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Energy Efficiency in Cold-Weather High-End Custom Homes

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ENERGY EFFICIENCY IN COLD-WEATHER HIGH-END

HOME BUILDING

by

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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ABSTRACT

ENERGY EFFICIENCY IN COLD-WEATHER HIGH-END

HOME BUILDING

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Nationally, there is increasing interest in energy efficient homes due to growing energy costs and increased awareness. However, many builders haven't yet incorporated energy saving products and practices into homes. Many builders don't have the resources to evaluate available options and prefer to rely on the experiences of other builders.

The purpose of this study was to create energy efficiency benchmarks for cold-weather, high-end custom homes and evaluate current building practices.

A list of energy-efficient products and practices was created through a review of relevant literature.

A group of expert builders was formed into a committee to help determine energy inefficiencies in cold-weather, high-end custom homes. The committee also

helped establish criteria used to evaluate building products and practices. Finally, the committee helped create a survey that was sent to a larger community of builders.

Energy Star Builders in Colorado, Idaho, Utah, and Wyoming were selected to take part in the survey. They were asked to evaluate their experience with energy-efficient products and practices and give recommendations in overcoming specific inefficiencies of cold-weather, high-end custom homes.

Payback calculations were performed on the products and practices identified in the survey to further evaluate their importance.

From the review of literature, interviews with the committee of experts, the builders' survey responses, and the payback calculations, a list of 22 energy efficiency benchmarks was created for building cold-weather, high-end custom homes.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Background of the Problem

High-end custom homes are generally more energy-efficient than other types of homes because of increased insulation, better materials[1], more efficient HVAC systems, and low-E windows.[2] Yet, many aspects of high-end custom homes, especially those built in cold-weather climates, increase energy consumption significantly as compared to other types of houses.[3]

Some of the things that increase energy costs in high-end custom homes in cold climates are: less design control, larger interior spaces, more exterior glass, greater HVAC and electrical loads, more building envelope penetrations, and unique, one-time, home designs.

In many instances, high-end custom home builders don't have control over the plans they build or the building lots on which they build.[4] Home-owners come to builders with finished, or nearly finished, construction documents and a purchased lot.

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[1] Paul Magelby, interview by Joseph Kearl, 26 June 2007, interview 7, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[2] John Kurowski, interview by Joseph Kearl, 17 April 2007, interview 2, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[3] Arden Hess, interview by Joseph Kearl, 17 April 2007, interview 1, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[4] Ibid.

This presents a problem since the orientation of the lot, the orientation of the house,[1] the primary view corridors, and landscaping can have significant impact on the energy efficiency of a home.[2] It is also less expensive to incorporate energy-efficient products and practices in the planning stage than to add them in the building stage of construction.

Many high-end custom homes tend to have more square footage[3], taller ceilings,[4] greater ceiling vaults[5], no attics,[6] and cathedral ceilings.[7] The larger airspace requires larger conditioning equipment.[8] Also, ceiling vaults and cathedral ceilings impact the amount and type of insulation that can be used in the ceilings.

High-end custom homes typically have more windows,[9] which are often larger than in other homes.[10] They also have more exterior glass doors. Glass, even high-efficiency glass, has a much lower insulation value than wall framing, and as such, any additional glass reduces energy efficiency.

Driveway and roof snowmelt systems are a common feature of many cold-weather, high-end, custom homes. They use more energy and significantly affect the efficiency of a home.[11]

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[1] Scott Ditteman, interview by Joseph Kearl, 28 May 2007, interview 5, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[2] Paul Ashby, interview by Joseph Kearl, 26 June 2007, interview 6, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[3] John Kurowski, interview by Joseph Kearl, 17 April 2007, interview 2, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[4] Arden Hess, interview by Joseph Kearl, 17 April 2007, interview 1, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[5] Mark Jorgensen, interview by Joseph Kearl, 25 April 2007, interview 3, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[6] Scott Treu, interview by Joseph Kearl, 04 May 2007, interview 4, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[7] Scott Ditteman, interview by Joseph Kearl, 28 May 2007, interview 5, transcript, *Energy Efficiency in Cold-Weather High-End Home Building,* Brigham Young University, Provo, UT.
[8] Treu, interview 4.
[9] Kurowski, interview 2.
[10] Treu, interview 4.
[11] Hess, interview 1.

