3 The house as a system SLIDE 1

THE HOUSE AS A SYSTEM

KEY CONCEPTS

Module overview

EXPLANATION

This module is part of a larger course on energy efficiency in remodeling. Although a remodeling project may involve only one room in a house, the project will affect other parts of the house because a house works as a system of its parts. For example, if replacing the siding on a home, check to see if the walls are insulated. Also, inspect the age and condition of the windows. It is usually always a cost effective practice to install an air barrier with seams properly lapped and taped. Consider whether an additional layer of rigid foam insulation might be a cost effective energy improvement, but be sure the material you use will not be a vapor retarder that could trap moisture. Attention to interactions is needed to ensure that the final product performs well and that the customer is happy. The objective of this module is to increase your understanding of a systems approach to remodeling and to demonstrate how a systems approach can improve the final product. Several examples will be presented.

RESOURCES

Systems Engineering Research - http://www.eere.energy.gov/buildings/building_america/se_research.html

Information Resources - http://pix.nrel.gov:8020/BASIS/nich/www/bapublic/SF

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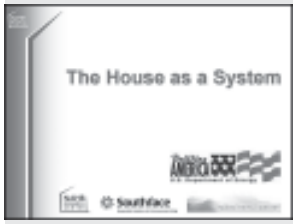


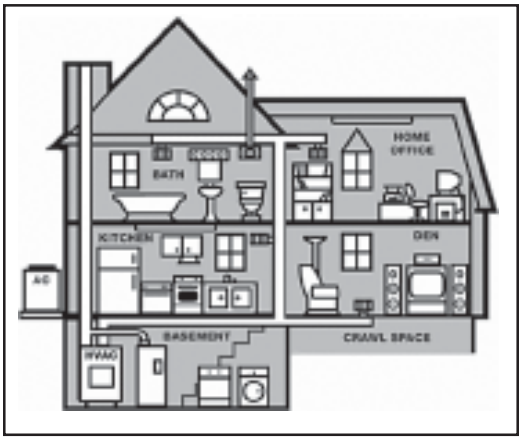
"SYSTEMS APPROACH" TO REMODELING

KEY CONCEPTS

The house is a system of components (building envelope, space conditioning equipment and distribution system, lighting, appliances, and water heating) that interact. How they interact will determine the home's performance (e.g., cost, energy consumption, humidity level, durability, structural integrity). A home's performance impacts the occupant's satisfaction (e.g., health, safety, comfort). A systems approach involves understanding the impact of remodeling on whole house performance and looking for opportunities to make improvements.

ACTION ITEMS

Understand that decisions made during remodeling can affect the home's performance. Help your customer make informed decisions upfront that will increase their satisfaction and avoid future problems.



RESOURCES

Systems Engineering – http://www.eere.energy.gov/buildings/building_america/se_research.html

ENERGY STAR http://www.energystar.gov

Home Energy Magazine http://www.homeenergy.org

No Regrets Remodeling (available through Home Energy Magazine), an over 200-page guide to energy efficiency in remodeling. Includes diagrams, worksheets, definitions, and concise explanations. An excellent resource for a remodeler interested in energy efficiency.

Energy Efficient Rehab Advisor (U.S. HUD) http://rehabadvisor.pathnet.org. A simple software tool for evaluating the top efficiency improvements in an existing house, including approximate costs and payback.

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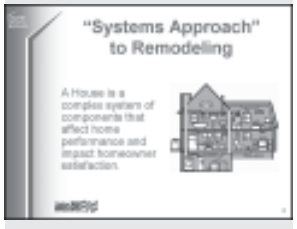


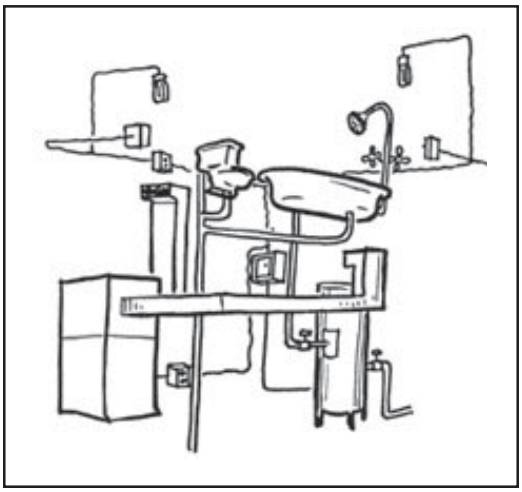
CONSIDER THE INTERACTIONS BETWEEN:

KEY CONCEPTS

Considering the interactions between the parts of the house system is key to making the best choices in a remodeling project.

EXPLANATION

The interactions between the building envelope, space conditioning, other components, and climate will be shown in several upcoming examples. The lifestyle of the occupants also plays an important role in the outcome. Understanding how your customers will use their house after remodeling is complete can help you recommend the best options. Homeowners who consume more energy (e.g., a household with a number of teens that take long showers and leave lights on in unoccupied rooms) are likely to save more through efficiency upgrades than those with more conservative lifestyles (e.g., a two-person household that sets the temperature back at night or when leaving for the day).



ACTION ITEMS

Develop an understanding of your customer's lifestyle. This will assist you in designing a remodeling project to best suit the customer's needs while maximizing energy savings.

RESOURCES

Building Envelope, Cooling Systems, Heating Systems, - http://pix.nrel.gov:8020/BASIS/nich/www/bapublic/SF

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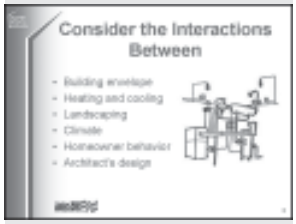

WHY EVALUATE THE HOUSE AS A SYSTEM?

KEY CONCEPTS

Understanding the interactions between components of the house makes it possible to improve performance. Evaluating trade-offs will help you provide the best overall value for the customer.

EXPLANATION

There are usually a number of ways to provide the basic functions of a house (e.g., heating, cooling, lighting, appliances). Understanding the interaction between components enables you to select the best options for a house. When heating and cooling a home, the windows, doors, walls, ceiling, floors, insulation, infiltration, climate, and lifestyle of the occupants all impact the heating and cooling energy consumption.

For example, changing the characteristics of any of these components can increase or decrease the home's energy needs and, hence, the HVAC equipment capacity that is needed. As energy needs increase (by increasing square footage, for example), more efficient space conditioning equipment becomes a better value. But as the load decreases, it can reach a point where the payback for the more efficient equipment may become unattractive. (However, decreased loads may lead to the ability to install smaller capacity equipment, thereby reducing initial investment in some cases.) Evaluating a house as a system helps you provide the best value to the customer.

Using a systems approach can achieve multiple benefits from one action. For example, by air sealing (caulking around windows, doors, and penetrations) you not only reduce the potential for moisture intrusion and space heating and cooling costs, but also increase comfort by reducing air infiltration and controlling humidity. Another example is the installation of motion and photo sensors on outdoor lighting that saves energy while providing improved security and safety.

