THE GREENING OF AFFORDABLE HOUSING THROUGH PUBLIC AND PRIVATE PARTNERSHIPS: DEVELOPMENT OF A MODEL FOR GREEN AFFORDABLE HOUSING

Yong Han Ahn,[1] Yuhong Wang,[2] Kang Hee Lee,[3] and Myung Hwa Jeon[4]

ABSTRACT

The trend towards affordable, green housing highlights the need for a Green Affordable Housing (GAH) model that produces durable dwellings that are not significantly more expensive to build, cheaper to operate, healthier for their occupants, and more environmentally sound. The model should also reduce the risk of poverty for those with low and moderate incomes, be close to public transportation, and support a neighborhood that is healthy, walkable and connected to the broader community and natural environment. This case study utilized detailed interviews with occupants, town officials, a developer, and a design builder to explore how green building strategies could be applied in real-world communities with the help of a Community Development Block Grant (CDBG) from the U.S. Department of Housing and Urban Development (HUD) and contributions from other funding bodies. Focusing on the Roanoke and Lee Street housing project in Blacksburg, Virginia (VA), this study demonstrated how green building strategies can be integrated into affordable housing with help from public programs and incentives to provide houses that are more durable, no more expensive to build, cheaper to operate, healthier, more environmentally sound and less risky for their occupants. The new framework includes ways to deal with neighborhood issues such as the deterioration of housing stock and infrastructure to support the creation of a vital and healthy neighborhood with improved public services and community spirit, as well as providing an integrated design process framework that enables stakeholders to work together to achieve the goal of building green and affordable housing.

KEYWORDS

affordable housing, green building, public and private partnership, integrated design process

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INTRODUCTION

"A decent home in a suitable living environment for every American family," one of the major goals stated in the United States Housing Act of 1949, was reaffirmed in the 1990 National Affordable Housing Act with the added condition that the housing should be affordable. In this context, a widely accepted definition of *affordable* is "Housing for which the occupant is paying no more than 30% percent of his or her income for gross housing costs, including utilities" (USHUD, 2012a). As the primary purpose of affordable housing is to provide safe and decent housing for low and moderate income households, it should be designed and built to be more durable as well as being not significantly more expensive to build and cheaper to operate, thus enabling homeowners to meet other basic needs such as nutrition and healthcare (Wells, Bardacke, & Global Green USA, 2007). Affordable housing shapes the lives of its residents, alters dynamics of neighborhoods, and affects the environment in many ways. It is also closely correlated with green building, which integrates three components of sustainability, namely social equity, economy and environment (Pearce, Ahn, & HanmiGlobal, 2012; Wells et al., 2007). The main objective of green building is to provide healthy living environments that reduce the use of energy and natural resources and minimize negative impacts on local, regional, and global ecosystems through adopting green building strategies and technologies throughout the building life cycle (Ahn & Pearce, 2007; Kibert, 1994, 2008; Pearce et al., 2012). It is therefore clearly preferable to integrate green building strategies and technologies into new affordable housing developments.

For the purposes of this study, Green Affordable Housing (GAH) is defined as housing that is designed and built to be more durable, not significantly more expensive to build, cheaper to operate, more environmentally sound, and less risky for its occupants, simultaneously improving both the local neighborhood and society as a whole. It should combine the goals of affordable housing and green building to provide affordable housing for low and moderate-income households that fulfill all these objectives. To achieve the goals of GAH, this study investigated how green building features can be integrated into affordable housing developments to reduce energy and water consumption; reduce the amount of raw materials used during construction and the generation of construction solid waste; provide a healthy indoor environment for occupants; and improve the neighborhood as a whole. The study also examined project-financing mechanisms that involve multiple public and private stakeholders and tap a variety of funding sources to expedite GAH development, and a post occupancy study systematically evaluated the performance of the new dwellings and asked occupants' opinions of their new homes. These goals were achieved via a case study focusing on the Roanoke & Lee housing project located in Blacksburg, Virginia (VA). Finally, a green affordable development framework is proposed to assist all the diverse stakeholders involved in green affordable projects and thus facilitate the provision of high-quality, affordable green housing for low and moderate-income households.

BACKGROUND STUDY

To establish a background for the main case study, a literature review was carried out to examine the current status of affordable housing in the United States, green building practices including the Energy STAR building program, and government programs for affordable housing development.

Affordable Housing

Although there is no widely accepted definition affordable housing, HUD considers that monthly housing costs in adequate housing or a decent home in a suitable living environment for family should not exceed 30% of household income (USHUD, 2009, 2012a; Wallace, 1995). However, many American families do not have access to housing that meets these criteria in which to live, enjoy their home and raise their children (Sparks, 2007; Wallace, 1995). This is a long-standing problem; Wallace (1995) reported that millions of low-income U.S. households lacked decent and affordable housing, with 40% of very low and moderate-income families suffering rent burdens that exceeded 50% of their income. According to Harvard University's Joint Center for Housing Studies (1993), most low-income households in the United States were receiving no federal assistance and had a priority housing problem, resulting in a severe housing cost burden related to the shortage of adequate housing. To address the issue of affordable housing for low and moderate income households, the federal government began to provide support for affordable housing including public housing programs, subsidies for privately owned multifamily rental properties, rental assistance to tenants, and various homeownership programs (Wallace, 1995). However, even though federal funding of capital costs has helped low and moderate income householders to some extent, increases in operating costs are recognized to be a major challenge for affordable housing projects (Haberl & Kootin-Sanwu, 1999; USGAO, 2008; Wallace, 1995). According to a 2008 GAO study related to affordable housing, steadily rising energy prices represent the single most important concern for many households. For example, HUD spends more than 10% of its budget, an estimated $5 billion annually, on energy, either directly in the form of public housing operation subsidies or indirectly through utility allowances and contracts for assisted multifamily housing (USGAO, 2008). In addition to energy prices, a number of studies have identified concerns about the environment, pointing out the implications for climate change of the development and operation of new houses including affordable housing (Connelly & Miller, 2009; Shafer, 2003; Sparks, 2007; Sullivan & Ward, 2012; USGAO, 2008). Rising energy prices and concerns about the environment have stimulated interest in green building that provides healthy living environments while at the same time reducing the consumption of energy and natural resources and minimizing negative impacts on local, regional, and global ecosystems.