Another feature of many cold-weather, high-end homes is a dual heating system. Owners like the warm feeling that radiant heat provides, especially under stone and tile, but they like the convenience of forced-air systems. Radiant heating systems typically take a couple of days to heat up and cool down as compared with a couple of hours for a forced-air system. Also, radiant heating systems can't be connected with air conditioning, air purifying, and air exchange systems. Because of this, many high-end, custom homes have dual heating systems that increase cost and energy use.[1]

Cold-weather, high-end custom homes typically have large electrical loads due to more audio-video equipment, spas, and steamers. The additional electrical loads require more energy to run and condition. The additional electrical equipment also requires more wiring which, in the exterior walls, can interfere with the insulation and reduce the R-value.[2]

Many custom homes also have additional connection details between timber beams, windows, doors, and architectural details that, if not sealed correctly, can reduce the energy efficiency of the home.[3]

Because each custom home is unique, "designing in" energy efficiency becomes more expensive because the cost can't be spread over several homes.[4] Also, as the home is engineered, each trade contractor tends to "over engineer" everything because of the prevailing philosophy that "it is better to have too much, than too little."[5] Home plans that are frequently repeated can be optimized for energy efficiency. But by over-

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[1] Arden Hess, interview by Joseph Kearl, 17 April 2007, interview 1, transcript, *Energy Efficiency in Cold-Weather High-End Home Building*, Brigham Young University, Provo, UT.
[2] Ibid.
[3] Ibid.
[4] Ibid.
[5] Paul Magelby, interview by Joseph Kearl, 26 June 2007, interview 7, transcript, *Energy Efficiency in Cold-Weather High-End Home Building*, Brigham Young University, Provo, UT.

engineering and adding more structural materials, there is less room for insulation; by making HVAC equipment and electrical service too large they become less efficient.[1]

Although high-end, cold-weather, custom homes can be more efficient, there are several specific aspects of them that are less efficient than other types of homes.

There are many reasons to build more energy-efficient homes. Energy prices have increased dramatically over the past several years,[2] and because of increased demand and geopolitical instability, prices are expected to continue to rise.[3]

Energy-efficient homes are also becoming more popular. In a survey by the National Home Builders Association (NAHB) 78 percent of respondents said they would choose one house over another if it were more energy-efficient.[4] People are willing to pay more for energy-efficient features that reduce energy bills.[5] Also, energy-efficient mortgages and local, state, and federal incentive programs are making the additional costs of energy efficiency more of a non-factor.[6]

Since energy costs can be a very high percentage of the total cost of the house over its lifetime, it is important for builders to make a continued effort to build more energy-efficient homes.[7] Even minor energy improvements can contribute significantly to lower energy costs.[8]

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[1] Paul Ashby, interview by Joseph Kearl, 26 June 2007, interview 6, transcript, *Energy Efficiency in Cold-Weather High-End Home Building*, Brigham Young University, Provo, UT.
[2] Steven Nadel et al., American Council for an Energy-efficient Economy, *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*, March 2006, available from http://www.aceee.org/pubs/a051.htm; Internet, accessed 1 September 2006, pg iii
[3] Ibid.
[4]"National Interest Spurs Energy Efficiency Concerns" *Nation's Building News*, 3 April 2006, available from http://www.nbnews.com/NBN/issues/2006-04-03/Green+Building/index.html; Internet; accessed 01 July 2006, pg 2.
[5] Ibid, pg 3.
[6] Southface Energy Institute, *(Energy Efficiency Make Homes More Affordable,)* 16 July 1998, available from http//www.southface.org/web/resources&services/publications/factsheets/save_nrg$.pdf; internet; accessed 23 August, 2006.
[7] Matthew Power, "How-To: Minimize to Maximize," *Builder Magazine*, 01 August 2003, pg 2.
[8] Michiana Business Publications, Inc., "Going Green," *Business People*, 01 Oct. 2004.