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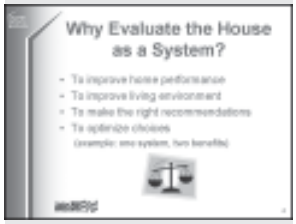

SYSTEMS APPROACH BENEFITS

KEY CONCEPTS

Each improvement in energy efficiency allows additional adjustments in the system to be made, further reducing energy consumption by the system as a whole.

ACTION ITEMS

Look for ways that the improvements your customer wants can work together as a system to give customers what they want and more.

EXPLANATION

As an example of the benefits of a systems approach, start by considering a building that is compliant with the Model Energy Code. By reducing air leakage through the building shell and through ducts, a smaller HVAC system with smaller ducts can be used to provide the same level of comfort in the home. Smaller ducts may be more easily run through conditioned space, reducing duct energy losses and allowing a further reduction in HVAC system size. This entire process frequently occurs with little or no impact to the project's first costs and with significantly lower operating costs for the finished product.

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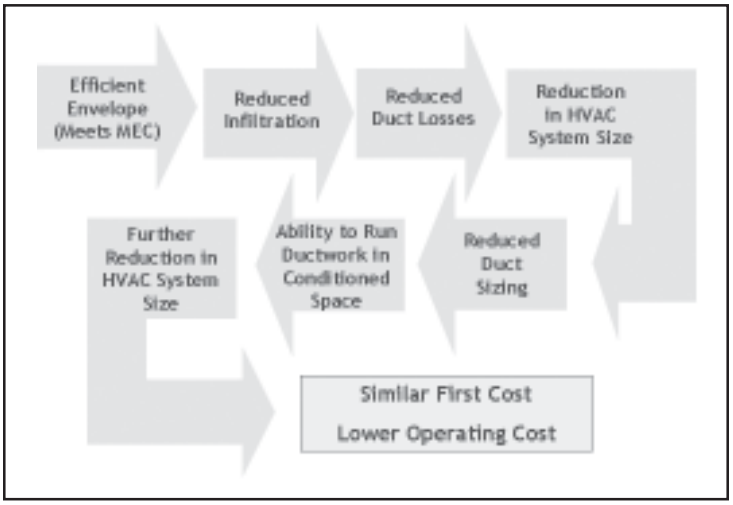

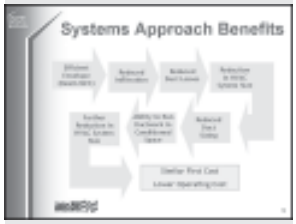

OTHER BENEFITS OF A SYSTEMS EVALUATION

KEY CONCEPTS

Understanding how parts of the systems interact may enable you to see why problems have occurred in the existing house and how to avoid them in the remodeled home. A systems approach will also help you to avoid potentially costly mistakes including mold, premature deterioration, and other callback (or lawsuit!) issues.

EXPLANATION

For example, in a bathroom remodeling project that includes the addition of a Jacuzzi tub, adding more efficient mechanical ventilation with a timer control is a good idea to avoid excessive moisture buildup, which can lead to mold and premature deterioration of building materials. In another example, it is best in almost all climates to avoid using a vapor barrier on exterior walls of bathrooms, since bath walls can get wet from both sides of the wall and need to be able to dry to the inside and outside. In this vein, it is advisable to steer clients away from wallpaper, especially vinyl wallpaper which can serve as a vapor barrier and impede drying. By adding ventilation to reduce moisture at its source and building walls systems that are able to dry out when they do get wet (from inside or outside), you can help reduce the chance of mold or premature deterioration of materials.

RESOURCES

Information Resources - http://pix.nrel.gov:8020/BASIS/nich/www/bapublic/SF

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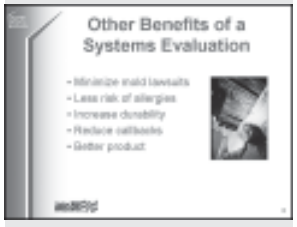

BUILDING SCIENCE

KEY CONCEPTS

The physical science "laws" (recall Building Science Basics) help us understand why houses perform as they do. Measuring and evaluating performance can help us evaluate potential changes before they occur, thereby maximizing potential improvements and avoiding costly mistakes.

EXPLANATION

For more information on this topic, also see the module on Building Science Basics.

Keep in mind that an understanding of the laws of physical science is only the first step. Applying this knowledge to an actual project is usually not straightforward and may take some investigation. There also typically are multiple reasons for a particular situation rather than only one. For instance, a mold issue may be a combination of building defects and homeowner practice. One home in the midwest had mold in certain areas of the wall near the floor (slab on grade) as well as on some windowsills and walls. The problem was traced to several causes: grade too high and not properly sloped away from the home, gutter downspouts not diverting water adequately, very high humidifier settings (60%), and several large aquariums. In most cases, combining good building practice principles with practical common sense can identify and resolve most issues.

RESOURCES

Building Science Topics, FAQs - http://www.southface.org/home/media/articles/articleFAQ.html

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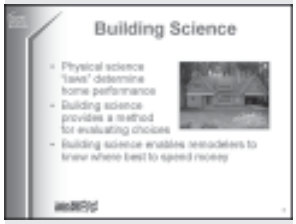

STEPS IN SYSTEMS EVALUATION

KEY CONCEPTS

Look beyond what you are doing to determine the impact of your actions on other components of the house.

EXPLANATION

It is often easy to focus only on the particular reason that you were requested to improve or alter the home and ignore other potential areas. As homes have generally become tighter and better insulated and equipment more sophisticated and often "bigger", it is essential to look beyond the scope of the job that you have been hired to do to determine the effect of the project on the function of a home. Without this foresight, callbacks or in the worst case, legal action can result as your work impacts other portions of the house (such as in the case of the example described on the slide).

ACTION ITEMS

Consider how the actions you take in the remodeling project will impact the rest of the house. Will the impact be "positive" or "negative"?

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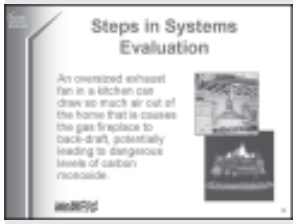


STEPS IN SYSTEMS EVALUATION

KEY CONCEPTS

A systems evaluation is an iterative process that seeks the best value for each component of the house. The steps include:

1. Identify and obtain simulation model
2. Collect data on existing house and occupant lifestyle
3. Input model, run simulation, and save
4. Identify changes for base case remodel
5. Input model, run simulation, and save
6. Evaluate the results of simulations and look for improvement opportunities
7. Test opportunities with the model
8. Repeat process until the best value has been reached

EXPLANATION

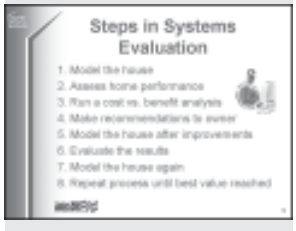
Simulation models enable the remodeling project designer to evaluate the impact of various options and alternatives relatively easily and quickly. Most models provide reasonably good results when looking at the various options based on a set of assumptions. However, because the results are based on assumptions, the actual energy consumption associated with a particular strategy or option may not reflect reality. It is generally unwise to quote specific savings to the homeowner based on modeling.