Green Building

Interest in the efficient use of energy and reduced environmental impacts of construction activities that is typically made possible by the adoption of green building approaches has increased markedly in recent years. The underlying purpose of green building strategies and technologies is to protect and preserve land and sites, enhance indoor environmental quality, reduce environmental impacts of materials, optimize energy performance and protect and conserve water (Ahn, 2010; Ahn, Pearce, & Ku, 2011; Pearce et al., 2012). Through implementing green building practices, it is possible to achieve a wide range of social, environmental and economic benefits including (Ahn, 2010; Ding, 2004; Pearce et al., 2012):

- Environmental benefits
  - Enhance and protect biodiversity and ecosystems
  - Improve air and water quality
  - Reduce waste streams

    - Conserve and restore natural resources
    - Reduce global warming and climate change
- Economic benefits
    - Reduce operating and maintenance costs
    - Improve the value of the home
    - Optimize life-cycle economic performance
    - Reduce civil infrastructure costs
    - Improve the image of building
- Social benefits
    - Enhance occupant comfort and health
    - Heighten aesthetic quality
    - Improve overall quality of life.

For example, it has been shown that the value of a home increases by about $20 for each $1 reduction in annual utility bills after controlling for living space and other home characteristics (Nevin, 2009). Other research conducted in the 1970s and 1980s found that home energy efficiency increased home values regardless of the type of heating fuel, providing some evidence to suggest that the premium for energy efficient homes reflected a rational trade-off between utility bill savings and the home's tax, mortgage and interest costs (Corgel, Geobel, & Wade, 1982). HUD is also looking at ways to increase energy efficiency in public housing and thus reduce excess utility costs for the occupants (Shafer, 2003). HUD's Energy Action Plan and Energy Strategy includes specific actions in support of these objectives and HUD has taken steps to implement many of these actions. Five major objectives are specified in HUD's energy strategy (USGAO, 2008):

- Objective I: Strengthen partnerships with federal agencies and local communities to promote Energy Star and improve energy efficiency in the residential sector;
- Objective II: Strengthen incentives and implement new statutory requirements for improved energy efficiency through HUD programs;
- Objective III: Provide training and technical assistance to support better energy efficiency for homeowners, renters, and property owners;
- Objective IV: Establish measures to track progress in reducing energy consumption and ensure accountability; and
- Objective V: Support further research and technological development in this area.

In September 2002, HUD, the Department of Energy (DOE) and the Environmental Protection Agency (EPA) signed a memorandum of understanding to promote the use of Energy Star Products in HUD's inventory of public assisted and insured housing (Shafer, 2003). In addition to their improved energy efficiency, green homes mitigate global warming since home energy use generates 21% of all greenhouse gases emitted in the United States (Schmidt, 2008).

However, one of the main challenges facing green home advocates has been the initial cost premium; cost perceptions are also a major obstacle for green homeowners and builders (Ahn & Pearce, 2007; Ahn et al., 2011; Kats, 2003a, 2003b; Pearce, 2008; Pearce et al., 2012; Schmidt, 2008; USGSA, 2004). Consequently, a crucial success factor for green homes is to minimize the first cost premium compared to conventional homes while at the same time

improving home energy and water efficiency; improving indoor air quality; protecting or preserving both land and site; and reducing the environmental impact of materials through green building strategies and technologies.

Green Affordable Housing

Integrating affordable housing and green building approaches can create synergies that make it possible to provide GAH for low and moderate-income householders in spite of these challenges. To achieve GAH, housing is designed and built to be more durable, not significantly more expensive to construct, cheaper to operate, more environmentally sound, and less risky to the occupants, while at the same time improving the neighborhood and society as a whole. Through GAH, low and moderate income householders find it possible to improve the affordability and durability of their housing, creating smaller environmental footprints and improving occupants' health, performance and well-being. They can also reduce operating costs (primarily though lower water and power bills) and experience a better sense of community and pride in owning or living in a superior home, thus helping to break the cycle of generational poverty (Connelly & Miller, 2009; Sparks, 2007; Wells, 2006). As a result, it is vital to develop a framework of green affordable housing that can create effective synergies between affordable housing and green building, while at the same time minimizing the initial cost premium of implementing green building strategies.

Government Affordable Housing Programs

The federal government has provided support for affordable housing, chiefly for low and moderate-income householders, for some time (Wallace, 1995). One of the main programs in this area is the Community Development Block Grant (CDBG), authorized under Title 1 of the Housing and Community Development Act of 1974. The purpose of the CDBG is to support the development of viable urban communities by providing decent housing and a suitable living environment and by expanding economic opportunities, principally for low-and moderate-income householders. It encompasses eligible activities such as the rehabilitation of residential and non-residential structures and activities related to energy conservation and renewable sources (USHUD, 2012a). The federal Self-help Homeownership Opportunity Program (SHOP) also awards grants to eligible national and regional non-profit organizations and consortia with which to purchase home sites and develop or improve the infrastructure needed to set the stage for sweat equity and volunteer-based homeownership programs for low-income individuals and families. These grants must be used for eligible expenses to develop decent, safe and sanitary non-luxury housing for low-income individuals and families who otherwise would not become homeowners (USHUD, 2012b).

