This report investigates the feasibility of making renovations to improve energy efficiency of any given old rental house in State College, Pennsylvania. The proposed renovations are to install additional insulation in the attic and exterior walls, to replace the existing windows with more energy-efficient models, and to do both. The savings in utility costs as a result of these proposed actions are determined using eQUEST, an energy-use computer analysis tool. In addition to a cost analysis, additional criteria are considered in evaluating the suitability of each proposed renovation as an investment.
Executive Summary

This report is concerned with the existence of lost rental income due to poor energy efficiency of older houses in the State College rental market, and the feasibility of making renovations to increase energy efficiency and rental income.

In conducting a thorough and quantitative analysis, a model house was created to represent the older, energy-inefficient houses in State College. This house has minimal insulation in the attic, no insulation in the exterior walls, single-paned windows, and is heated by electric baseboards. The U.S. Department of Energy gave a recommendation for adding insulation based on the climate of State College, the characteristics of the house, the cost of materials and installation, and the interest rate for the project funding source. In addition, energy-efficient double-paned replacement windows were selected.

The computer analysis tool eQUEST was used to calculate the energy usage for one year of the model house in each of four proposed renovation project cases: original design, additional insulation, replaced windows, and both added insulation and new windows. The total cost of each renovation project, including lost rental income during installation, was determined.

The insulation-only renovation project was calculated to cost $4345 upfront and pay itself back from energy savings in 42 to 45 months (depending on how much cash and how much debt is used to fund the project). The windows-only renovation project was found to cost $5086 upfront and reduce the energy costs by less than 2%. The insulation and windows renovation project was determined to cost $8531 upfront and pay itself back in 77 to 87 months.

The high return on investment and low upfront cost of the insulation-only project makes it a feasible investment, while the replacement of windows is not a sensible renovation to make in terms of gains in energy efficiency. This report recommends for owners of rental houses heated by electric baseboards to investigate the amount of insulation and, if it is insufficient, install additional insulation, and then gain the additional income as a result of the energy savings. A homeowner may wish to use the threshold amounts of existing insulation stated in this report to make a decision how much, if any, insulation should be added, or to redo the analysis outlined in this report by using the eQUEST program and the more exact specifications of a given house.
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Introduction

Problem

Many houses in State College, Pennsylvania, were constructed prior to the 1980s, and some houses many more decades before then. Since the time these houses were built, new materials and construction techniques have been developed, many of which have been incorporated over the years into the standards for new house construction. These have included, but not been limited to, improvements in insulation in exterior walls and attics, and window glass and frames. Unless older houses, which had lower standards during construction, are renovated with newer technologies, they will become increasingly more expensive to live in compared to standard new houses.

For many of the houses in the rental market, the tenants are responsible for the energy bills (i.e., electric, heating, and cooling) of the property. The tenants themselves do not have the economic incentive, the permission, or the ability to make major renovations on the rental property to decrease their energy bills; this responsibility rests solely on the property owner.

Large energy bills will exist for a house that is older and energy inefficient. For rental agreements in which the renters are held responsible for the utility bills, we assume that renters will be aware of and concerned with the total price of residence, which is primarily the sum of rent and utility bills. For a house with high utility bills, the rent will subsequently be depressed so that, all else being equal, a market-competitive total price results. If a property owner makes renovations on a property that increase its energy efficiency and reduces the renters’ energy bills, the rental rate can be raised to maintain the market-competitive total price, and the earnings on the house for the owner will rise. If the property owner is responsible for the utility bills, then, all else being equal, increasing the energy efficiency of a house will reduce the expense of utility bills and earnings will rise.

So what, if any, are the feasible renovations that would increase the energy efficiency of a rental house?

Methodology

To answer this question, we will consider two means by which to renovate a house to increase energy efficiency: insulation in exterior walls and attics, and window technology. We will obtain the government recommendation for attic and wall insulation for a single-family house in central Pennsylvania and determine the cost and details of installation to meet this recommendation. We will conduct research into the solutions available for window systems with a focus on cost and details of installation.