When selecting among options in the evaluation process, it is prudent to look for large or significant changes or differences. Small differences in energy savings (a few percent) are unlikely to make a noticeable difference in actual conditions (that are affected by other factors such as weather and occupant behavior).

ACTION ITEMS

- Identify a simulation model that will enable you to evaluate alternatives. Acquire and become familiar with operating the model. This can frequently be accomplished in four to six hours.
- Test the model with inputs from one of your projects to determine the type of information provided and its usefulness to you and/or the homeowner. Once you feel comfortable using the model and understand what it can provide and how to use that information, begin making it a part of your normal design process.
- Show the results to homeowners if they are interested or curious.
- Alternately, consult with a contractor who can perform simulations for you, such as a HERS rater.
- Software program costs are $300 to $500 and these programs can be used on many remodeling projects. However, this added cost and effort is likely to be most appropriate and beneficial for a major remodeling project. Measuring the house, window and door area, type of mechanical equipment, and other factors to input into a computer model can be time consuming – and more so for an existing home than a new home for which you have a set of plans.

- Using a "systems approach" does not necessarily require this level of effort. Most remodelers will not go to this effort for many of their projects. There are many levels at which to implement "systems thinking" – e.g., from simply replacing a roof (look at and consider attic ventilation, bath ventilation, possible dryer vent, attic insulation) to single



STEPS IN SYSTEMS EVALUATION

room renovation/addition (added insulation, ventilation, lighting), to larger or whole house renovation projects (use modeling/simulation to evaluate options).

RESOURCES

Potential simulation programs include:

REM/Design, http://www.archenergy.com/products/rem/rem_design/

TREAT, http://www.treatsoftware.com

There is a directory of Certified Home Energy Raters at http://www.energystar.gov

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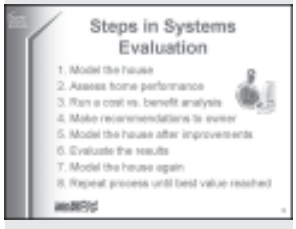

DECISION MAKING TOOLS

KEY CONCEPTS

Become familiar with tools available to help you and your client understand the costs and benefits of energy improvements.

EXPLANATION

TREAT is the first all-inclusive tool that allows one to model different energy improvements and provides a summary of the reduction in energy use and associated monthly expenses. Developed by Ithaca-based company, Performance Systems Development, the software enables you to enter a description of the existing home and location and data regarding current utility bill and energy usage. Then, various upgrades can be entered to determine the costs and savings. Projects can be uploaded to a universal database that not only continues to serve the underlying "brains" of the software, but also can be readily accessed by program administrators to document the progress of a project. For instance, an agency who has funded a weatherization project might want to track how much work had been completed. The cost of the TREAT software is $495.

REM Design is very similar to REM Rate, the ENERGY STAR approved software for certifying new homes. A description of the existing home—including square footage of walls, windows, and floors, R-value of attics and floors, and other factors—and current utility rates is entered. The program provides a summary of estimated annual space heating and cooling costs/energy use, water heating costs, lighting and appliances, etc. Recommendations are also given for the most cost effective energy improvements. Proposed energy improvements can be entered and the program estimates energy use reductions for the improvements. The energy use of the baseline as well as the improved home is "estimated" based on typical usage for a home that size. It may or may not accurately reflect your clients' situation. It does, however, provide an idea of the relative benefits and savings to be achieved by the energy improvements.

ACTION ITEMS

Consider investing in the energy modeling software.

RESOURCES

TREAT – Available from Performance Systems Development, Inc., Ithaca, NY

REM Design – Available from Architectural Energy, Inc.

NOTES

TREAT SOFTWARE

EXPLANATION

TREAT is a whole-house energy analysis program designed for examining the energy benefits of remodeling and renovation projects. It is challenging to use and the cost is fairly high. It is geared more towards weatherization programs and building performance contractors or energy specialists rather than the typical remodeler. However, it is the only tool available that can perform detailed analysis of an existing home and model the energy impact of improvements.

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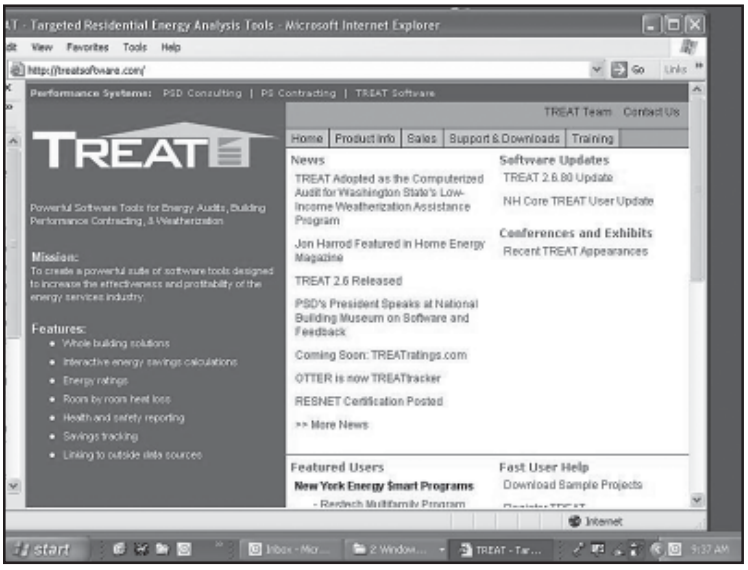

http://www.TREATsoftware.com
$495

REM & ENERGY-10 SOFTWARE

EXPLANATION

REM Design is a whole-building analysis program and would be appropriate in cases where your client may want a detailed picture of the energy performance of his current home versus the home once improvements have been made. It requires detailed inputs from the user regarding window and wall geometry, R-values, construction materials, type of HVAC system, water heater, and other inputs. It requires quite a bit of time to enter an existing home accurately, but once this is completed, it is easy to make modifications and view the impact on energy use and cost.

REM/Software
The choice for home energy savings.

http://www.archenergy.com/products/rem/
Cost: $300

ARCHITECTURAL ENERGY CORPORATION
Integrated Engineered Solutions

Energy-10 is a more sophisticated hourly simulation tool for energy design. It is suited for architects and building designers to determine the most cost effective energy saving measures. These software tools are shown to give you an idea of what is available for energy simulation and modeling.

NREL ENERGY-10

www.sbicouncil.org
Cost: $300

REM DESIGN-INPUT SCREEN

KEY CONCEPTS

Sample input screen for REM Design. Note detailed inputs required. TREAT is similar in terms of level of detail.

