A SYSTEMS APPROACH FOR DESIGN AND CONSTRUCTION OF SUPER-ENERGY-EFFICIENT (SEE) HOMES

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START: 01 MAR 2010 **TERM:** 30 SEP 2015

NON-TECHNICAL SUMMARY: U.S. homes account for approximately 22% of national energy use and 21% of total carbon dioxide emissions. The situation is deteriorating since new homes are continuously added into our existing building stock. Minimizing homes' energy consumption and environmental impacts is a critical task for researchers and practitioners. Although many energy efficient home technologies have existed for several decades, they are not widely accepted and applied by the industry. The proposed study of a systems approach for design and construction of Super-Energy-Efficient (SEE) homes is important for the housing construction industry to provide affordable, healthy, and energy efficient homes to Ohio residents and reduce adverse environmental impacts of the state. In addition, the promotion of SEE homes will help revive the building industry and create new jobs.

OBJECTIVES: The investigation of the history of Super-Energy-Efficient (SEE) homes and the ongoing programs to promote them has revealed that due to various causes, there is still very limited market penetration of SEE homes. It is apparent that existing programs (whether research-based or government and/or industry-driven) have not resulted in large numbers of SEE homes being added to the production housing stock industry wide. This study is a research component of an on-going effort of OSU researchers who seek a more holistic approach. It involves partnering with various sectors of the home construction industry to bring about a revolutionary change in energy efficient home construction through a coordinated and far reaching program of research, education, training, outreach, and demonstrations with SEE living learning lab homes and retail owner-occupied SEE homes. Objectives: 1. Develop the whole-house systems approach for best energy performance including standardized SEE home designs for the Ohio region. 2. Evaluate commercial products for sensor, metering and home energy management systems. 3. Develop an integrated project management system that can better manage SEE home methods to enhance construction quality while minimizing project costs. 4. Perform long-term data collection and the subsequent analysis of actual energy performance of SEE model homes.

APPROACH: This study will build on three workshops that involved participants of the housing industry to (1) identify barriers to the wide acceptance and application of SEE home technologies and (2) solicit comments and buy-in for a holistic approach to increasing the number of SEE homes being built. EE home technologies will be carefully reviewed according to several criteria: applicability in the region, level of efficiency, code requirements, system integrity, cost factor, complexity of construction, etc. Four to six different types of home plan (based on floor areas, with or without a basement, all electric or electric and gas, and appearance) will be designed by incorporating selected EE home technologies based on a systems approach for best energy performance. Whole-house computer simulation will be performed to evaluate and optimize the energy performance of various designs. Cost estimate will be conducted simultaneously in selecting more cost-effective EE measures to achieve no or minimal cost increase for SEE homes to be built when compared to market homes with similar features. Survey of commercially available products for sensor, metering and home energy management systems will be performed to identify proper products for control and monitoring of the energy-related performance of major home subsystems including heating, cooling, hot water, lighting, major home appliances, and stand-by power. These products will be incorporated into the SEE model home designs and will provide instant and rich performance information after the homes are built. A review of major issues related to housing construction processes and management methods/systems will be conducted. This study will incorporate lean construction and other innovative project management methods and technologies into several typical project delivery models used by homebuilders. The developed project management systems will be tried by selected homebuilders to improve the efficiency of SEE home construction and enhance the quality of homes being built. The scope of data collection and analysis will be dependent on the financial support that could be obtained for the SEE program and the relationships developed between the project team and the Ohio housing construction industry. This study will monitor and analyze the energy performance of conventional and SEE homes built under the SEE program based on funding availability.

PROGRESS: 2010/01 TO 2010/12
OUTPUTS: The findings of the three workshops held in 2008 and 2009 among OSU researchers and homebuilding related practitioners were summarized into a journal publication. The cost effectiveness of home energy efficient (EE) improvement measures was researched in an honor thesis study of an undergraduate student by using the following methodology. The EE measures including replacing 2x4 with 2x6 in stud walls, upgrading the interior and exterior finishes, altering the framing and truss style for more insulation in the attic, etc. were added into three selected home plans in 2500, 3700, and 6000 square feet. The energy performance of these three EE enhanced houses and their conventional counterparts was simulated in the eQuest program. The reduction of annual energy consumption of each of these houses compared to its counterpart was tracked and related cost savings were calculated. The cost differences between implementing the EE improvement measures in the enhanced houses and building conventional components in normal houses were estimated. A payback year calculation for those selected EE improvements was performed to assess