To determine the changes in energy consumption with different systems in place, we will use eQUEST Version 3.64 [1]. In this simplified energy-use analysis tool from Energy Design Resources in California, we will create a model house that is representative of older single-family houses in State College in both structure and features. The program will determine how much energy is used to operate the house in its given condition. Then we will create different renovation plans by adding different combinations of possible renovations, and let eQUEST determine the change in energy consumption for each renovation plan. We will also determine the cost of each renovation project.

Finally, we will research the unit cost of the relevant forms of energy, and then convert energy consumption into utility costs. The utility costs will change as any renovations cause a change in energy consumption. A cost analysis will be performed to determine how long it takes the increased rental earnings (assumed to be equal to the reduction in utility costs) to make-up the cost of the renovation project, as well as to determine the return on investment per year.

The feasibility of a renovation plan will be evaluated on three criteria:

- Is the expected payback period in this investment sufficiently short? Included in cost of the project are any lost rental revenue during renovation and financing costs.
- Is the risk on total operations with this investment sufficiently small? (Are the capital requirements not prohibitive?)
- If tenants are living in the house during renovation, will they be sufficiently satisfied with the living conditions?

Report Structure

This report will be organized by the following sections:

- Description of Existing House
Description of Existing House

This section describes the model house created in eQUEST. The US Department of Energy has reported that 80% of houses built before 1980 lack proper insulation. This model house represents houses in State College that were built during this time and are energy inefficient.

Basic Construction

The model house is wood-framed with red bricks on the exterior wall and brown shingles covering the roof. It is one-story and 1500 square feet (50’ X 30’), and the 25°-sloped roof overhangs the exterior walls by 2 feet. The ceilings are 10 feet high, and the attic consists of the area under the sloped roof plus an additional 1 foot above the interior ceiling.

Features

There is batt insulation with R-value of 11 installed above the ceiling in the attic. There is no insulation inside the interior or exterior walls, or anywhere else in the house. There is also no insulation sheathing along the exterior walls. (See Appendix A for what is meant by “batt insulation,” “R-value,” and “insulation sheathing.”)

The windows are made with single-paned 1/8” glass and measure 32” by 23”. They are vinyl clad windows with 1.5-inch-wide frames. The frames are operable.

Energy Consumption

The house is heated with electric baseboards, and the heat point of the thermostat is at 70°F at all times. There is no air conditioning.

The eQUEST software determined the energy consumption of this model house if subjected to climate of State College, Pennsylvania. Over the course of one year, 37,460 kWh (kilowatt-hours) are used by the electric baseboards for space heating alone.

Retrofit Options

This section describes the means by which the model house and most any other house could be renovated to increase energy efficiency.

Addition of Attic and Exterior Wall Insulation

An upgrade of the insulation around the house will be considered. Oak Ridge National Laboratory, an affiliated entity of the U.S. Department of Energy, recommends that the model house be renovated such to add insulation with R-value of 38 in the attic, and R-value of 13 in the exterior walls [2]. For the exterior wall insulation, they recommend specifically to “blow insulation into any uninsulated exterior wall cavity” [2]. (See Appendix A for what is meant by “R-value” and “blow insulation.”)

With the additional insulation added, the total insulation in the attic would have an R-value of 49, and in the exterior walls an R-value of 13. This recommendation is based on the specific existing insulation in the model (see “Description of Existing House: Features”). However, similar recommendations are made for different values of existing R-values of insulation. Specifically, they recommend that:

- Attic insulation be improved to total R-value of 49 if existing attic insulation has R-value ranging from 0 to 30
- Exterior walls be blown-in with insulation of R-value of 13 even if insulation sheathing, up to 1” thick and Foil-faced, had been installed during construction
The recommendation analysis assumes the typical rate for electricity for the area (10.48 cents/kWh), and the typical cost of materials and installation in the area in 2008. (Further information regarding the specific facts of the model house used in determining the recommendation is in Appendix B.)


Replacing Windows

The replacement of all 14 of the windows will also be considered. The replacement windows under consideration are double-pane Argon-filled Low-E windows with 1/8" glass panes. The frame of these windows is operable and made of vinyl [3].