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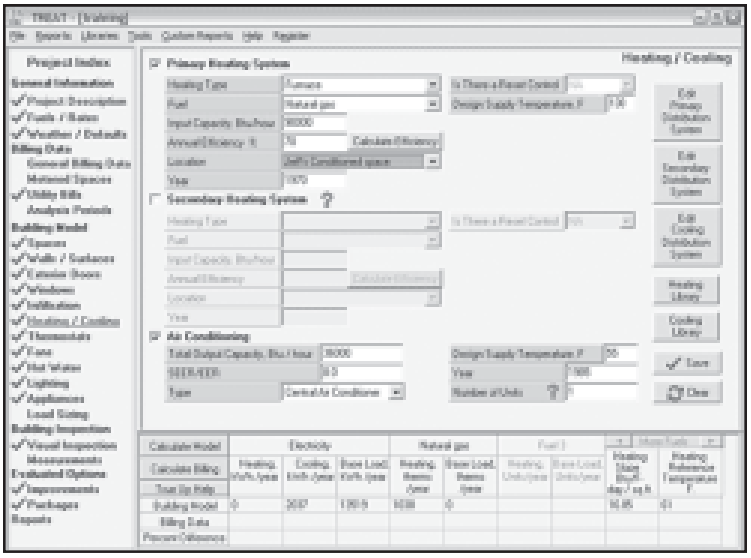

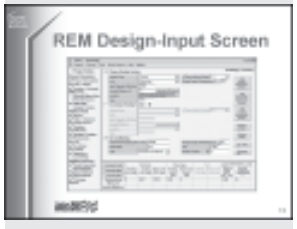

REM DESIGN-INPUT SCREEN

KEY CONCEPTS

Sample input screen for REM Design – Mechanical Systems.

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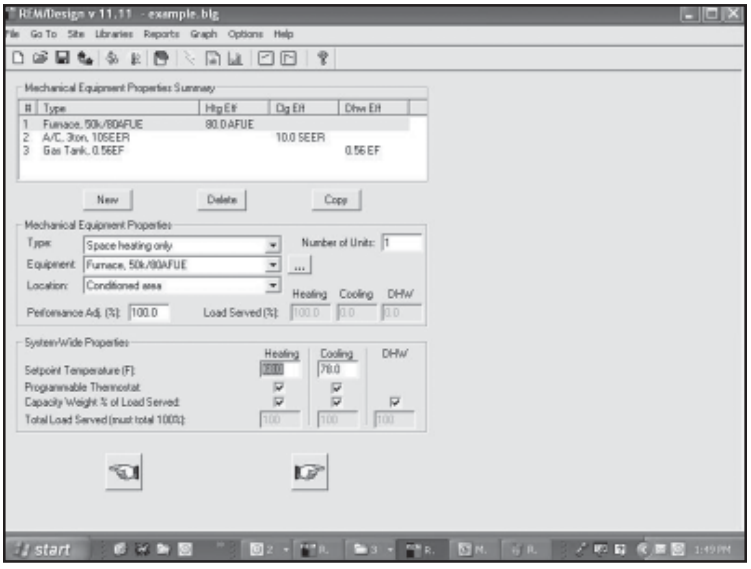

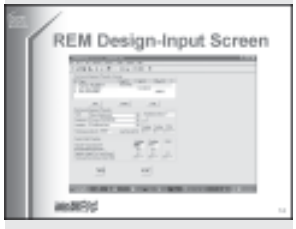

REM DESIGN-ANALYSIS SCREEN

KEY CONCEPTS

Sample analysis screen for REM Design.

EXPLANATION

There are numerous project summaries and formats that REM Design will output – tables, bar charts, energy use by component, cost summaries, and suggested improvements.

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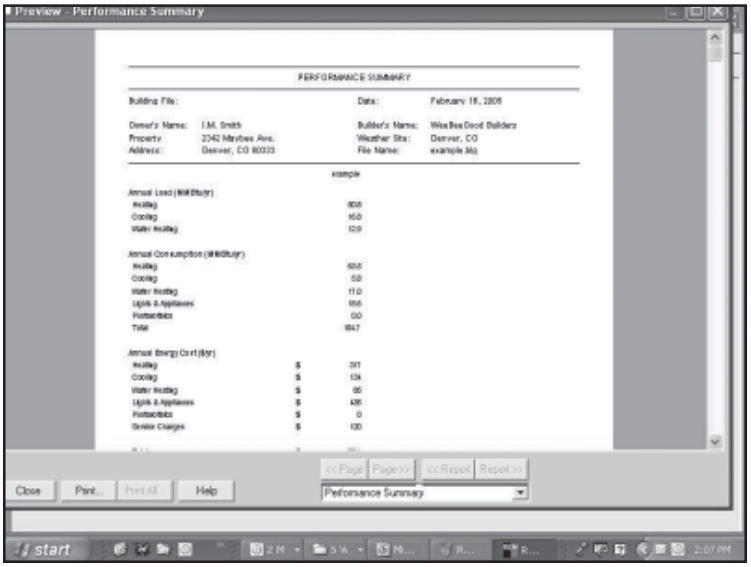

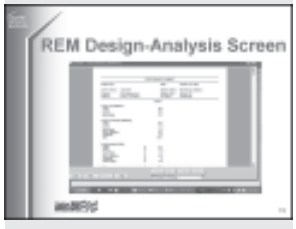

REM DESIGN-ANALYSIS SCREEN

KEY CONCEPTS

Sample analysis screen for REM Design.

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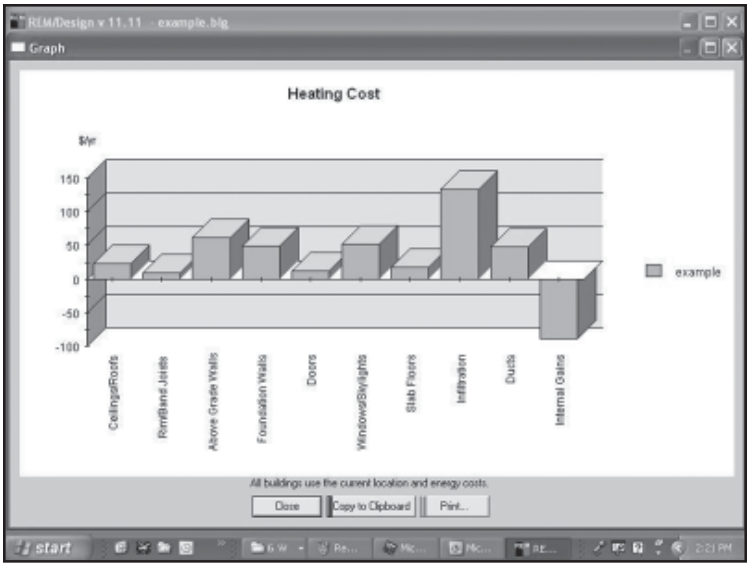
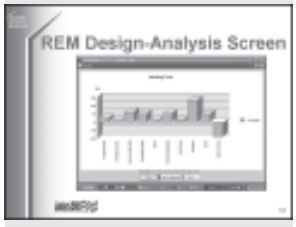




SYSTEMS EVALUATION SPACE ADDITION

KEY CONCEPTS

An example of how the systems evaluation process works with space additions.

