree Street, Atlanta, GA demonstrates some of the barriers that are currently present achieving energy efficiency and sustainability in adaptive reuse and strategies that were used to overcome those barriers.

Introduction

Although progress towards the adoption of energy efficient and sustainable building practice across the globe is encouraging, the sustainability movement mainly focused on transforming building practices for new construction. To date, however, sustainable building practices have underemphasized the importance of sustainable retrofits of existing building stock across the globe (Tobias et al. 2010). Many existing structures were built before the establishment of energy efficiency code. These buildings, which were designed according to the traditional approaches, are the primary consumers of energy and resources (Basarir et al. 2004).

In most developed countries, more than 98 percent of the building stock consists of existing buildings. Sustainable new construction, no matter how environmentally sensitive and energy-efficient, cannot by itself significantly change the environmental impact of the built environment (Tobias et al. 2010). So existing buildings must be subjected to a process of retrofit to create the intended ecological impact.

Existing Building Energy Performance

Existing buildings tend to undergo performance degradations, change in use, and unexpected faults or malfunctions over time (Heo et al. 2012). These events often result in significant deterioration of the overall system performance, inefficient operation and unacceptable thermal comfort conditions. A study supported by the U.S. Department of Energy identified more than 100 types of faults that may happen in commercial building services systems and these faults can account for 2–11% of the total energy consumption of commercial buildings (Roth et al. 2005).

In a sustainable adaptive reuse, existing building performance assessment and diagnostics are used to benchmark building energy use, identify system operational problems, and find energy conservation opportunities. Energy audits and surveys enable identification of energy use and costs, from which energy cost and consumption control measures can be implemented and reviewed (Standards Australia, 2000).

Building Performance and Simulations Tools

Performance analysis, energy modeling and simulations are used during the design process to understand and quantify performance of different design strategies. These also require to inform design in energy efficient and sustainable adaptive reuse (Aksamija et al. 2013). Reliable estimation and quantification of energy benefits are essential in a sustainable building retrofit decision-support system for prioritization of retrofit measures. The performance of different retrofit measures is commonly evaluated through energy simulation and modelling. There are a number of whole-of-building energy simulation packages, such as EnergyPlus, eQUEST, DOE-2, ESP-r, BLAST, HVACSIM+, TRNSYS, etc., that can be used to simulate the thermodynamic characteristics and energy performance of different retrofit measures.

Building information modelling (BIM) can also be used to predict the energy performance of retrofit measures by creating models of existing buildings, proposing alternatives, analyzing and comparing building performance for these alternatives and modelling improvements (Tobias et al. 2010).

Energy simulation plays an essential role in analyzing the performance of retrofit measures. Since different models (and tools) offer different prediction reliabilities with different uncertainties, the model (and tool) selection and its parameter identification are essential to ensure reliable estimates.

Adaptive Reuse Technologies

Building envelope is the most effective predictor of the energy which is used for heating, cooling, lighting and ventilation of the buildings. Because of being in direct interaction with the external environment conditions, building envelope is defined as the interface of energy loses. For reducing the energy use in buildings, the energy requirements of buildings must be minimized, the efficiency of energy use must be increased and systems must be set up which support the use of sustainable energy sources (Basarir et al. 2004). Energy efficient and sustainable adaptive reuse technologies can be categorized into three groups, they are, supply side management, demand side management, and change of energy consumption patterns, i.e. human factors (Ma et al. 2012).

Energy efficient and sustainable adaptive reuse technologies for supply side management includes building electrical system retrofits and alternative energy supply systems to provide electricity and/or thermal energy for buildings such as solar hot water, solar photovoltaics (PV), wind energy, geothermal energy, etc.

Energy efficient and sustainable adaptive reuse technologies for demand side management consist of the strategies to reduce building heating and cooling demand, and the use of energy efficient equipment and low energy technologies. The heating and cooling demand of a building can be reduced through retrofitting building fabric and the use of other advanced technologies such as air tightness, windows shading, etc. Low energy technologies may include advance control schemes, natural ventilation, heat recovery, thermal storage systems, etc.

Case Study: 1315 Peachtree Street

1315 Peachtree is an adaptive reuse of a 78,956 square foot 1985 office structure transformed into a high performance civic-focused building. Located in the heart of Midtown Atlanta across from the High Museum of Art, the new building continues to house the Peachtree Branch of the Atlanta-Fulton County Public Library and introduces a new street-level tenant space occupied by the Museum of Design Atlanta (MODA). The Perkins+Will Atlanta office occupies the top four floors with office space for up to 240 employees.

