HIGH ENERGY-EFFICIENCY RETROFITS TO BALTIMORE'S ROW HOMES

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INTRODUCTION

The idea of energy-efficient and sustainable housing in the urban context is something that many large metropolitan cities are investigating. Not only is this idea applied to new buildings, but it is also applicable to renovations of existing structures, which are experiencing problems unique to the urban setting. Oak Ridge National Laboratory (ORNL), along with Argonne National Laboratory (ANL), initiated a research-based project at Morgan State University to investigate this idea. Using new and existing technologies in the field of building energy-efficiency, Morgan State University investigated and applied these technologies and methods of construction to obtain energy-efficient and sustainable housing in the urban context. The research team established at Morgan includes student investigators in the fields of architecture and engineering, as well as faculty investigators. The purpose of involving students into this project is to allow the students to obtain useful knowledge in research and administration of that research into "real-life" projects. These projects would foster professional development of the students and their faculty in the "real" world of the built environment.

THE PROBLEM

A major problem in the housing community in Baltimore, Maryland is the use of pre-existing buildings. The problem of housing in Baltimore raises the broad question, how do we get people interested in living in the urban core of America again? Prospective residents are sometimes very leery of living in the core of an urban city. Since the homes for this research project are located in a less than favorable area, why would someone want to purchase a rehabilitated existing house in the city’s core?

Another aspect of the problem that this research team discovered went beyond sparking interest in purchasing of these homes, but also how to fix them, in simple terms. The existing row homes are located in eastern Baltimore, Maryland. These homes are conveniently located adjacent to the John’s Hopkins Medical Center and Hospital. Unfortunately, it is also located a few blocks from the kind of “urban decay” that is affecting many large, metropolitan cities in the U.S.

Providing healthy, economical, highly energy efficient and environmentally conscious housing was a major objective of the research team, and could increase the desirability of living within the urban core.

THE RESEARCH PROJECT

ORNL and ANL initiated the research project for the Department of Energy’s (DOE) Office of Buildings Technology. The purpose of the research project is to develop high-performance, energy-efficient retrofits of existing row homes in Baltimore, Maryland. These efficiency enhancements are to optimize building envelope improvements, mechanical equipment improvements and operational improvements to the highest cost-effective level. Furthermore, this project is to investigate and demonstrate the impact of high-performance energy-efficiency retrofit improvements on row homes in the Historic East area of Baltimore. Three homes awaiting renovation are planned to receive building envelope, mechanical system, and electrical system improvements that will improve their energy performance. An incremental additional cost ceiling of $4000 for the energy efficiency improvements, beyond those normally installed, has been set by the project.
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The baseline model that the proposed efficiency improvements were compared to was prepared for Enterprise Development Corporation by MIM’Architects. One initial goal was to use technologies that were identified by ORNL and ANL. The project team later expanded this to include materials identified in the Maryland Department of Natural Resources “Green Building Program”. We also investigated other energy-efficient retrofit projects in cities such as Philadelphia, Chicago, and Madison, Wisconsin.

The project is organized around a project advisory team. The core of this team comprises of the student investigators and the faculty investigators/ advisors. There are two student investigators in the fields of architecture and electrical engineering, along with two faculty advisors and a project manager. All of these participants are from Morgan State University. Along with this core research team, there are a number of advisory members. These include community development organizations (Historic East Baltimore Community Action Coalition, HEBCAC and Enterprise Development Corporation), utilities advisor (Robert Light, and now Kevin Young- Baltimore Gas & Electric, BG&E), and research materials advisors and overall sponsors (Robert Wendt-ORNL and James Cavallo-ANL). There are a number of additional contributors to research and information that are listed in the acknowledgment section of this paper.

The research project covers initial research and investigation through construction, testing and then on to monitoring. The project was outlined in four different phases.

**Phase I of the project began October 1997.**

This phase of the project included:
1. Case study research.
2. Establish design parameters.
3. Develop and evaluate conceptual designs describing energy-efficiency options potentially available.
4. Review conceptual designs and finalize design for documentation.
5. Presenting findings at a national conference.

**Phase II began in summer 1998. This phase of the project was to address field-testing and evaluation of the designs developed.**

This phase was to:
1. Identify three specific houses for use as a field test of the chosen design. Done in collaboration with the community development organizations.
2. Develop working drawings and specifications to implement in the final design.
3. Evaluate in detail, the actual costs and ease of construction of the energy-efficiency measures implemented.

**Phase III was scheduled to begin May 1998 and end in the fall of 1999 and consisted of performance monitoring and analysis of community economic impact. This work has been delayed.**

In this phase the team is to:
1. Prepare a monitoring plan to gauge the performance of the of the field test house for energy consumption, indoor air quality, and overall occupant comfort.
2. Reviewing monitoring plan with the advisory team, and establish a monitoring program for one year and analyze and document the data collected.
Phase IV, or the "wrap-up phase", was scheduled to begin in the fall of 1999 and be completed by the end of 1999. This work has also been delayed. This phase includes:

1. Establish future participation in the continued development and application of the findings of the project by interested parties.
2. Consolidate documents for all phases and archive at Morgan State University for future reference.
3. Present the results as a complete project at a national conference.