EXPLANATION

Using the inputs needed for the simulation program, gather the information you will need to perform a systems evaluation. Note that highly detailed and "accurate" data (e.g., 6'-10 1/2") is not generally required and that simplified inputs (e.g., 7') will usually suffice. In the field, major dimensions should be measured, but minor ones can be estimated. For example, the overall size of the house is important, but the exact width of a door is less critical.

Once collected, the data is input to the simulation model and the software performs the calculations. Results from different models tend to be similar, although not exactly the same.

This example shows that the planned addition will increase the heating and cooling design load beyond the capacity of the relatively new furnace and air conditioner. This could be an "unpleasant surprise" to the homeowners.

However, further evaluation demonstrates how the homeowners can continue using the existing furnace and air conditioner (a cost savings of ~$5000 over replacement) while saving about $200 annually in utility bills. This kind of information should bring smiles to the homeowners' faces.

ACTION ITEMS

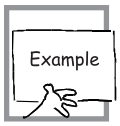
Go through the example worksheets provided with this module. Discuss the results with your instructor and other students.

RESOURCES

Building Science Topics, FAQs - http://www.southface.org/home/media/articles/articleFAQ.html

Hot-Humid Climate Homes - http://pix.nrel.gov:8020/BASIS/nich/www/bapublic/SF

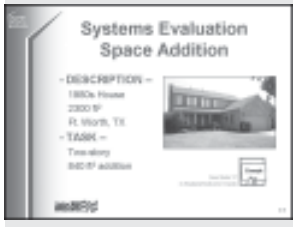
SPACE ADDITION – 1980s HOUSE



Location: Fort Worth, Texas

Current House Description

The current house is a two story, four bedrooms, 2.5 baths, 2296 ft^2, built in the early 1980s. It has a slab on grade foundation, wood frame and wood lap siding walls with R-11 insulation, and an attached garage. The windows are double pane aluminum frame without thermal break (14 @ 3'-0" x 4'-0", four



SYSTEMS EVALUATION SPACE ADDITION

per N&S walls, three per E&W walls). It has R-30 attic insulation, no foundation insulation, 6 panel solid wood front door (north facing), and an aluminum frame with double pane glass patio doors 6'-0" x 6'-8" (south facing). The envelope has moderately high infiltration due primarily to "sloppy" initial construction. The home currently has central heating and air conditioning with a gas furnace (80% AFUE), air conditioner (10.0 SEER), and ducts in the interstitial space between floors that are moderately leaky. Everything in the home is original (20+ years old) except the roof at 5 years old, and the furnace and air conditioner at 2 years old.

Space Addition Description

The owner desires to add an ~840 ft^2 two story addition to the west side of the existing home that will house two additional bedrooms and a bath on the second level and will permit the expansion of the family room and kitchen on the first level. In addition, the high cost of cooling the existing home has the homeowner open to considering paying the added costs of upgrading this home where these improvements will payback in less than three years.

Base Case

Add the additional space as described above without considering efficiency upgrades for other portions of the house. This addition is to be done to a minimum code compliant level. Determine if the two year old furnace and/or air conditioner have to be replaced because they are too small. If they are, identify cost effective upgrades to the existing structure to reduce the design load sufficiently to fit, if possible, within the capacities of the existing equipment.

Potential Energy Efficiency Upgrades

In addition to identifying the best available technologies to upgrade the base case and permit retention of the existing heating and cooling equipment, the following potential upgrades are to be evaluated to determine their annual energy savings:

1. Upgrade front door to steel with urethane foam core and upgrade new and replace existing windows with double pane low-E argon filled glazing in a vinyl frame.
2. Increase attic insulation to R-60.

In determining the payback for items above, you should use the full cost increase since these items are not included in the base case. Divide the additional costs by the energy saving to determine the payback for each item.

Energy Evaluation

Using Rem/Design or other residential energy simulation models, determine the annual heating and cooling energy consumption and cost for both the existing home and the home following the space addition. Also evaluate potential energy efficiency upgrades for their annual energy savings. The results from an analysis using Rem/Design are shown following in **bold**.

Existing house

Annual heating and cooling energy consumption - 74.1MBtu/yr, and cost - $876

Design load for heating - 46.7Btu/hr, and cooling - 41.6kBtu/hr

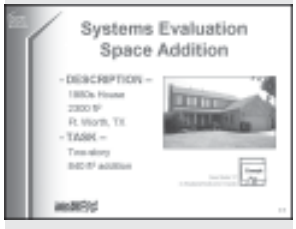
Base case addition

Annual heating and cooling energy consumption – 93.7MMBtu/yr, and cost - $1080

Design load for heating – 59.9kBtu/hr, and cooling – 53.1kBtu/hr

Base case addition with upgrades

Upgrades include: reduce infiltration from 1.0ACH to 0.7ACH, increase attic insulation from (R-30 to R-38, and upgrade windows used in the addition from double pane metal frame to double pane low-E metal frame with thermal break.



SYSTEMS EVALUATION SPACE ADDITION

Annual heating and cooling energy consumption - 74.4MMBtu/yr, and cost - $894

Design load for heating - 49.4Btu/hr, and cooling - 44.2Btu/hr

*Potential energy efficiency upgrades with rough estimate of installed costs and annual energy cost savings (**shown in bold**).*

*Replacement door as steel with urethane foam core and thermal break **$450 cost, $3 savings***

*Replacement/new windows as double pane, low-E, argon filled, vinyl frame **$4900 cost, $94 savings***

*Add R-30 attic insulation (R-60 total) **$1720 cost, $5 savings***

Comments

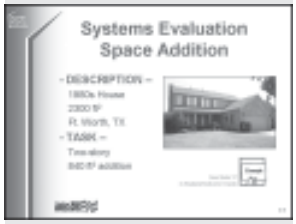
The base case house addition increases the design load for both heating and cooling beyond the capacity of the existing two and five year old equipment. Replacing this relatively new equipment would add about $5000 to the project. Given the situation it is prudent to investigate upgrades to the existing house and addition that would reduce the design load of the enlarged home to within the capacity of the existing equipment.

Reducing the infiltration from 1.0ACH to 0.7ACH through sealing the envelope is relatively inexpensive and has a large impact. Adding insulation in the existing attic, while having less impact, is easy to accomplish while the addition in insulated. Upgrading the windows used in the addition helps to reduce load and can be accomplished for only the incremental cost above the standard windows used in the base case.

While these improvements may not have attractive paybacks on the basis of energy savings alone, the fact that they permit avoiding the replacement of the furnace and air conditioner ($5000 savings) makes them economically justified. In addition the homeowner will save $186 per year on utilities.

In the potential energy efficiency upgrades for this house, the full cost of replacement windows throughout the entire house and front door is shown. This is because the homeowner did not request that windows or the front door be replaced and replacement was not required for other reasons. Thus, the first cost must be justified by the potential energy savings alone. The paybacks on these options was well beyond what the customer considered acceptable.