Figure 1: a) Before & b) after views of 1315 Peachtree Street. After photo credit Eduard Hueber © Arch Photo, Inc.

An integrated design approach was followed to evaluate and maximize the energy reductions of the building. Solar studies and energy modeling informed decisions regarding daylighting, glazing replacement, glazing materials and shading systems. These studies, along with lighting analysis, were critical to inform the load calculations and sizing and selection of the HVAC systems.

Innovative "living lab" design of the HVAC systems combines elements never before used in this hot/humid climate, including radiant heating/cooling, under-floor air distribution, Chilled Beams, MicroTurbines, an Adsorption Chiller, 7.2 kW Photovoltaic Panels and an Energy Recovery Wheel. Energy recovery and desiccant dehumidification strategies were used to reduce ventilation cooling loads. Lighting systems were designed for minimum egress level ambient lighting coupled with LED task lighting, controlled by an occupancy and daylight sensing system. Rainwater is captured and used in a grey-water system. Evacuated tube collectors and photovoltaic panels are in place for renewable hot water and power production. This project is registered as Georgia's first LEED® Platinum V3 certification.

Building Performance and Simulations Tools

EcoTect was the primary environmental modeling tool, and IES/VE was used for daylight modeling. The building automation and monitoring system monitors and records continuous, real-time data for all energy use; chilled, hot and condenser water; MicroTurbines; rainwater collection; CO2 levels; temperature; and humidity. Since many sustainability strategies used are not commonly found in the region, the owner felt it was important to track performance and share results in order to better inform future design.

System Solutions

Of the project's stated goals, the greenhouse gas reduction target of 60% had the largest influence on the system solutions. It was determined from concept phase analysis that to attain the desired reduction in GHG, partial energy source substitution was required. Since approximately 95% of the power sold by Georgia Power is generated by burning coal, the utility power for this building is very carbon intensive. The solution involved a cogeneration strategy using natural gas-fired MicroTurbines to provide power, hot water for heating and cooling from a hot water driven adsorption chiller. This combined solution extracts the maximum amount of energy from the natural gas source, which has much lower carbon intensity than coal and resulted in a 67% decrease in CO_2 emissions.

The generation and distribution of electricity from the power grid often has a transmission loss of up to 65%. By generating distributed power on-site through a tri-generation system, waste heat is captured and used for both heating a cooling, thereby achieving much greater efficiencies. In addition, the switch to natural gas as a primary fuel source to generate building electricity reduces CO_2 that would be generated from the local coal-burning power plants.

The building is still connected to the grid and relies on grid electricity when there is insufficient demand within the building for the heating and cooling that the tri-generation system provides. This flexibility has contributed to 58% cost reduction and 68% greenhouse gas reduction for the project. The system also includes an Adsorption Chiller designed to cool water by using a silica gel media instead of refrigerants and the "waste" heat from two MicroTurbines.

Significant energy efficiency is achieved by using water rather than air to heat and cool the space. Cold and hot water is pumped through small capillary mats in the metal ceilings panels throughout. A Heat Recovery Unit, also referred to as an Enthalpy Wheel, exchanges heat and humidity from one air-stream to another on the rooftop. Rather than discard used building air, an enthalpy wheel salvages useful energy and transfers it to incoming, fresh air. This saves energy by reducing the need for cooling in the summer and heating in the winter. Using the waste heat from the MicroTurbines and the Adsorption Chiller produced "free" heating and cooling water for the radiant heating and cooling system. In hot/humid climates, radiant systems are rarely used because the warm, moist outside air would produce condensation on the cool-water tubing. The design team had to work very closely to make sure the system was balanced between the amount of exposed concrete, the size and spacing of the radiant mats and the number and location of any operable openings.

Energy Usage

Project lighting utilizes either LED or T-5 Fluorescent lamps for maximum efficiency. Pendant direct/indirect studio lights are individually controlled with daylight and occupancy sensors. Corridors use only light borrowed from project team rooms. In addition, most employees operate laptop computers with flat-screen monitors and computational node "clouds" to further reduce plug-load energy use. The radiant system, using water as the energy transmission source is more efficient than air-based systems. Humidity and condensation issues preclude the use of operable windows in most of the studio areas. All these contributes to Total EUI of 97 kBtu/sf/yr and Net EUI of 28 kBtu/sf/yr. 51% Reduction from National Median EUI for Building Type and Lighting Power Density is 0.55 watts/sf.