OBJECTIVES AND RESEARCH METHOD

The primary objective of this study was to identify how GAH can concurrently achieve the goals of green building and affordable housing, with private and public partnerships working together supported by federal government programs. We then went on to construct a framework for GAH development that can be applied to other similar projects in the future to achieve the goals of building homes that are both green and affordable for low and moderate income Americans. To achieve these objectives a qualitative research approach was adopted, specifically a case study research method based on a series of in-depth interviews using a

semi-structure interview method with the town manager, architect, builder, and occupants of the Roanoke & Lee housing project in Blacksburg, VA. The authors developed an interview guide including a list of questions and topics that had to be covered during the interview. The interview questions covered the overall goals of the project, the relationships among stakeholders, green building practices relevant to affordable housing developments, the project delivery system, success factors of the project, challenges associated with the project, and so on. This case study plus interview approach proved to be a particularly effective strategy for this research as it involved an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence, thus enabling the collection of highly detailed, in-depth, and comprehensive information and facilitating its analysis to pinpoint the specific variables relevant to GAH (Robson, 2002; Yin, 2003). A post-occupancy study was also conducted to systematically evaluate the residents' opinions of their new houses and the green building strategies and technologies implemented, from the perspective of the people actually using them. The building occupancy survey was developed by the authors utilizing selected questions from the "Occupant Indoor Environmental Quality (IEQ) Survey" originally developed by the Center for the Built Environment at the University of California at Berkeley (Abbaszadeh, Zagreus, Lehrer, and Huizenga, 2006). Data collected for the Roanoke & Lee Street case study and the building occupancy survey were then used to develop a GAH framework to support the goals of green building and affordable housing while minimizing initial cost premiums.

ROANOKE & LEE STREET DUPLEX PROJECT

Project Description

The Roanoke & Lee Street (RLS) project is located in the town of Blacksburg, VA, the home of Virginia Polytechnic Institute and State University (Virginia Tech), with a population of 42,620 according to the 2010 U.S. Census. The town had a very low median house income of $29,617 and a relatively high median gross rent of $826 in 2011 (US Census, 2013). The subject of this case study, the RLS project is part of the Roanoke-Lee Street Neighborhood Improvement project funded by the Virginia Community Development Block Grant (VCDBG). This project was designed to improve the RLS neighborhood by upgrading 2,807 feet of eight-inch water lines, 300 feet of twelve-inch sewer lines, and 2,053 of six-inch sewer lines; installing 15 new street lights; constructing 1,220 feet of five-foot wide sidewalks, 3,374 feet of curbs and gutters, and 400 feet of storm drains; repaving eight neighborhood streets; rehabilitating 7 owner-occupied homes and 10 renter-occupied homes, and substantially reconstructing 3 homes; constructing fourteen duplex units for new home owners; providing down-payments of $3,000 for the fourteen new housing units; demolishing one dilapidated structure; and constructing a 410-foot road extension, complete with water lines, sewers, curbs and gutters, sidewalks, storm drains, and street lighting. The project was funded by a combination of private and public funds including the VCDBG of $1,099,394, a grant from the town of Blacksburg of $530,740 and private funds for housing development.

The RLS duplex project, part of the Roanoke-Lee Street Neighborhood Improvement project (Figure 1) is a new affordable housing development comprising 14 green, affordable, duplex housing units. This development utilized four building designs for the duplex units, providing a total of 16,100 sq. ft of living space spread over 1.82 acres on two sites. These new green affordable homes are located in an established neighborhood with many trees and

sidewalks within walking distance of public bus routes, Blacksburg's downtown area, and the Virginia Tech campus. Since this development was specifically designed to offer affordable housing and contribute to the town's revitalization, home sales were restricted to first-time homebuyers with incomes at or below 80% of the area median.

This RLS GAH development was developed by Community Housing Partners (CHP), a regional, nonprofit housing and community development corporation located in Christiansburg, VA, in partnership with the town of Blacksburg. The houses were designed by the Community Design Studio (CDS), the in-house design team at CHP, and all buildings were constructed by CHP. Several local organizations provided additional assistance based on their prior experience in providing affordable housing and improved housing conditions for low and moderate-income families; these included the Virginia Center for Housing Research, the Community Design Assistance Center and the Department of Building Construction at Virginia Tech.

House Layout and Design

The RLS project comprises 14 units of duplex housing utilizing four building designs, of which nine are two-bedroom units and five three-bedroom units. Each duplex housing unit has two floors and is approached via a porous paving area that serves as a car driveway, a sidewalk and a rain garden with native landscaping (Figure 2). The first floor consists of a kitchen, a bathroom, a living room and dining room, with bedrooms and a bathroom on the second floor.

Project Development and Financing

As this project was a public and private partnership development designed to support the dual goals of affordability and green building, the town of Blacksburg and CHP both played significant roles throughout the housing development process, from management to construction, marketing and financing. In order to provide affordable housing for low and moderate income first home buyers, the project team secured funding from the Blacksburg Community Development Block Grant, the Virginia Department of Housing & Community Development,

FIGURE 1. Roanoke and Lee Street housing project description.

Location: Blacksburg, VA

Size: 14 units, totaling 16,100 sq.ft on 1.82 acres

Project completion: 2007

Affordability: All units sold to households earning 43–80% of the area medium income

Project team:
- Community Housing Partner
- Community Design Studio (CDS)
- Virginia Center for Housing Research
- Town of Blacksburg

Development cost:
- Total funding: $3,307,175

Cost/Savings of greening:
- Total cost of greening: $246,600
- Rebates and grants: $57,000
- Net cost of greening: $189,600

FIGURE 2. Typical RLS duplexes.

NeighborWorks American-Home Depot, Enterprise Green Communities, the Housing Assistance Council (HAC) Green Fund, and the HAC Self-Help Homeownership Opportunity Program (SHOP). The project team also arranged below market rate financing from the Federation of Appalachian Housing Enterprises and other loan agencies to lower the cost of the construction loans and thus increase affordability for the eventual homebuyers. The total budget for the 9 two-bedroom units and 5 three-bedroom units, ranging in size from 1,001 sf to 1,317 sf, was $3.3 million. To further offset the cost of the project, the project team raised an additional $823,175, 25 % of the total, from the following sources:

- Blacksburg–CDBG $356,175
- Virginia DHCD Home funds: $200,000
- NeighborWorks–Home Depot: $30,000
- Enterprise Green Communities: $17,000
- Housing Assistance Council (CAC) Green Fund: $10,000
- HAC SHOP: $210,000.