Cost Analysis

This section will go over the determination of the payback period (the amount of time required for the cost of the renovation to be recouped by the raise in rental rates associated with energy savings) and annual return on investment for each possible renovation project.

The calculation of payback period will include the impact of interest. The payback period will differ between using cash and having to take a loan to fund the renovation because they have different interest rates. Therefore, both options will be considered.

The cost analysis will use 10.48 cents/kWh for electricity [2], a 4% APR for loans, a 0.5% APY for cash, and a rental rate of $1800/month.

Insulation Only

According to Oak Ridge National Laboratory, the cost to add 38 to the R-value of the attic insulation is $0.88/square foot, including installation [2]; since the above-ceiling area in the attic is 50’ X 30’, it would cost about $1320 to install the attic insulation. Similarly, it would cost $1.29/square foot to add 13 to the R-value of the exterior wall insulation [2]; since there is about 1647 square feet of exterior wall (excluding area of windows and doors), it would cost about $2125 to install the exterior wall installation. Installation would require the house to be unrented and tenant-free during that time. It is reasonable to estimate that this work could be done in half a month, so $900 of lost rent would be an additional expense. The total upfront expense would therefore be about $4345.

With the proposed additional insulation included in the attic and exterior walls, the eQUEST software determined that 25,320 kWh would be used to heat the house over the course of a year. The insulation reduced the space heating energy requirement by 12,140 kWh per year, or by nearly 33%. This would result in a reduction of utility bills by $1272 per year.

The payback period of this investment would be 42 months if cash-financed or 45 months if debt-financed. The return on investment is over 29% per year.

![Figure 2: The monthly change in debt or lost cash during the payback period for renovating insulation only](image-url)
Windows Only

The double-pane windows cost $99 each [3], and installation could be conservatively estimated at $200 per window. Replacing the 14 windows would therefore cost $4186. Installation of the windows would require the house to be unrented and tenant-free. It is reasonable to estimate that this work could be done in a half a month (including potential weather delays), so $900 of lost rent would be an additional expense. The total upfront expense would therefore be about $5086.

With the proposed window upgrades, the eQUEST software determined that 36,830 kWh would be used to heat the house over the course of a year. The upgraded windows reduced the space heating energy requirement by 630 kWh per year, or by 1.7%. This would result in a reduction of utility bills by $66 per year.

If this project was financed with debt at 4% APR, the interest payment of about $200 per year would be greater than the increased rental revenue; there is no payback period for debt financing. If the project was financed with cash, the payback period would be 97 years and 5 months. The return on investment is only about 1.3% per year.

Both Insulation and Windows

As determined above, materials and installation costs are about $3445 for the insulation, and about $4186 for the windows. Both installations could be done in the same half-month period, so the additional expense of lost rent is only $900. The total upfront expense would therefore be about $8531.

With both insulation and windows upgraded, the eQUEST software determined that 24,470 kWh would be used to heat the house over the course of a year. The upgrades reduced the space heating energy requirement by 12,990 kWh per year, or by nearly 34%. This would result in a reduction of utility bills by $1361 per year.

The payback period of this investment would be 77 months if cash-financed or 87 months if debt-financed. The return on investment is nearly 16% per year.

Figure 3: The monthly change in debt or lost cash during the first 96 months after renovating windows only
Evaluation of Criteria

This section will go over the evaluation of each criterion in order to determine the feasibility of each possible renovation. As previously stated, the criteria are: 1) sufficiently short payback period of investment, 2) manageable capital requirements, and 3) satisfactory living conditions for tenants while work is being done.

In all projects, all tenants are absent while the work is being done, so criterion 3 is not applicable.

**Insulation Only**

A payback period of 45 to 48 months is more than sufficiently short, and a return on investment of 29% per year is high. It is like that there are not many opportunities for other investments such as asset acquisitions, as few if any new houses are being constructed in downtown State College. Even if a similar existing house with similar rental rates could be purchased for around $200,000, the return on investment for this would be only about 11% per year.