Light and Air Management

West façade was redesigned with high-performance low-e glazing with fixed vertical and horizontal sunscreens to prevent solar heat gain and glare from the west. This was modeled to reduce solar heat gain on this face by about 94% compared to the existing configuration. The 5th floor atrium allowed to reshape the structure with minimal impact and provide connections between the floors of the office as well as add an exterior terrace, creating a variety of spaces to support a creative and collaborative atmosphere for office-wide meetings and events. A steel trellis and motorized shade system protects from too much sun penetrating the space.

Air is delivered at very low velocity through a raised floor plenum, maximizing the ventilation air-delivery effectiveness. This system is inherently more comfortable than air-based systems due to the radiant cooling and heating effect and the lack of drafts.

Natural daylight with occupancy and daylight sensors and usable outdoor space reduced the amount of energy needed for lighting by 67%. Daylighting at levels that allow lights to be off during daylight hours is 84%, Views to the Outdoors is 98%.

Figure 2. a) Open-plan workspaces to support a creative and collaborative atmosphere. b) A steel trellis and motorized shade system prevent solar heat gain and glare from the west. Photo credit Eduard Hueber © Arch Photo, Inc.

Water Efficiency

Rainwater from the roof and the 5th-floor terrace is captured and stored in an underground 10,000-gallon cistern. It is filtered, treated with ultraviolet light, then pumped to all flush fixtures in the building. Excess water is used for irrigation or released into bioswales. 76% of rainwater from maximum anticipated 24 hour, 2-year storm event that can be managed onsite. More than 172,000 gallons of water are captured annually and used on-site, thereby reducing the demand for municipally supplied potable water. No potable water is used for irrigation. Since the cistern is not visible, a publicly visible water feature adjacent to the civic plaza recirculates captured rainwater or sends overflow water to the bioswales, where it naturally recharges the aquifers. Vegetation within the bioswales improves the quality of water that enters, while soil designed to support infiltration reduces the quantity of water that reaches the storm sewer system.