NOTES



SYSTEMS EVALUATION SPACE CONVERSION

KEY CONCEPTS

An example of how the systems evaluation process works with space conversions.

ACTION ITEMS

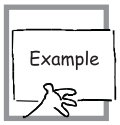
Go through the example worksheets.

RESOURCES

Building Science Topics, FAQs - http://www.southface.org/home/media/articles/articleFAQ.html

Cold Climate Homes - http://pix.nrel.gov:8020/BASIS/nich/www/bapublic/SF

SPACE CONVERSION – 1970s HOUSE



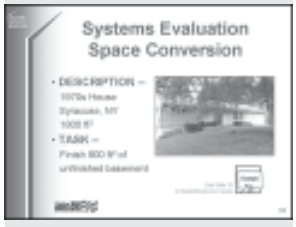
Location: Syracuse, New York

Current House Description

The current house is a one story, three-bedroom, two-bath, 1820 ft^2 home with an unfinished basement built in the 1970s. Approximately half of the basement is used as a garage. The basement walls are exposed above grade 3 ft on the south and west exposures and fully covered on the north and east. The main floor walls are wood frame with wood lap siding and R-11 insulation. There is R-30 attic insulation, but no floor, foundation or band joist insulation. The front door is 6 panel solid wood (south), while on the north wall there are wood frame, single pane patio doors 6'-0" x 6'-8". The windows are double-pane aluminum frame windows without thermal break (10@ 3'-0" x 4'-0"- two per east & west wall, three per north & south wall). The envelope has moderate infiltration associated with the original poor quality construction and a variety of air leak sources. The home currently has heating and cooling from a 10 year old oil furnace (80% AFUE) and air conditioner 10.0 SEER, with moderately leaky ducts in the unconditioned basement space. Everything else is original (30+ years old) except the roof at 10 years.

Space Conversion Description

The owner desires to convert ~900 ft^2 of the unfinished basement into a recreation room, two additional bedrooms and a full bath. In addition, the high cost of heating with fuel oil has the homeowner open to considering upgrading his home where these improvements will payback in less than three years.



SYSTEMS EVALUATION SPACE CONVERSION

Base Case

Convert the basement alone without considering efficiency upgrades for other portions of the house. This conversion is to be done to a minimum code compliant level. Determine if the ten year old furnace and/or air conditioner have to be replaced because they are too small. If they are, identify cost effective upgrades to the existing structure to reduce the design load sufficiently to fit, if possible, within the capacities of the existing equipment.

Potential Energy Efficiency Upgrades

In addition to identifying the best available technologies for the base case, evaluate the following potential upgrades to determine their annual energy savings and whether they can provide a three to five year payback:

1. Upgrade replacement furnace to 90% or 95% AFUE and air conditioning to SEER 12 or 16.
2. Install replacement door (steel with urethane foam core) and replacement windows with double pane low-E argon filled glazing in a vinyl frame.
3. Increase attic insulation from R-30 to R-60.
4. Insulate floor to R-19.
5. Reduce infiltration to 0.7ACH.

In determining the payback for item 1, use the incremental cost increase if the existing furnace and air conditioner are too small and must be replaced. Otherwise use the full cost of these items. These incremental costs are usually only the increase in the material costs since the installation labor in most cases is about the same. Divide the additional costs by the energy saving to determine the payback for each item.

Energy Evaluation

Using Rem/Design or other residential energy simulation models, determine the annual heating and cooling energy consumption and cost for both the existing home and the home following the space conversion. Also evaluate potential energy efficiency upgrades for their annual energy savings. The results from an analysis using Rem/Design are shown following in **bold**.

Existing house

Annual heating and cooling energy consumption - 200.5MBtu/yr, and cost - $2507

Design load for heating - 72.5kBtu/hr, for cooling - 33.4kBtu/hr

Base case space conversion

Annual heating and cooling energy consumption - 169.2MMBtu/yr and cost - $2096

Design load for heating - 66.5kBtu/hr, for cooling - 29.7kBtu/hr

*Potential energy efficiency upgrades with rough estimate of installed costs and annual energy cost savings (**shown in bold**).*

*90% AFUE furnace - $3500 **cost**, $176 **savings**, 95% AFUE furnace - $3700 **cost**, $248 **savings***

*12 SEER air conditioner - $2400 **cost**, $7 **savings**, 16 SEER air conditioner - $2600 **cost**, $16 **savings***

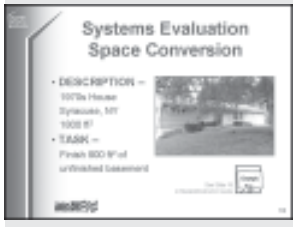
*Replace front door with steel door with urethane foam core and thermal break - $450 **cost**, $13 **savings***

*Replace windows with double pane, low-E, argon-filled glazing in vinyl frame - $3500 **cost**, $161 savings*

*Add R-30 attic insulation (R-60 total) - $2730 **cost**, $67 **savings***

*Insulate floor to R-19 - $1100 **cost**, $234 **savings***

*Reduce infiltration to 0.7ACH - $600 **cost**, $295 **savings***



SYSTEMS EVALUATION SPACE CONVERSION

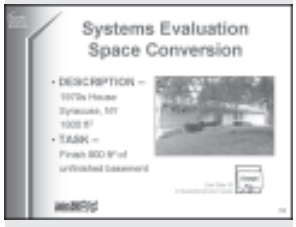
Comment

The simulation of the existing and base case space conversion shows that the design loads actually drop as the unconditioned space in the basement is insulated and added to the conditioned space. The existing ten year old furnace and air conditioner will not need to be replaced reducing potential costs by about $6000. This conclusion could be missed if the increased amount of conditioned space was the only factor considered. Because replacement is not required, upgrading these items to higher efficiency replacements requires the full cost of the replacement must be used. This will extend the payback well beyond the homeowner's desires.

Of all the options investigated, only reducing infiltration (air sealing) and adding floor insulation over the basement garage have an acceptable payback. The air sealing payback is about 2 years and should be an easy sell to the homeowner on the basis of energy savings alone. It should also make the house more comfortable by reducing cold drafts in the winter. The payback for the added floor insulation is 4.7 years and might require more effort to sell because this is near the customer's "upper limit" of 5 years. It would be wise to mention the comfort improvements (warmer floors) along with the energy savings when presenting this option to the homeowner.

Additional attic insulation with a savings of $67 per year will have a payback beyond five years. The front and patio door replacements along with replacement windows would save $174 annually. The payback for these items is also well beyond the homeowners desires.

NOTES



SYSTEMS EVALUATION MAJOR REPAIR

KEY CONCEPTS

An example of how the systems evaluation process works with major repairs.

EXPLANATION

This house has been damaged by a major flood and requires a major repair and upgrading to meet the criteria of FEMA's National Flood Insurance Program (NFIP).

ACTION ITEMS

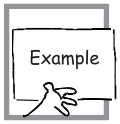
Go through the example worksheets.