The capital requirement of this investment is also highly manageable and presents much less risk than an asset acquisition. The cost of the project would be well under 10% of the value of a given house, so to finance it with the equity of the given house would present little risk.
Windows Only
A payback period of 97 years or more is certainly not sufficiently short. This is longer than the lifetime of the windows themselves.

The capital requirement of this investment is manageable. However, since it is not profitable to finance the investment with debt, cash would have to be used. The reduction of available cash would increase overall operational risk.

Both Insulation and Windows
A payback period of 77 to 87 months is sufficiently short, and a return on investment of nearly 16% per year is about comparable to an investment in new assets.

The capital requirement of this investment is manageable. The cost of the project would probably represent less than 10% of the value of a given house, so to finance it with the equity of the given house would present relatively low risk.

Conclusions
To upgrade the insulation would be feasible and a profitable investment. It is also feasible to upgrade both the insulation and windows, but the high cost of the windows and small energy savings from them significantly diminishes the return on investment compared to insulation alone. Additionally, it is significantly less capital-intensive to renovate the insulation alone than both insulation and windows.

According to Oak Ridge National Laboratory, it is feasible to upgrade the exterior wall and attic insulation for a range of amounts of existing insulation, not just that specifically of the model house (see “Retrofit Options: Addition of Attic and Exterior Wall Insulation”). There were no eQUEST energy simulations and cost analyses conducted for any of these other combinations of existing insulation. It is likely that the cost, the payback period, and return on investment of any of these modified projects will differ from those of the model house. However, since the Oak Ridge recommendations are based on significant level of other details of the model house (see Appendix B), it can be assumed that any of these projects would fulfill the criteria as well.

It is not feasible to replace functioning windows with energy-efficient windows. However, it may be economically feasible to pay extra per window for increased energy efficiency for when windows are in need of replacement. This issue warrants its own investigation.

Recommendations

- Determine the amount and effectiveness of insulation in a given rental house that is heated by electric baseboard.
- If the attic insulation has R-value of 30 or less, add insulation to the attic to bring total R-value to 49 (if possible, considering house construction).
- If there is no insulation in the exterior wall cavity, blow-in insulation into the cavities to obtain an R-value of 13 (if possible, considering house construction).
- Schedule the house to be tenant-free for a half-month to do any of the preceding work.
- Increase the rental rate by however much is saved on utility bills if the bills are paid by the tenants, otherwise enjoy the savings directly.

An estimation of the decrease in energy consumption for a given house could be calculated using eQUEST. This freeware can be downloaded for no charge at http://www.doe2.com/equest/ [1].
References


Appendix A

Glossary

Batt Insulation: a type of blanket insulation which has been cut lengthwise into sections, and is available in the standard widths between wall studs or attic joists; roll insulation differs from batt insulation primarily in that it has not been precut lengthwise [4]

to Blow (or Blow-In) Insulation: taking a mass of loose insulation fibers (called “loose-fill insulation”) and using a special machine to blow the mass out of a tube; the tube can be stuck inside wall cavities to stuff the wall full of insulation, or be brought in the attic to create a loose pile of insulation above the ceiling [4]

Insulation Sheathing: rigid foam board insulation which has been installed outside of the exterior wall [4]

R-value: a measure of the effectiveness of an insulating product at resisting heat flow; it is the inverse of heat conductivity at a given thickness of material, and has units (in the United States) of square-feet degrees Fahrenheit hours per British Thermal Unit (ft²·°F·h/Btu) [4]
Appendix B

Additional details regarding the Oak Ridge National Laboratory insulation recommendation

The recommendation to increase the insulation in the attic to R-value of 49, and in the exterior walls to R-value of 13, is based on all of the following facts about the model house:

- The house is located in State College, PA.
- The house is wood-framed, and contains the exact R-value of insulation that exists in the model house.
- The house is primarily heated by electric baseboard and has no air conditioning.
- The project is funded by a loan which bears annual interest at 4% or less, or is funded by available capital which earns the same. [2]