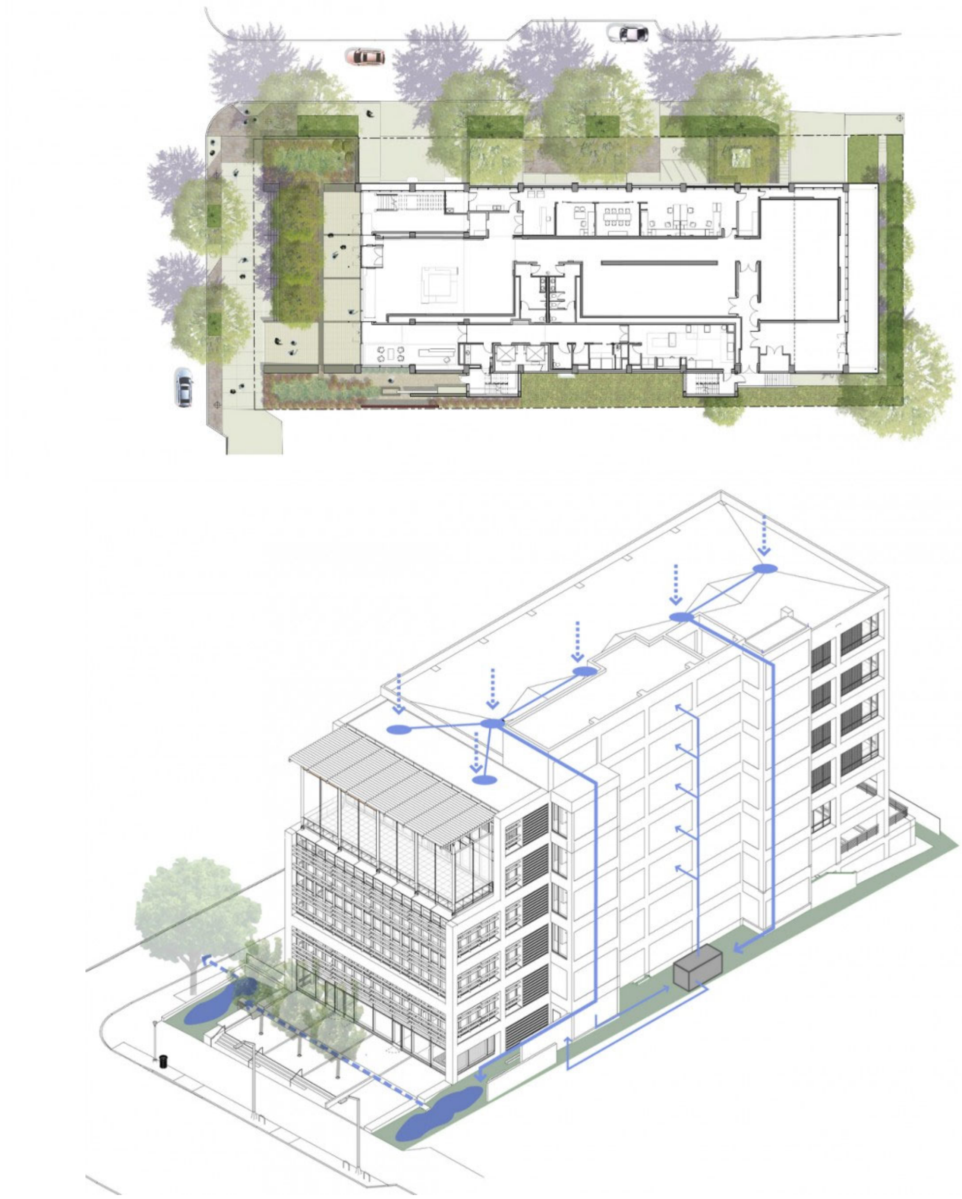

Figure 3. a) Vegetation and bioswales around the site. b) Rainwater collection and distribution diagram.

Other water-saving features used are low-flow flush fixtures, including 1.23 gal/flush toilets and 0.125 gal/flush urinals, and sensors on flow fixtures that prevent faucets from being accidentally left running. All these contributes to 77% reduction of regulated potable water.

Materials and Construction

In order to reduce the amount of demolition and construction waste sent to the local landfills, the team set a target that 75% of waste generated would be reused, repurposed, recycled or otherwise diverted. 80% (630 tons) of demolition and construction waste was diverted from landfills or recycling yards to more than 20 local nonprofit organizations.

In addition, building materials used were rigorously screened to be free of known or suspected toxic substances, including PVC. As a result, materials are 75% free of added halogenated compounds, contained 40% recycled content and 37% were extracted/manufactured within 500 miles of the project site. Wood sourced from FSC-certified forests comprises 82% of the total used. The board room conference table used to be cherry baseboards.