The project team was thus able to both reduce the overall cost of the project and offset the initial cost premium due to the incorporation of green building features in the new houses. In addition, the CDBG provided down-payment assistance of $3,000 to those purchasing the 14 new housing units. Funding specifically related to the project's green building features consisted of the $57,000 in grants from the Enterprise Green Communities Initiatives, CAC Green Fund, and NeighborWorks-Home Depot fund. These funding sources helped the project team to offset the initial cost premium, reducing the $246,600 for the green building features to $189,600. As a result, the low and moderate-income first time homebuyers were able to buy the 14 green affordable homes for between $173,500 and $184,500.

TABLE 1. Green features incorporated in the RLS duplex project.

Site Design and Landscaping • Utilize existing roads and utility infrastructure • Achieve maximum allowable density while preserving green space • Protect existing vegetation • Use pervious paving • Implement a comprehensive erosion and sediment plan **Energy** • Exceed code requirements for insulation • Increase roof overhangs for climate control • Install low-e windows • Install compact fluorescent lighting • Daylight sensors for exterior lighting • Building commissioning • Energy audit (HERS score of 75)	**Water** • Low-flow water fixtures • Dual flush toilets • Rain barrels • Rain gardens with native tree species **Material and Resources** • Apply advanced framing techniques to reduce the amount of lumber used and the waste generated during construction • Recycled content materials **Indoor Air Quality** • Low volatile organic compound (VOC) paints, primers, adhesives caulks, and sealants

Green Building Strategies

The primary goals of affordable housing developments are to provide safe, decent, and affordable housing that contributes to the development of strong and economically vibrant communities, all of which are supported by green building methods. Low operating costs (especially energy and water bills), low maintenance costs, and proximity to public transportation are also linked to green building objectives. As a result, the project team including CHP, the town of Blacksburg and CDS made a commitment to develop high quality green affordable homes with many green features to lower operating costs in the long-term and provide healthier living environments for their occupants. Throughout the development process, the project team adopted integrated design approaches that both supported efficient and innovative design and facilitated the adoption of green building strategies at every stage of the design and construction. These integrated green building strategies are shown in Table 1.

Integrated Design Process

CHP implemented an integrated design process whereby the CDS, the town of Blacksburg, CHP, the construction manager, the energy consultant, the project manager, town citizens, and the project engineer worked together to produce a thorough, efficient and innovative design. According to the Director of Design at CDS, the project team set three goals:

- Affordability
- Part of the community
- Green building features and performance.

To achieve these three development goals, the project team conducted three charrettes, consisting of integrated public and design meetings that included all the stakeholders involved in the effort to build green affordable homes (Figure 3). The meetings enabled local residents to present their opinions of this development including the need to incorporate a neighborhood park, create sidewalks, relocate utility lines underground, and clean neighborhood streets. Local organizations and representatives of the town of Blacksburg were also included in the charrettes as part of their commitment to develop this green affordable project as a

FIGURE 3. Integrated design meeting (charrette) for green affordable housing.

private-public partnership. At the design charrettes, the project team identified green strategies that were applicable to the project; defined the strategies that could be applied to offset the first cost premium of each of these strategies; explored the impact of the new development on the neighborhood as a whole; and discussed who would be the potential buyers of the houses. In addition, the project team members attempted to lower the initial cost premium of green features through advanced framing techniques, choosing the smallest possible heating, ventilating and air conditioning (HVAC) equipment using a recognized building energy software tool, conducted a life-cycle cost analysis (LCCA) for specific green materials and systems, and so on.

Site Design and Layout

The project was split between two separate sites in close proximity since this was an in-fill development in the neighborhood of Roanoke and Lee Street. The Phase I Environmental Assessment was undertaken by a licensed engineer to determine the condition of the existing sites. The site plan also took into account the need to reduce the building footprints, preserve existing trees and vegetation, incorporate a rain garden, and set aside open spaces and recreation areas (Figure 4). This thorough environmental assessment made it possible to reduce the building footprint and hence significantly lower the construction cost of the project.

The project is located in the center of the town within walking distance (1/4 of a mile) of downtown Blacksburg and the Virginia Tech campus, thus allowing the residents easy access to public transportation (Blacksburg Transit), government offices, the Blacksburg farmer's market, restaurants, libraries, shopping, recreation, and other businesses. Therefore, the project not only limits the need for automobiles, with an associated reduction in greenhouse gas emissions, but also encourages residents to use public transportation or walk.

Energy

Energy efficient design was the most important design strategy adopted in this project to achieve the dual goals of green building and affordability. Energy efficiency was achieved through effective insulation (Slab: R-7.5; Wall: R21; Ceiling: R 38), advanced framing techniques, increased roof over-hangs for climate control, low-e windows, the use of 100% Energy Star rated appliances, and compact fluorescent lighting. The energy consumption of each

