# EXECUTIVE SUMMARY

*By Sam Borchard, adapted from the EPA Executive Summary*

## Problem Description

Our world faces an impending energy crisis due to overreliance on fossil fuels. As our stores of fossil fuels run low, China, India, and other countries around the world are modernizing and increasing their energy use, and the threat of human-induced global climate change is increasing. Half of the United States' 23% consumption of the world's energy is from buildings. Organizations like LEED and the SBIC are working to make new building designs as efficient as possible, but very little work is being done to improve existing buildings, which is the focus of our work.

Our specific focus is on the diametric relationship between air exchange and energy efficiency in buildings. The relationship is conceptually simple, but often goes unacknowledged in the industry – homeowners are advised to conserve energy and decrease their heating bills by sealing up the leaks and cracks in their home; rarely is it mentioned that this can adversely affect indoor air quality. According to Dr. Richard Corsi (UT 2006), "… exposure of Americans to toxic substances is dominated by what we breathe and touch while we are indoors," and "If you put indoor radon and indoor air pollution together, they are by far the number one environmental threat to the American public." Information regarding this threat to human health needs to be well publicized for homeowners. Additionally, quantitative tools need to be made available to homeowners trying to navigate complex retrofitting decisions.

## Objectives and Methods

To address these concerns, we continued work on objectives in three areas of increasingly broad scope. The first area of focus was collaboration with the team's original partner, the Stony Brook-Millstone Watershed Association, hereafter referred to as "The Watershed Association." The team's objective in this area was to provide the Watershed Association with the information necessary for them to transform an existing residential structure, the Buttinger Nature Center, into a model of efficient and renewable energy. During the 2006-2007 school year the team performed a wide range of assessments on the building, including an air exchange test and an energy audit. Building on this work, team members this fall collated and analyzed several years of historical data related to the building's photovoltaic array and "grid" electric consumption to increase the understanding of electricity usage patterns and suggest areas for improvement.

Our second objective for this year was to quantify air exchange rates – a key factor in air quality – in typical American homes and relate these rates to specific house features. To collect data for this analysis, the team began a study of air exchange rates in homes in the Princeton area. The team used a blower door test at each house to measure the air exchange rate. To supplement the data collected from the blower door tests, the team gathered data on a number of factors that could potentially affect home air exchange rates and energy efficiency using a questionnaire, which also increased awareness about the interrelated nature of energy efficiency and air quality. This study provided the foundation for our third area of study, and offered the local community a valuable service.

Our third objective was the creation of a quantitative online tool to share the results of our study with the public. We named the tool Greentrofit™ – a combination of the words "green" and "retrofit." Greentrofit™'s goal is to assist homeowners in estimating and understanding their home's air exchange rate and energy consumption by providing them with quantitative information based on the statistical correlations determined during our study. Greentrofit™ was written in the Java programming language using modular design.

## Summary of Findings:

### *Watershed Association:*

Analysis of the data from the solar panel inverters and monthly meter readings showed that the 15kW array has met approximately 89.2% of the Watershed Association's power needs since the completion of its installation. Research on possible options for further monitoring of solar results was performed, and a full analysis of the costs and benefits of several options were reported to the Watershed Association.

### *Air Exchange Rate Study*

The raw data from the blower door were analyzed, revealing a large range of air exchange rates, as shown in Figure 1. The homes we tested have rates varying from 0.2 to 2.1 ACH. The mean air exchange rate is 0.9 ACH, the median rate is 0.7 ACH, and three of the homes have air exchange rates near or below 0.35, the minimum for healthy air for humans as suggested by ASHRAE.

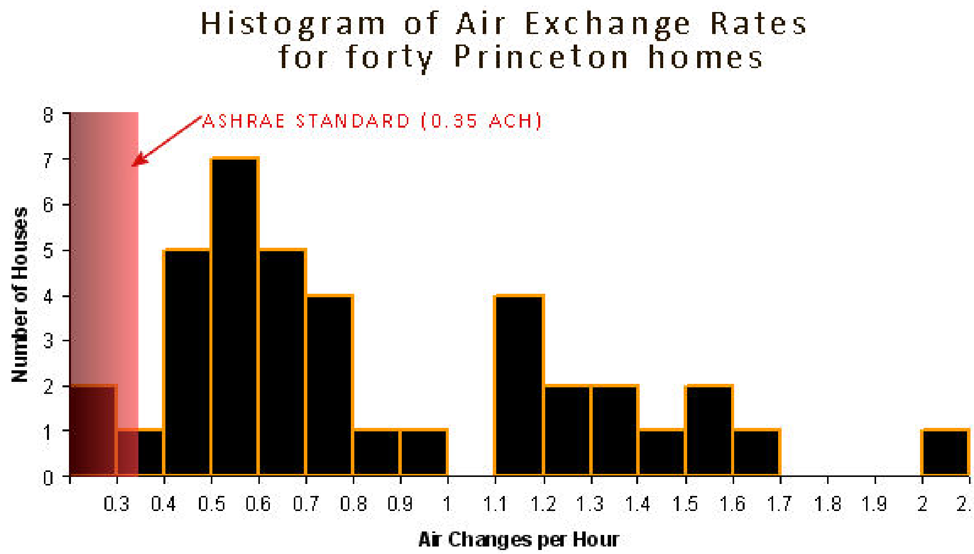


Figure 1 - Histogram of Air Exchange Rates from Study

One home surveyed during the study adopted a series of low-cost retrofits (less than $50), consisting mainly of weatherstripping, after our test. We performed a second test on the house after these retrofits were put in place and found a large decrease in the air exchange rate from its initial value of 1.35 ACH to a final value of 0.69 ACH.