their cost effectiveness. The effectiveness of EE improvement measures implemented in public housing was also researched by a graduate student for a Master's Thesis. In particular, questionnaire surveys were conducted among residents living in Columbus's public housing to understand the thermal performance and energy consumption of these public houses. Interviews with the director and management staff in Columbus Metropolitan Housing Authority (CMHA) were performed to learn the current status of public housing projects in Columbus, OH and green renovation projects CMHA is executing. Interviews with project architects were also conducted to identify EE improvement measures they were putting into place. Based on the collected information, energy simulation for a selected house was performed in eQuest under three conditions: before renovation, after renovation and under current codes. The simulated energy uses in these three houses were compared to determine how effective these EE improvement measures are. The cost effectiveness of several EE improvement measures proposed by researchers was also evaluated by adopting a similar approach as described above. The PI is teaching a green building course at OSU that incorporates research findings on super energy eneficient (SEE) homes. A guest lecture on energy-efficient building technologies was given by the PI to the students in the Department of FABE's graduate student seminar. Another guest lecture on green construction presented to students taking the Department of Industrial Engineering's seminar series on Energy and the Environment. PARTICIPANTS: Collaborators: Kinzel, G., Zimmerman, A., Potter, S., and Lichtensteiger, M. These collaborators and the PI organized three workshops that involved participants of the housing industry to identify barriers to the wide acceptance and application of SEE home technologies and solicit comments and buy-in for a holistic approach to increasing the number of SEE homes being built. Training was provided to one undergraduate student, M. Kellermeyer, and one graduate student, Q. Ma in researching energy efficient homes and performing whole house energy simulation. TARGET AUDIENCES: Building Industry, Public Agencies, General Public, Homeowners and Students PROJECT MODIFICATIONS: Not relevant to this project.

IMPACT: 2010/01 TO 2010/12
The workshop findings included in the journal publication established a thorough understanding about the major barriers to the wide spread adoption of SEE homes and proposed a holistic approach to promoting SEE homes. The workshop results also revealed that it is not only necessary to build each new home as an integrated system, but also think of the home building industry as a system where all of the stakeholders need to be involved in the process to change the home building culture. This document will offer useful insights to researchers, practitioners, and public agencies in promoting SEE homes. In the comparable research performed by the undergraduate student, the cost differences between the EE enhanced houses and conventional houses in 2500, 3700, and 6000 square feet were found to be $5461, $6530 and $8271, respectively. The total energy and utility bill cost savings for these EE enhanced houses are 9343kWh ($432), 13060kWh ($612), and 20314 kWh ($1139), resulting in a payback period of 12.5, 10.5, and 7.2 years, respectively. This analysis proved that the longer payback period makes EE improvement measures unattractive to homeowners since most of them would sell their houses within five years. This barrier should be well

addressed for any EE home program to work. Through the questionnaire survey among residents in Columbus public housing, it was found that most of residents were satisfied with the thermal comfort in their houses but not their high energy costs. Energy simulation and analysis disclosed that the green renovation being performed by CMHA could only improve a house's energy performance by 12%. When compared to the requirements of current building energy codes, another 57% reduction in the house's energy consumption needs to be achieved. This research further proposed several cost-effective EE improvement measures that can be added to the renovated house to further cut down its energy consumption. These measures, including improving shell tightness, adding window shading and blinds, implementing an economizer for the HVAC system, and promoting behavior changes, could achieve additional 24.2% energy savings. The associated project costs could be paid back in approximately 2.7 years based on a simple economic analysis. The completed thesis was provided to CMHA and hopefully will benefit their future green renovation projects.

PUBLICATIONS (not previously reported): 2010/01 TO 2010/12

1. Chen, Q., Kinzel, G., Zimmerman, A., Potter, S., and Lichtensteiger, M. 2010. Barriers and Impediments to a Holistic Approach to Promoting Super-Energy-Efficient (SEE) Homes. Journal of Green Building. Vol.5, no. 4. In press
2. Kellermeyer, M. 2010. An Economic Comparison of Super-Energy-Efficient Houses to Standard Built Houses. Honor Thesis. The Ohio State University, Department of Food, Agricultural and Biological Engineering, Columbus,OH.
3. Ma Q. 2010. A Study of the Energy Efficiency Improvement of Public Housing in Columbus, OH. Master's Thesis. The Ohio State University, Department of Food, Agricultural and Biological Engineering, Columbus, OH

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