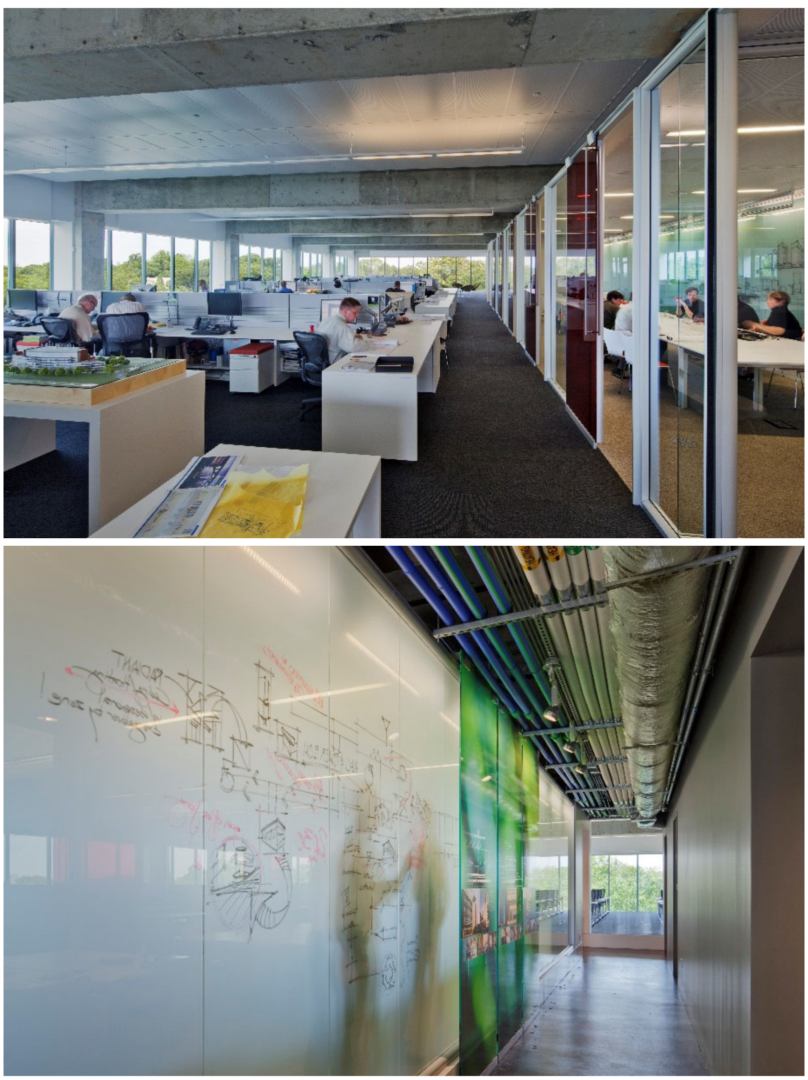

Figure 4. a) Use of daylighting, with occupancy and daylight sensors, reduces lighting energy by 67% over code. b) Corridors use only light borrowed from project team rooms. Photo credit Eduard Hueber © Arch Photo, Inc.

Conclusions

The best opportunity for positive environmental impact was to select an existing building, retain as much of the structure as possible and upgrade and optimize systems such as exterior glazing, HVAC, lighting and water. Design of energy-efficient and high-performance adaptive reuse requires that building performance and simulations tools are used and integrated with the design process (Abdullah et al. 2014).

1315 Peachtree Street is a living model for small urban sites that emphasize sustainability. Essentially "upcycling" an outdated office building on Atlanta's signature boulevard, the site now showcases elegant energy efficiency and sustainability upgrades. As for energy efficiency upgrades, the building makes use of natural daylighting, energy efficient lighting, lighting controls, passive sun shading on lower levels and an active, dynamic exterior sunshade on the building terrace level to control afternoon sunlight and heat gain. For climate control, the building uses Raised Flooring and a Radiant Heating and Cooling System, MicroTurbines and an Absorption Chiller. Rainwater is collected in a 10,000 gallon cistern and used for landscape irrigation and low-flow toilets and urinals. Overall the building's carbon footprint is reduced by 68% and complies with the 2030 Challenge for reduced greenhouse gas emissions. In addition to LEED Platinum, the project is already a recipient of the Urban Land Institute's Development of Excellence Award. "Perkins+Will has designed a showpiece building. 1315 Peachtree Street exemplifies the kind of environmentally sustainable measures that can be taken during a building retrofit. It has earned its high LEED score and will continue to pay dividends through energy saving measures for decades to come." Rick Fedrizzi – President, CEO and Founding Chair of the U.S. Green Building Council.

Most of the previous studies and researches were carried out based on numerical simulations. The actual energy savings due to the implementation of the selected retrofit measures were not reported. More research and application work with practical case studies on commercial office building retrofits is essentially needed. This can help to increase the level of confidence of building owners to retrofit their buildings for better performance.

References

Abdullah, A., Cross, B., and Aksamija, A. 2014. "Whole Building Energy Analysis: A Comparative Study of Different Simulation Tools and Applications in Architectural Design" In *Proceedings of ACEEE 2014 Summer Study on Energy Efficiency in Buildings.*

Aksamija, A. and Abdullah, A. 2013. "Building Technology Research in Architectural Practice: Lessons Learned from Implementations of Energy-Efficient Advanced Building Technologies" In *Proceedings of ACEEE 2013 Summer Study on Energy Efficiency in Industry.*

Basarir, B., Diri, B., and Diri, C. 2012 "Energy Efficient Retrofit Methods at the Building Envelopes of the School Buildings." In *Proceedings of Retrofit 2012.*

Heo, Y., Choudhary, R., and Augenbroe, G. 2012 "Calibration of Building Energy Models for Retrofit Analysis under Uncertainty." *Energy and Buildings 47: 550-60*

Ma, Z., Cooper, P., Daly, D., and Ledo L. 2012 "Existing building retrofits: Methodology and state-of-the-art" *Energy and Buildings 55: 889-902*

Roth, K., Westphalen, D., Feng, M., Llana, P., and Quartararo, L. 2005 “Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential”, *Final Report, TIAX LCC, Cambridge, MA.*

Standards Australia, Australian/New Zealand Standard: *Energy Audits* (AS/NZS 3598:2000), Standards Australia International Ltd and Standards, New Zealand, 2000, ISBN: 0733735762.

Tobias, L., Vavaroutsos, G., et al. 2010 “Retrofitting Office Buildings to be Green and Energy-Efficient: Optimizing Building Performance, Tenant Satisfaction, and Financial Return”. Urban Land Institute (ULI), Washington, DC.