CURRENT PROJECT STATUS

THE ROWHOUSES

The three row homes are located in eastern Baltimore, Maryland. The homes are located on Washington Street near Johns Hopkins Medical Center and University. One of the row homes is an interior unit (row home 818). The remaining two row homes are adjacent to each other and share the same parting wall (row homes 837, and 839). The row homes are basically structurally sound, but still require a "gut" rehabilitation. There is a termite infestation in the row homes as well as slight water and mildew damage. The damage appears to be from penetrations in the building envelope that allowed rainwater to enter the structure.

*The interior of the row homes has water damage from penetrations through the building's envelope. The existing conditions of these row homes warrants a "gut rehab". With the use of energy-efficiency measures, these homes will become affordable and comfortable.*

*The facades of the row homes are in better shape than the interior in most cases. Some of the better homes only have broken windows.*
THE APPROACH

The research team established a target solution to the problem. The project team decided that the best approach to find the optimum improvements to the row homes was to go through a process of comparison. We analyzed the baseline model first, and then compared various options of envelope improvements in terms of the insulation and subsequent R-values for the walls and ceiling. The doors and windows also were analyzed. From this, we developed the “optimum” envelope improvements based on:

- The performance of the improvements based on computer output from the Rem Design program. (A product of Architectural Energy Corporation)
- The overall incremental cost of the improvements
- The energy savings of the improvements
- The architectural and construction issues associated with the changes suggested

The next step in our analysis was to determine the “optimum” upgrades for the mechanical systems for the row homes. Again, for optimum performance analysis, we evaluated changes to each of the three mechanical components in the row homes; the water heater, the air conditioning unit, and the gas furnace. Following the same approach and criteria that we set for choosing the envelope improvements, we chose the best unit for each of the three systems without applying the envelope improvements suggested before. This gave us a more accurate account of just how much changing these units alone affected the overall performance of the row homes.

ASSUMPTIONS

The following is a list of the assumptions that were used for this preliminary report:

- Energy-efficient upgrades applicable to one row home will be applicable to the remaining two row homes with slight variations that will not affect overall thermal performance.
- Cost assumptions were made from information obtained from reference sources (see references) for the financial analysis.
- For payback analysis, we are rounding the total energy cost per year to the nearest dollar for simpler numbers
- The cost of the composite system versus the 2 x 4 framing system with batt insulation is negligible from the following calculation:
  - Cost of 2 x 4 framing with batt insulation: around $5.10 / square foot
  - Cost of wet spray cellulose: around $4.98 / square foot
  (Based on 1997 construction cost estimates—See reference 1)
- Target air changes per hour infiltration rate of 0.4 (after renovation) versus 0.7 (before renovation).
- Oversize factor for preliminary computer analysis to be 125%.
  (An oversize factor is a safety factor used for calculating loads for mechanical equipment to ensure “good” performance under more than design load conditions)
- The information received from the Rem Design program is correct, based on the parameters set by the user and the specifications of the manufacturer of the program.
- The cost of wet spray cellulose is $0.80 / square foot more than traditional insulation. (this is an average number taken because the cost of wet spray cellulose ranges from $0.75 to $1.00 / square foot—See reference 3).
There would be only slight complications in the installation of the upgrade improvements, therefore there was no real increase in construction labor costs.

BUILDING UPGRADE LIST & INCREMENTAL COST ANALYSIS

BASELINE MODEL
Below is a list of the energy efficient features provided by the baseline design architect. Since this model is the reference model, there are no associated incremental costs.

Building Envelope Improvements
- R-30 batt insulation 10” thick (roof)
- R- 21 batt insulation 5-1/2” thick (endwalls)
- R-15 batt insulation (sidewalls)
- Double glazed, low-E, aluminum windows with a thermal break
- 1-3/4” thick, wood panel door with solid core construction (front & rear)

Building Equipment Improvements
- Conventional Air Conditioning Unit with SEER of 10
- Gas fired furnace with AFUE of 78%
- Gas fired water heater with Energy Factor of 0.56
The architect also provided 12 fluorescent and 4 incandescent light fixtures for the homes.

UPGRADE MODEL
Below is a list of the energy-efficient upgrades selected provided by the project team. Please refer to Table I and Table II to see the incremental costs, energy savings and payback on these upgrades.

- R-43 sprayed cellulose (roof)
- R-15 composite wall system (endwalls)
- R-15 composite wall system (sidewalls)
- Double glazed, low-E, aluminum windows with a thermal break
- 1-3/4” thick, wood panel door with solid core construction (front & rear)

The composite wall system is a new technology created by ORNL. The composite wall system is composed of a layer of ½” thick “FiberBond” fiber reinforced gypsum wall panels. “Tuff-R” polyisocyanurate insulation (R-12@ 1-1/2” thick), and “EnerFoam” adhesive. This system costs slightly less than traditional 2x4 framing with batt insulation. One of the major advantages of this system is that it can be constructed using only ½” of the space that it would require over the traditional methods of wall construction.