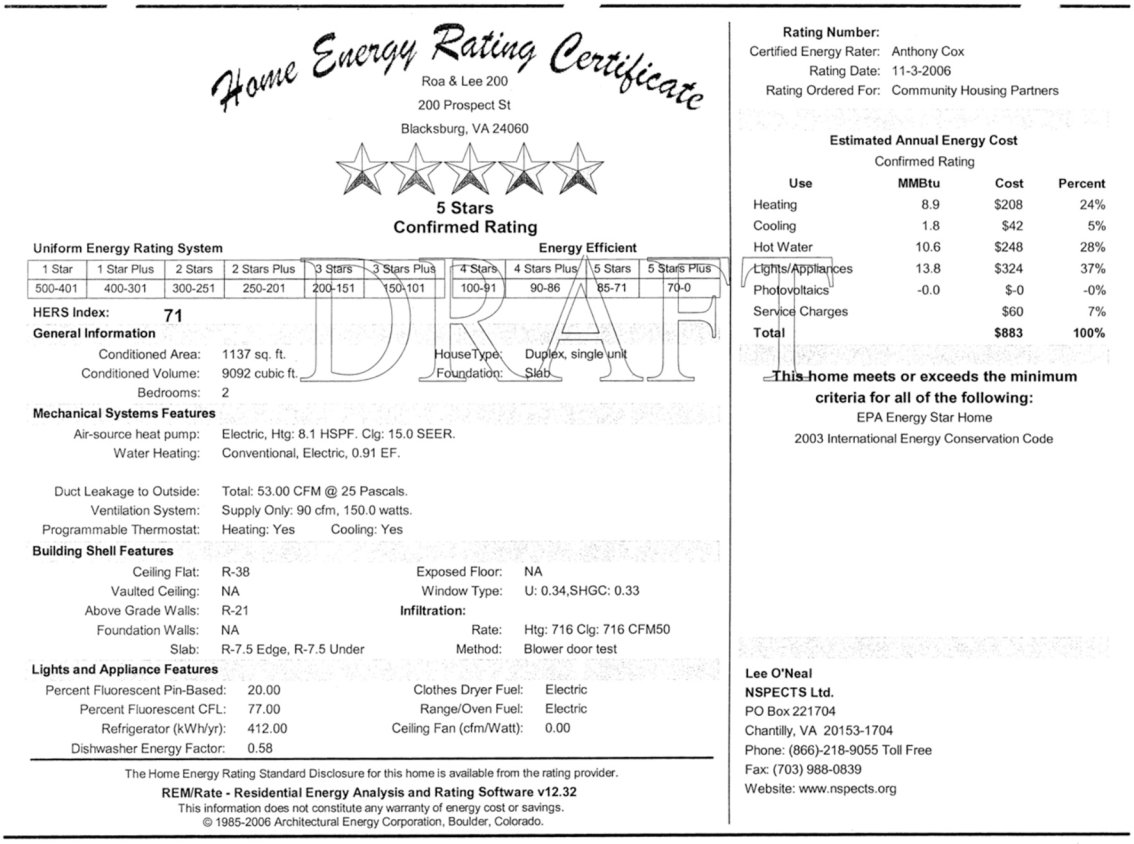
FIGURE 4. Rain garden and recreation park.

building was predicted using the "Residential Energy Analysis and Rating Software V12.32" package developed by Architectural Energy Corporation in Boulder, Colorado. The integrated energy saving strategies were predicted to result in a 33% reduction in electricity usage for an average unit in the first year of occupancy (11,286 kWh versus 16,856 kWh for a typical new home of the same size based on predicted results by the Energy Star Certification by the US Environmental Protection Agency (USEPA)). All external lights were fitted with daylight sensors in order to shut off automatically during the daytime. To improve energy efficiency and optimize the size of the HVAC system, building energy software was utilized to determine the smallest heating, ventilation and air conditioning equipment needed for each unit. Choosing and installing the optimal size of HVAC system should reduce both the initial cost of a high efficiency HVAC system and the subsequent operation costs once the occupants move in.

Commissioning for the homes was performed as part of the Energy Star Certification process, including energy modeling, ductwork and building envelop testing, and HVAC system testing. Residential Energy Service Network (RESNET) certified staff performed pre-occupancy tests, including dust sealing and post construction blower door tests, to confirm that the building envelope's air leakage characteristics were satisfactory (Figure 5). Figure 6 shows the results for one of the project buildings. All the buildings were found to exceed the Home Energy Rating System (HERS) targets with an average score of 75, and were therefore awarded five Energy Stars by the Energy Star rating system developed and implemented by US Environmental Protection Agency and US Department of Energy. Based on its home energy-rating certificate, the house described in Figure 6 consumed 8.9 MMBtu for heating, 1.8 MMBtu for cooling, 10.6 MMBtu for hot water, and 13.8 MMBtu for lights and appliances.

FIGURE 5. Improved ceiling insulation to R-38.

FIGURE 6. Home energy rating certificate, incorporating energy saving opportunities.



Home Energy Rating Certificate

Roa & Lee 200
200 Prospect St
Blacksburg, VA 24060

5 Stars
Confirmed Rating

Uniform Energy Rating System — Energy Efficient

1 Star	1 Star Plus	2 Stars	2 Stars Plus	3 Stars	3 Stars Plus	4 Stars	4 Stars Plus	5 Stars	5 Stars Plus
500-401	400-301	300-251	250-201	200-151	150-101	100-91	90-86	85-71	70-0

HERS Index: 71

DRAFT

General Information
Conditioned Area: 1137 sq. ft.
Conditioned Volume: 9092 cubic ft.
Bedrooms: 2
HouseType: Duplex, single unit
Foundation: Slab

Mechanical Systems Features
Air-source heat pump: Electric, Htg: 8.1 HSPF. Clg: 15.0 SEER.
Water Heating: Conventional, Electric, 0.91 EF.
Duct Leakage to Outside: Total: 53.00 CFM @ 25 Pascals.
Ventilation System: Supply Only: 90 cfm, 150.0 watts.
Programmable Thermostat: Heating: Yes Cooling: Yes

Building Shell Features
Ceiling Flat: R-38
Vaulted Ceiling: NA
Above Grade Walls: R-21
Foundation Walls: NA
Slab: R-7.5 Edge, R-7.5 Under
Exposed Floor: NA
Window Type: U: 0.34,SHGC: 0.33
Infiltration:
Rate: Htg: 716 Clg: 716 CFM50
Method: Blower door test

Lights and Appliance Features
Percent Fluorescent Pin-Based: 20.00
Percent Fluorescent CFL: 77.00
Refrigerator (kWh/yr): 412.00
Dishwasher Energy Factor: 0.58
Clothes Dryer Fuel: Electric
Range/Oven Fuel: Electric
Ceiling Fan (cfm/Watt): 0.00

The Home Energy Rating Standard Disclosure for this home is available from the rating provider.
REM/Rate - Residential Energy Analysis and Rating Software v12.32
This information does not constitute any warranty of energy cost or savings.
© 1985-2006 Architectural Energy Corporation, Boulder, Colorado.