## *Data Analysis*

Linear regression analysis was performed on the data from the air exchange study with some success. A preliminary formula, based on six house attributes was created, however it was handicapped by a lack of complete data in the data sets. After further research the data sets were completed, and variables were consolidated to improve the analysis. This second analysis proved to be much more accurate, yielding an $R^2$ value of 0.60. The final predictive model is shown below in Figure 2.

$$ACH = -.001833C - .001662U - .0004107A + .2093F + .3307H - .001548N + .01126P - .5493S - 1.551$$

*C* = total conditioned space (including attics/basements);

*U* = unconditioned spaces like garages or additions;

*A* = unconditioned attic space;

*F* = number of floors;
*H* = height of each floor;

*N* = the age of the house in years;

Figure 2 - Predictive Model for Air Exchange Rate

*Greentrofit™*

The team completed a prototype design of the Greentrofit™ online tool. Greentrofit™ is implemented via five main modules that collect user input, process the data using the regression equation in Figure 2, and output the results to the homeowner. Each module of the program is designed so that it can be independently modified or exchanged as our model expands and improves.

Greentrofit outputs the results of the analysis to the user in a comprehensible form, shown in Figure 3. The estimated air exchange rate for the home is compared to national averages and indoor air quality standards. In addition, the dynamic output allows the user to see the effects of selectable retrofits appropriate for his or her home.

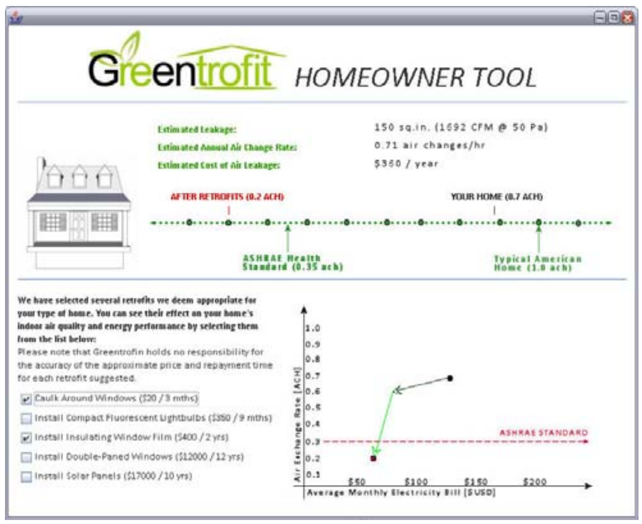


Figure 2 - Screenshot of Greentrofit™ output display

## Conclusions

Since its creation, our team has made significant progress in addressing the conflicting information available regarding energy conservation and air quality in residential environments. The team has and will continue to increase awareness of the effectiveness, costs, and risks associated with green retrofitting in homes. We have created and will continue to refine quantitative, predictive tools to help homeowners navigate the complex decisions that surround energy efficiency and human health in the context of green residential retrofitting.

Our findings demonstrate the risks created by the lack of information and quantitative tools available to homeowners regarding the interaction of air quality and energy efficiency. Three homes in the study were at the threshold of the recommended minimum air exchange rate according to the ASHRAE standard, yet the homeowner of at least one of these homes was considering implementing retrofits to seal his home for energy savings. This is particularly concerning given the results from the home tested before and after retrofits, the data from which show that after the retrofits were applied the air exchange rate dropped 48.9%. Applying this finding to the homes in our study reveals that 45% of the houses we tested would fall below health standards for air exchange rates if they implemented similar retrofits.

In light of these findings, we will continue to work to increase public awareness regarding the possible dangers of over-sealing one's house to conserve energy. We urge the government to increase awareness of these issues through educational programs and endorsements of organizations that recognize the Greentrofit™ concept. The government should also increase funding for the development of quantitative tools to help homeowners make informed decisions regarding their homes and their health. These initiatives will help the general population use energy more efficiently, and do so in a safe way.

The creation of a prototype of Greentrofit™ marks the beginning of a movement to acknowledge the connection between air quality and energy conservation in the residential sector. The potential influence of such a tool extends to the entire building industry, and the universal accessibility of Greentrofit™ broadens the impact of the tool beyond the borders of the US to the entire planet. Given customized quantitative information, homeowners can make smarter, more sustainable decisions about energy efficient retrofitting and the maintenance of personal health. Full development of this tool should be the main priority of our team moving forward.