RESOURCES

Building Science Topics, FAQs - http://www.southface.org/home/media/articles/articleFAQ.html

Cold Climate Homes - http://pix.nrel.gov:8020/BASIS/nich/www/bapublic/SF

MAJOR REPAIR – 1960S HOUSE



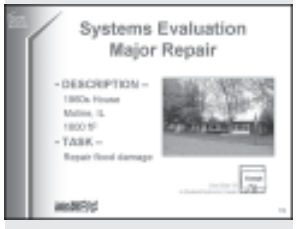
Location: Moline, Illinois

Current House Description

The current house is a one story, three bedroom, two bath, 1820ft^2 home built in the early 1960s. It has a vented crawl space, wood frame brick veneer exterior walls with R-11 insulation, R-19 attic insulation, no floor insulation, 6 panel solid wood front door (north facing), single-pane wood frame windows with storm windows (6 @ 3'-0" x 4'-0"- two per west wall, three per north and south wall), wood frame with single pane glass patio doors (6'-0" x 6'-8" - south facing). The envelope has moderate infiltration due to the construction practices of the 1960s. The home currently has heating and air conditioning from a gas furnace (70% AFUE) and air conditioner (8.5 SEER), with ducts in the crawl space that are moderately leaky. Everything is original (40+ years old) except the roof at 5 years, the furnace at 15 years, and the air conditioner at 10 years. There is an attached garage on the east side.

Major Repair Description

In the spring, a dike along the Mississippi River broke permitting flood water to enter this home to a level of two feet above the floor. The envelope, equipment and virtually all contents



SYSTEMS EVALUATION MAJOR REPAIR

were damaged and will require renovation or replacement. Flood insurance will cover the cost of renovation which is less than half of the replacement value. However, with the loss of the use of their home for many months while repair is occurring, the homeowners are desirous of minimizing the length of any future loss by using flood damage resistant materials and systems. In addition, the high cost of heating has the homeowners open to considering paying the added costs of upgrading this home where these improvements will payback in three to five years.

Base Case

The repair of the flood damaged house will be "in-kind" except where required to upgrade to meet National Flood Insurance Program's (NFIP) flood-damage resistance requirements. These requirements include: SPUF insulation in the walls, insulated metal or fiberglass exterior doors, aluminum or vinyl replacement windows, ducts relocated to the attic (above potential flood level), and raising the furnace and air conditioner above potential flood level but with an in-kind replacement. With the exception of the preceding items the base case repairs are assumed to be the lowest cost currently available technology that will meet building code requirements.

Potential Energy Efficiency Upgrades

In addition to identifying the impact of the lowest cost available technologies for the base case the homeowner desires to have the following potential upgrades evaluated to determine their annual energy savings and potential payback:

1. Upgrade replacement furnace to 90% or 95% AFUE and air conditioning to SEER 12 or 16.
2. Upgrade new ductwork by sealing all joints
3. Upgrade replacement windows to double pane low-E argon filled vinyl frame.
4. Increase attic Insulation to R-30.
5. Insulate floor to R-19.

In determining the payback for items 1-3, use the incremental cost increase since these items are included in the base case. These incremental costs are usually only the increase in the material costs since the installation labor is in most cases is about the same. For items 4 & 5, use the full costs since they are not included in the base case major repair and must be justified on energy savings benefit alone. Divide the additional costs by the energy saving to determine the payback for each item.

Energy Evaluation

Using Rem/Design or other residential energy simulation models, determine the annual heating and cooling energy consumption and cost for both the existing home and the home following the space conversion. Also evaluate potential energy efficiency upgrades for their annual energy savings. The results from an analysis using Rem/Design are shown following in **bold**.

Existing house

Annual heating and cooling energy consumption - 180.7MMBtu/yr, and cost - $1453

Design load for heating - 76.5kBtu/hr, for cooling - 36.7kBtu/hr

Base case major repair

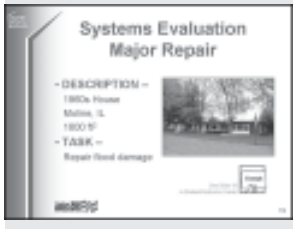
Annual heating and cooling energy consumption - 112.2MMBtu/yr, and cost - $912

Design load for heating - 54.0Btu/hr, and cooling - 26.4Btu/hr

*Potential energy efficiency upgrades with rough estimate of installed costs and annual energy cost savings (**shown in bold**).*

90% AFUE furnace - $500 cost, $66 savings

95% AFUE furnace - $ 700 cost, $94 savings



SYSTEMS EVALUATION MAJOR REPAIR

12 SEER air conditioner - $400 cost, $29 savings, 16 SEER air conditioner - $600 cost, $65 savings

Seal all joints in ductwork - $600 cost, $144 savings

Upgrade replacement windows with double pane, low-E argon filled glazing, vinyl frame - $120 cost, $5 savings

Add R-11 attic insulation (R-30 total) - $1800 cost, $44 savings, Insulate floor to R-19 - $6000 cost, $190 savings

Comments

The extensive flood damage required that the home's equipment be replaced. Therefore, only the incremental cost of the energy-efficiency upgrade, rather than the entire cost of the new equipment, is used in determining payback.

The base case major repair improvements have reduced the heating design load by ~25% and cooling design load by ~33% permitting a smaller, less expensive replacement furnace and air conditioner. The heating and air conditioning contractor should resize the replacement equipment based on the reduced loads.

Because the existing ducts in the crawl space were damaged by the flood, the replacements were relocated to the attic and insulated in the base case. Sealing the joints in the ducts can be easily accomplished during installation and will markedly reduce space conditioning costs. The payback on this item will be less than three years.

Since the attic insulation was unaffected by the flood and the existing floor was uninsulated, the full cost of these two upgrades must be used in calculating the paybacks.

Unfortunately, insulating the floor with an energy savings of nearly $200 per year is not a prudent economic choice because the NFIP requires flood damage resistant materials in this location and that would dictate the use of sprayed polyurethane foam (SPUF) insulation in lieu of fiberglass or other less costly insulation. The payback on this upgrade, therefore, is over 30 years.

The same NFIP criteria which made floor insulation unattractive also requires that wall insulation be resistant to flood damage, thus dictating the use of SPUF to replace the existing fiberglass in that location. This both improves the R-value and air sealing properties of the walls and permits a reduction in the size of heating and cooling equipment. It will also improve comfort (less drafts and higher wall temperature) and lower the utility cost to the homeowner.

Note: NFIP criteria currently (2005) dictates the use of materials resistant to flood damage. However, no official designation has been placed on either fiberglass or SPUF at that time. Thus the details of this example are somewhat hypothetical.

NOTES

SYSTEMS EVALUATION WHOLE HOUSE RENOVATION

KEY CONCEPTS

An example of how the systems evaluation process works with whole house renovations.

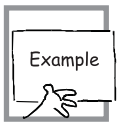
ACTION ITEMS

Go through the example worksheets .