Rating Number:
Certified Energy Rater: Anthony Cox
Rating Date: 11-3-2006
Rating Ordered For: Community Housing Partners

Estimated Annual Energy Cost
Confirmed Rating

Use	MMBtu	Cost	Percent
Heating	8.9	$208	24%
Cooling	1.8	$42	5%
Hot Water	10.6	$248	28%
Lights/Appliances	13.8	$324	37%
Photovoltaics	-0.0	$-0	-0%
Service Charges		$60	7%
Total		**$883**	**100%**

This home meets or exceeds the minimum criteria for all of the following:
EPA Energy Star Home
2003 International Energy Conservation Code

Lee O'Neal
NSPECTS Ltd.
PO Box 221704
Chantilly, VA 20153-1704
Phone: (866)-218-9055 Toll Free
Fax: (703) 988-0839
Website: www.nspects.org

Water

To improve water efficiency, all water fixtures in the units were low-flow, water-conserving fixtures. Dual flush toilets, low flow faucets and showerheads, Energy Star clothes washers and dishwashers, rain barrels and rain gardens were installed in all the project duplexes (Figure 7). The water saving strategies and technologies incorporated made it possible to minimize the use of potable water, thus reducing both the cost to the homeowner and the burden on municipal water supply and wastewater systems. The project team also planted native trees and vegetables that required little or no irrigation, thus not only further reducing the use of potable water but also providing valuable habitat for the local wildlife and promoting bio diversity.

FIGURE 7. Rain barrel for irrigation.

Material and Resource Conservation

The project adopted innovative and/or green strategies to reduce construction waste and lower material consumption. For example, advanced framing techniques were utilized to reduce the amount of lumber used and the waste generated during construction for the Roanoke and Lee Street project. Wall studs, floor joists, and roof rafters were spaced 24 inches on-center, and two stud corner framing and inexpensive drywall clips for drywall backing were used instead of studs to lower costs and reduce material consumption. Materials were selected with a view to reducing raw material consumption, including oriented strand board (OSB) wall and roof sheathing, cellulose wall and attic insulation, fiber cement board siding, open-cell porous paving, concrete with 15% fly ash recycled content, and Trex wood/plastic composite lumber for decking.

Indoor Air Quality

To provide a healthier indoor environment, low VOC paints, primers, adhesives, caulks, and sealants were used throughout. Hardwood flooring and ceramic tiles were installed as an alternative to carpet or PVC flooring to reduce off-gassing and enhance durability. Each house was designed to introduce sufficient daylight to create a warm and inviting indoor environment (Figure 8).

FIGURE 8. Daylighting provides an attractive indoor environment.

Neighborhood Development

This project was initiated as part of the Roanoke-Lee Street neighborhood development project, which was designed to improve this historic neighborhood close to the town center. From being a rough and undesirable neighborhood with deteriorating housing stock and infrastructure, the project aimed to create a vibrant and vital community by improving public utilities, roads and sidewalks; rehabilitating 7 owner-occupied homes and 10 renter-occupied homes; and substantially reconstructing another 3 homes in addition to the 14 new duplexes (Figure 9). As part of this overall development, the GAH project made synergic effects to

FIGURE 9. Neighborhood development.

revitalize the neighborhood in conjunction with local public transportation and community amenities. In an interview, the town planner stated that the project benefited an estimated 51 existing residents, of whom 27 (53%) were low and moderate-income residents residing in the neighborhood, as well as an estimated 76 new residents moving in to the new infill housing and converted student housing.

Green Affordable Loan Programs for the Project

An important aspect of any affordable housing project is the opportunity it provides for public programs to help low and moderate income first-time homebuyers. As noted above, a number of public programs and incentives contributed to the RLS project. The specific benefits for each homebuyer were as follows:

- The lower initial price for each housing unit
- A low interest rate loan over 30 to 40 years, consisting of:
  - $76,500: Interest rate of 3.75%—Federation of Appalachian Housing Enterprises
  - $30,000: Interest rate of 0.00%—Federation of Appalachian Housing Enterprises
  - $17,870: Interest rate of 0.00%—CDBG Block Grant
  - $40,000: Interest rate of 0.00%—Community Housing Partner Cooperation loan arrangement
  - $12,000: Interest rate of 0.00%—Self-help Homeownership Opportunity Program
- Help with the down payment and closing costs: $3,000.

These low or no interest mortgage loans enabled low and moderate-income first-time homebuyers to afford the new green affordable housing units with very low payments. These public programs and incentives thus provided an opportunity for low and moderate-income individuals and families who otherwise would never become homeowners to buy a green affordable home.

Residence Education for New Green Affordable Homeowners

To help these first-time homebuyers to operate and maintain their green affordable homes, an electronic homeowner's manual was developed through a partnership between CHP staff and the Department of Building Construction at Virginia Tech and provided to the homebuyers free of charge.

Each homebuyer was given an Owner's Operation and Maintenance Manual as well as a "Homeowner's Guide to Green Community Housing Partner Corporation" containing information on how to maintain and operate their new home's green features. This manual was incorporated into an electronic homeowner's operation and maintenance manual for green features (http://www.nw.org/network/green/documents/RoanokeLeeHomeownersManual.pdf). Each homeowner can check their homeowner's guide to green features when they need to know how to operate any of the green strategies and technologies implemented in their home and encourages them to learn about basic green building strategies and technologies. CHP also conducts a post-purchase homebuyer education session to cover financial planning and budgeting for maintenance, operation and maintenance, and improvements that helps the project's first time homebuyers learn how to use the installed systems in their house efficiently.

Post Occupancy Satisfaction

The researchers conducted a post occupancy evaluation for this study to help develop a better understanding of precisely how living in the new units impacted the occupants' lives, identify their level of satisfaction with GAH, and solicit suggestions on ways to improve the design and development of future GAH projects. This survey was returned by eight of the twelve homeowners who had already moved in to the new duplexes in March 2012. The first question was related to their overall satisfaction with the design of their unit using a 5-point Likert-scale (ranging from unsatisfied-1 to very satisfied-5). The survey results indicated that over 75% of all respondents indicated that they were either satisfied or very satisfied with their green affordable housing unit (Table 2).

TABLE 2. Satisfaction with the design and overall quality of the unit.