Building Equipment Improvements
- Conventional Air Conditioning Unit with SEER value of 15
- Integrated system-(containing a properly sized water heater & fan coil that serves both the domestic hot water and space heating needs.)
  System description: Seasonal Efficiency = 90%
- Energy efficient refrigerator w/ 437 kWh / yr consumption

The project team provided 12 fluorescent and 4 incandescent light fixtures for the homes.
TABLE I

INCREMENTAL COST ANALYSIS

<table>
<thead>
<tr>
<th>Building Improvement Item</th>
<th>Associated incremental cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-43 sprayed cellulose insulation (roof)</td>
<td>$475.00</td>
</tr>
<tr>
<td>R-15 composite wall system (endwalls)</td>
<td>$0.00</td>
</tr>
<tr>
<td>R-15 composite wall system (sidewalls)</td>
<td>$0.00</td>
</tr>
<tr>
<td>Double glazed, low-E, aluminum frame windows with a thermal break</td>
<td>$0.00</td>
</tr>
<tr>
<td>1-3/4” thick, wood panel door with solid core construction (front &amp; rear)</td>
<td>$0.00</td>
</tr>
<tr>
<td>Conventional Air conditioning unit with SEER = 15</td>
<td>$600.00</td>
</tr>
<tr>
<td>Integrated system- (containing a properly sized water heater &amp; fan coil that serves both the domestic hot water and space heating needs.)</td>
<td>$300.00</td>
</tr>
<tr>
<td>System description: AFUE = 90%</td>
<td></td>
</tr>
<tr>
<td>Total system Energy Factor = 0.90</td>
<td>$1,375.00</td>
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TABLE II

ANNUAL ENERGY COST COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Upgrade Model</th>
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</thead>
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<tr>
<td>Heating</td>
<td>$161</td>
<td>$83</td>
</tr>
<tr>
<td>Cooling</td>
<td>$121</td>
<td>$62</td>
</tr>
<tr>
<td>Water Heater</td>
<td>$152</td>
<td>$94</td>
</tr>
<tr>
<td>Lights &amp; Appliances</td>
<td>$281</td>
<td>$262</td>
</tr>
<tr>
<td>Service Charges</td>
<td>$174</td>
<td>$174</td>
</tr>
<tr>
<td>Total Annual Cost</td>
<td>$888</td>
<td>$663</td>
</tr>
<tr>
<td>Average Monthly</td>
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<td>$55</td>
</tr>
<tr>
<td>Incremental Cost</td>
<td>$0</td>
<td>$1,375.00</td>
</tr>
<tr>
<td>Decrease in Annual Costs</td>
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<td>$225</td>
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<tr>
<td>Payback in years</td>
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<td>6</td>
</tr>
</tbody>
</table>

FUTURE PROGRESS OF PROJECT

The project team is in the final phases of Part II outlined in the beginning of this paper. This includes completion of the working drawings and specification booklet with complete documentation. A contractor has been selected with the collaboration of the Community Development Corporation. Renovation of the row homes, using all of the energy-efficiency measures established by the project team, is scheduled to begin construction in the spring of 1999.

The project team is also developing monitoring systems for the evaluation of the row homes once construction has been completed. This part of the project involves field-testing and monitoring by the electrical engineering component of the Morgan State University project team. This is effectively part of Phase III outlined in the beginning of the paper. The final aspect of phase III that the team is scheduled to complete is the
preparation of an analysis of the projected community economic impact of widespread application of the retrofit improvements throughout Baltimore.

Phase IV is scheduled to begin after one year of monitoring and testing during Phase III of the project. This is the culmination of the entire project from Phase I to Phase III. This includes finalizing all documents and data into a concise form and preparing this document for future use by the university. The final aspect of this project is presenting this information at national conferences concerning sustainable and energy-efficiency retrofits in the built environment.

CONCLUSION

High performance energy efficiency retrofit measures applied to Baltimore's historic row homes can cost effectively increase the affordability of the homes by significantly reducing energy consumption and associated utility costs. The application of these measures and other green building measures will increase the health and comfort of the building inhabitants, while also contributing to the sustainability of this portion of the City of Baltimore.

Through computer modeling and analysis, the project team yielded excellent results in terms of energy consumption and cost savings. The row house model designed by the project team projected, on average provides, a energy performance 25% better than all reference energy performance standards. The high-energy efficiency retrofit developed by the project team can provide a standard for urban housing renewal in Baltimore, Maryland.
REFERENCES


Energy-Efficient Rehabilitation of Multifamily Buildings in the Midwest. Argonne National Laboratory Decision and Information Sciences Division.


Rheem product information and specification manual. Space heating equipment and space cooling equipment. 1997


REFERENCE FOOTNOTES

- For the REM Design program analysis report, the MEC (Mechanical Electrical Code), ASHRAE (American Society of Heating, Refrigerating and Air conditioning Engineers) and Energy Star standard comparison values for energy consumption do not change. Any changes that do occur are a result of changes in equipment types rather than performance improvements in the individual units.

- The cost of gas provided from BGE (Baltimore Gas & Electric) Company, is $0.60 per therm.

- The energy savings and preliminary analysis will require monitoring and in-field measurements.
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