RESOURCES

Building Science Topics, FAQs - http://www.southface.org/home/media/articles/articleFAQ.html

WHOLE HOUSE RENOVATION – 1930s HOUSE



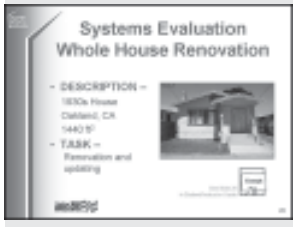
Location: Oakland, California

Current House Description

The current house is a one story, three-bedroom, one bath, 1440 ft² home built in the early 1930s. It has a vented crawl space, uninsulated wood frame stucco exterior walls, R-11 attic insulation, and no floor insulation. The front door is 6 panel solid wood (east facing), and windows are single-pane wood frame windows (8 @ 3'-0" x 4'-0"- two per wall). There is also a wood frame with single pane glass patio door (6'-0" x 6'-8" - west facing). The envelope has moderately high infiltration due its age and deteriorated, "drafty", windows and doors. The home has only heating from a 25 year old gas furnace (70% AFUE), with ducts in the attic that are moderately leaky. Everything is original (70+ years old) except the roof at 10 years old, and the furnace and ducts at 25 years old. There is no attached garage.

Renovated House Description

The owners have paid dearly for this location and desire to update the building to current housing practice. This includes reconfiguring to two bedrooms and adding a second bath, as well as replacing the central heat and adding air conditioning. A new master bath is to have all current amenities and the same is true of the renovated kitchen. They would also like to take advantage of a spectacular view to the west and add more natural light to other portions of the house. They have ample (but not unlimited funds) to complete the renovation and are will to consider energy efficiency improvements that have a "reasonable payback" (3-5 years).



SYSTEMS EVALUATION WHOLE HOUSE RENOVATION

Base Case

In addition to making the desired interior modification and renovations described above and also covered in other training modules, the following changes with potential significant energy consumption impact are to be accomplished:

1. Replace existing 25 year old furnace and add air conditioning.
2. Replace existing ductwork to fit the renovated home's new layout.
3. Replace existing 70+ year old doors and windows.
4. Increase the size of west facing glazing from 24 ft^2 to 36 ft^2, and add 12 ft^2 of glazing to the south and east walls.

In order to focus the renovation on the upgrading of the interior of the house, the preceding items from the base case are assumed to be the lowest initial cost, currently available technology that will meet building local code requirements.

Potential Energy Efficiency Upgrades

In addition to identifying the best available technologies for the base case with payback of 3 to 5 years the following potential upgrades are to be evaluated to determine their annual energy savings:

1. Upgrade replacement furnace to 90% or 95% AFUE and air conditioning to SEER 12 or 16.
2. Upgrade new ductwork by sealing all joints
3. Upgrade replacement doors to steel with urethane foam core and new and replacement windows to double pane low-E argon filled vinyl frame.
4. Increase attic Insulation to R-30.
5. Insulate exterior walls to R-13.
6. Insulate floor to R-15.
7. Reduce infiltration to 0.7ACH.

In determining the payback for items 1-3, use the incremental cost increase since these tasks are already included in the base case. These incremental costs are usually only the increase in the material costs since the installation labor is in most cases is about the same. Divide the additional costs by the energy saving to determine the payback for each item.

Energy Evaluation

Using Rem/Design or other residential energy simulation models determined the annual heating and cooling energy consumption and cost for both the existing home and the home following the space conversion. Also evaluate potential energy efficiency upgrades for their annual energy savings. The results from an analysis using Rem/Design are shown following in **bold**.

Existing house

Annual heating energy consumption - 79.5MMBtu/yr, and cost - $142

Design load for heating - 42.8kBtu/hr

Base case renovation

Annual heating and cooling energy consumption - 72.4MMBtu/yr heating, 2.4MMBtu/yr cooling, and cost $72 heating, $78 cooling

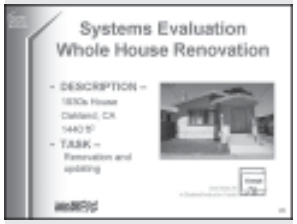
Design load for heating - 31.9kBtu/hr, and cooling - 15.4kBtu/hr

Potential energy efficiency upgrades with rough estimate of installed costs and annual energy cost savings (shown in bold).

90% AFUE furnace - $500 cost, $7 savings, 95% AFUE furnace - $700 cost, $9 savings

12 SEER air conditioner - $400 cost, $13 savings, 16 SEER air conditioner - $600 cost, $29 savings

Seal all joints in ductwork - $400 cost, $23 savings



SYSTEMS EVALUATION WHOLE HOUSE RENOVATION

Upgrade front door with steel door with urethane foam core and thermal break - $50 cost, - $1 savings

Upgrade new windows with double pane, low-E, argon-filled glazing in vinyl frame - $160 cost, $0 savings

Add R-19 attic insulation (R-30 total) - $1100 cost, $10 savings,

Insulate exterior walls (R-13) - $3500 cost, $3 savings, Insulate floor (R-19) - $2100 cost, $42 savings

Reduce infiltration to 0.7ACH - $450 cost, $3 savings

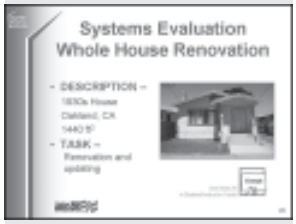
Comments

The base case remodeling improvements have reduced the heating design load by ~25% potentially permitting a smaller, less expensive furnace. These improvements also reduce annual heating and cooling cost to only $8 more that heating alone in the existing house.

The low total cost of heating and cooling (~$150/yr) makes it difficult to justify virtually all efficiency upgrades. In fact several upgrades produce negative savings since enhanced insulation and reduced infiltration reduces the natural cooling potential in Oakland, California.

Building shell energy efficiency upgrades are very difficult to justify in climates where outdoor temperatures are close to desired indoor temperatures as they are in Oakland, California. In this circumstance, improvements that lower energy consumption will have to be justified on the basis of other reasons such as aesthetics, comfort, durability, reduced maintenance, etc. However, energy efficient lighting and appliances might be a good choice in a mild climate, especially in California which has relatively high electricity rates.

NOTES



SUMMARY

KEY CONCEPTS

Using the systems approach to remodeling can make a BIG difference in a project's outcome.

EXPLANATION

In addition to saving your customer on utility bills and making a home more comfortable, you'll be benefiting yourself by avoiding potential mistakes (e.g., mold, combustion safety) and the risk of litigation. In short, you'll be able to help customers get the best value for each dollar they have spent on their remodeling project.

ACTION ITEMS

Attend seminars and conferences (e.g., EEBA's *Houses that Work*, Affordable Comfort) to learn more and share experiences. Set up a log of your accomplishments using the systems approach, and share these accomplishments with potential future clients.

RESOURCES

Houses that Work Seminar information: (http://www.eere.energy.gov/buildings/building_america/rh_0604_houses_seminars.html)

Affordable Comfort regional conferences and training events, http://www.affordablecomfort.org/html/events.html

NOTES