Rating	Design (#)	Design (%)	Quality (#)	Quality (%)
1 (Unsatisfied)	1	12.5%	1	12.5%
2	0	0%	0	0%
3 (Neutral)	1	12.5%	1	12.5%
4	4	50%	3	37.5%
5 (Very Satisfied)	2	25%	3	37.5%

The next questions were related to their satisfaction with some of the green features of their new home (Table 3). The survey results indicated that 75% of the respondents were either satisfied or very satisfied with the air quality and temperature in their homes. Most of the respondents also indicated that they were satisfied with the landscaping, open space and recreation area provided, and with their pervious paving parking slot. However, only half of the respondents were satisfied with the installation of their rain barrel; the two respondents who were unsatisfied reported problems with some parts of the rain barrel falling off.

TABLE 3. Satisfaction with some of the green features of the housing unit.

Rating	Air Quality	Temperature	Landscape	Open Spaces & Recreation Park	Rain Barrel	Pervious Paving
1 (Unsatisfactory)	1	2	0	1	2	0
2	0	0	1	1	0	0
3 (Neutral)	1	0	2	1	2	4
4	2	3	2	0	1	2
5 (Very Satisfactory)	4	3	3	5	3	2

The next question was related to their satisfaction with the level of daylight in their home. Seven out of eight respondents indicated having a "just right" level of natural light, although one respondent indicated that they thought it too low. Subsequent questions were related to their perception of energy and water use and their associated costs. Seven of the eight respondents thought that their units were efficient and were likely to save them money by reducing energy costs (Table 4). All the respondents believed that their units were performing well in reducing water use.

TABLE 4. Satisfaction with the level of energy and water consumption.

Rating	Energy Use and Cost	Energy Use and Cost (%)	Water Use and Costs (#)	Water Use and Costs (%)
1 (Not at all)	1	12.5%	0	0%
2	0	0%	0	0%
3 (Somewhat)	1	12.5%	2	25%
4	4	50%	4	50%
5 (Very efficient)	2	25%	2	25%

In addition, the study asked about their level of satisfaction with the interior layout of their home. The purpose of this question was to identify ways to improve the design of rooms for green affordable housing. As Table 5 shows, the kitchen was reported to cause the most dissatisfaction. In the occupant interviews, three respondents stated that the kitchen was small and had insufficient ventilation. Two respondents also thought that the unit's bedrooms were too small.

TABLE 5. Satisfaction of rooms in the house.

Rating	Bedrooms	Kitchen	Bathrooms	Dining Room	Laundry room
1 (Poor)	0	3	2	1	0
2	0	0	0	0	0
3 (Neutral)	3	2	5	5	7
4	2	1	0	0	0
5 (Excellent)	3	2	2	2	1

The survey concluded by asking several open-ended questions, the first of which was "What aspects of the house do you especially like?" Four respondents singled out "daylighting" and "wood floor" as their favorable aspects of their new homes. Two respondents commented that they enjoyed the location of the unit on an improved street. The following were also identified as favorable features of the units:

- Playground in backyard
- Size of the unit is appropriate for first-time homebuyers
- Energy and water efficiency, with Energy Star appliance and water saving fixtures
- Rain barrel
- Open design of living room / dining room.

The next open-ended question was "What aspects of the house do you especially dislike?" Three respondents replied that the weakest aspects of their unit were inadequate storage areas and closets and the small kitchen and its quality. Other weaknesses were:

- Rain garden (too labor intensive)
- Soundproof construction
- Floor plan
- Cold air around windows & doors.

The final question asked about government incentives and affordable housing programs, including low interest rate loan programs and assistance with down payments and closing

costs. Five respondents stated that these programs had helped them to buy the house since the programs reduced the interest payments significantly, as well as the down payment and closing costs.

Challenges of the Project Development

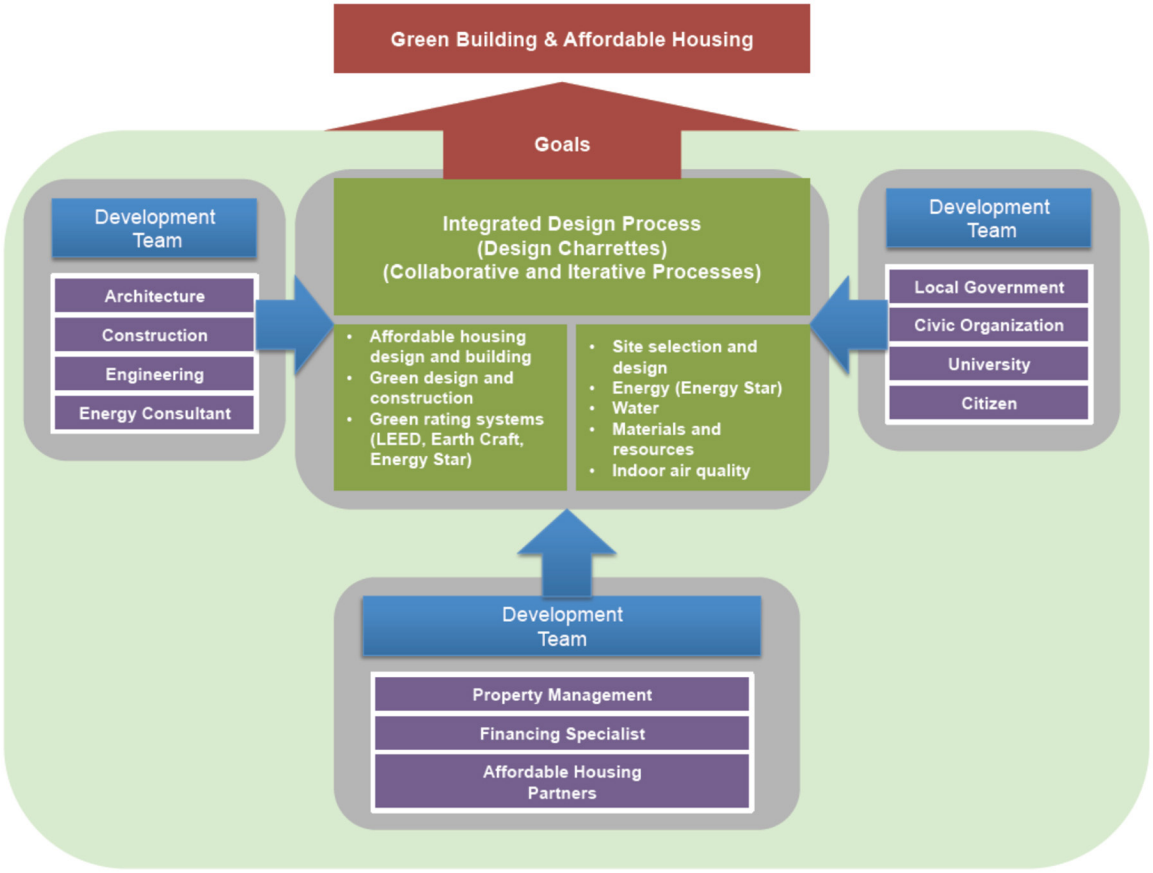
The study identified several challenges associated with this green affordable housing development project. Of these, the most important was the escalation of construction costs, in particular the additional costs associated with green building strategies and technologies. The second challenge was to foster an interest in green affordable housing concepts and approaches in neighborhood residents, many of whom knew nothing about green building. The third challenge was to select the final occupants of the new dwellings from among the many low-medium income households applying to buy units in this green affordable housing project. These major challenges were all resolved through extensive collaborative work among all the stakeholders, especially local community leaders and representatives of the town of Blacksburg, a developer of the project. The cost escalation challenge was solved by applying for various government and organization incentives and grants. The second challenge was solved by holding several education and town hall meetings to education local people regarding the goals and benefits of this green affordable housing project. The final challenge was met by the project team developing a set of clear selection criteria to choose the families that would be the best-fit for this development.

DISCUSSION AND DEVELOPED FRAMEWORK

This study identified a framework that can be applied to achieve the dual goals of green building and affordable housing while minimizing the initial cost premium of implementing green building strategies and reducing operation and maintenance costs. To achieve the study objectives, a background study of affordable housing, green building for homes, green affordable housing, and project financing was performed to support the subsequent case study of the Roanoke and Lee Street green affordable housing project designed to offer societal, economic, and environmental benefits to low and medium income householders and their community. The new GAH framework consists of five best practices, namely close collaboration among all stakeholders to achieve the goals of green building and affordable housing; infill development; the availability of financing for green affordable housing projects; education for the new home owners; and a change in the cultural perception of affordable housing.

The first step in the new GAH framework was to identify the project stakeholders, including architects, engineers, a contractor, and a developer who have experience in green affordable housing development. A partnership was then established with local government and civic organizations, as the project was expected to have a substantial impact on efforts to improve the community. The development team also opted to participate in a private and public partnership for the development because a green affordable housing project involves a complex web of public financing and incentives, including two large grants (CDBG $356,175 and Virginia DHCD home funds $200,000) and a number of smaller ones, as well as links to other neighborhood development projects. Furthermore, the project stakeholders needed to build their understanding of applicable green building strategies and technologies; learn about green building incentives and grant programs; and recognize the value of the integrated design process. The GAH framework developed in this study to achieve the dual goals of green

FIGURE 10. Green affordable development framework.



building and affordable housing is shown in Figure 10. One of the most important factors contributing to the success of GAH in this project was the implementation of an integrated design process that involved all the stakeholders working together to achieve these goals. The use of this type of integrated design process also optimizes all the systems in the project, thus minimizing the initial cost premiums and lowering operation costs once the house is occupied. The project team conducted a comprehensive study to identify and apply for as many grants and incentives as possible related to affordable green building housing development. Finally, the project team developed an operation and maintenance manual covering all the project's green features to help the occupants operate and maintain their new properties and provided a training and education session at the housing hand over stage.

CONCLUSION

This case study and post occupation survey of the RLS project in Blacksburg, VA, was used to develop a green affordable housing development framework that could achieve the dual goals of green building and affordable housing. With regard to the green building features, an important finding was that infill development that utilizes an existing infrastructure can be particularly effective as it revitalizes the local neighborhood by taking advantage of well-established public transportation links and community amenities. To improve energy and water

efficiency, the project team considered a number of strategies and technologies that would significantly reduce energy and water consumption in the long term and thus lower the monthly utility bills over the building's lifetime, reducing the householders' utility bills and improving affordability. The project team chose environmentally friendly materials, appliances and techniques for the construction to make the home healthier to build and live in. The major challenge of reducing the initial cost premium of these green building features was successfully offset through existing rebate and incentive programs such as the Enterprise Green Community Initiative and the Housing Assistance Council program.

Another important aspect of the affordable housing development process identified by the study was the success the development team had in arranging low interest loans to reduce the new homeowners' interest payments. In the RLS duplex project, the project team successfully arranged loans charging 0% interest for over 50% of the total mortgage loan. The resulting low interest rate significantly reduced the monthly mortgage payment for these buyers, all of whom had incomes below the national average. Additional support for the down payment and closing costs also helped these low and moderate-income first-time homebuyers to purchase their own homes.

An important part of the project was the education program to help the homeowners understand the green strategies and technologies incorporated in their new homes and teach them how to maintain and use them properly. This could be extended in future projects to include information on all the equipment and appliances installed in their home. One option could be to work with a construction management program to develop a custom-made interactive electronic homeowner's manual, although the conventional manual used here worked well for the buyers. The development team's post occupancy survey identified which aspects of their new homes occupants were most satisfied and dissatisfied with and allowed them to make suggestions for further improvements. The survey singled out an improved design and layout for the kitchen as being most helpful in improving occupants' satisfaction with their new home.

The next success factor for similar projects would be to set up a suitable framework that facilitates collaborative work and encourages forums among all stakeholders, including town officials, developers, town civic leaders, and local citizens. In addition, it is very important to have a highly-experienced project team who know how to motivate all the stakeholders to work together as a single team with clearly developed goals and objectives.

The final verdict on the success or otherwise of this project should go to the city planner for the Town of Blacksburg. He considers that not only has the RLS GAH successfully addressed one of the most significant barriers to efforts to improve our nation's affordable housing, namely its bad image, but the project has also significantly revitalized this previously run-down, historic neighborhood and changed the perception of many citizens as to what should constitute affordable housing.

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