Despite all these reasons for building an energy-efficient home, "the production of highly efficient homes with advanced energy-saving features hasn't yet saturated the mainstream production home building market."[1]

Home-owners are reluctant to accept energy-efficient products if they lower comfort and convenience standards.[2] Builders are often reluctant to incorporate new energy-efficient products and practices into homes because of lack of knowledge, additional up-front costs, or fear of product failure.[3]

One of the biggest problems for builders is having time and resources available to try new products or practices. "The average builder can't afford" the additional risks and costs.[4]

There is ample research available through books, articles, websites, and training seminars to help builders overcome their lack of knowledge or fears[5], however, many builders "evaluate an innovation, not on the basis of scientific research by experts, but through the subjective evaluation of others who have adopted the innovation." [6]

By studying energy-efficient building practices, the author intends to create a database of best practices that, when compared to standard products and practices, will produce superior results. [7]

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[1] Builder Staff, "Powering Down," *Builder Magazine*, 01 May 2006.
[2] Ibid.
[3] Rangel Ruiz, University of Calgary (Canada), *"Energy-efficient Building Design in Cold Climates: Schools as a Case Study,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006, pg 3.
[4] Pat Curry, "Concern Mounts Over Defect Litigation," *Big Builder Magazine*, 10 May, 2002, pg 3.
[5] Ruiz, *"Energy-efficient Building,"* pg 3.
[6] Ibid.
[7] Quantum Consulting, National Energy Efficiency Best Practices Study: Volume S – Crosscutting Best Practices and Project Summary (Berkeley, CA: Prime Contractor, Quantum Consulting, December 2004) pgS1.

Statement of the Problem

High-end custom homes built in cold environments have many energy inefficiencies not typical of other types of homes or high-end custom homes built in warmer climates. Despite increasing energy costs and growing popularity of energy-efficient homes, most home builders have yet to incorporate many of the energy saving products and practices now available. Builders prefer, instead to wait and see the success or failure of other builders.

Purpose and Importance of the Study

The purpose of this study was to create energy efficiency benchmarks, based on relevant literature and builder experience, to overcome inefficiencies of cold-weather, high-end custom homes. It was also to evaluate different products and practices currently in use by Energy Star Builders in Colorado, Idaho, Utah and Wyoming.

Area of Interest

The study focused on energy-efficient building practices and products in four similar cities: Vail, Colorado, Park City, Utah, Sun Valley, Idaho and Jackson, Wyoming. These cities are located in the mountain region of the United States and have heating degree days between 7981 and 9866 heating degrees with a base of 65.

- Sun Valley – 9866 heating degrees[1]
- Vail – 9826 heating degrees[2]

[1]Western Region Climate Center, Idaho Climate Summaries, available from http://www.wrcc.dri.edu/summary/climsmid.html; Internet; accessed 14 July, 2007.
[2]Western Region Climate Center, Colorado Climate Summaries, available from http://www.wrcc.dri.edu/summary/climsmco.html; Internet; accessed 14 July, 2007.

- Jackson – 9622 heating degrees[1]
- Park City – 7981 heating degrees[2]

Study Assumptions

The assumptions of this study are as follows:

1- House designs are similar in each of the cities.

2- Building standards are similar in each of the cities.

3- Builders encounter similar energy efficiency challenges in each of the cities.

4- Building costs are similar in each of the cities.

5- Workmanship, knowledge, and skill are similar in each of the cities.

6- Trade contractors are similar in each of the cities.

7- Survey answers are honest and accurate.

Study Limitations

The limitations of this study are as follows:

1- The survey group is limited to Energy Star qualified builders in the selected states.

2- The questions in the survey are limited to those thought to be most important by the researcher and a committee of experts.

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[1] Western Region Climate Center, Wyoming Climate Summaries, available from http://www.wrcc.dri.edu/summary/climsmwy.html; Internet; accessed 14 July, 2007.
[2] Western Region Climate Center, Utah Climate Summaries, available from http://www.wrcc.dri.edu/summary/climsmut.html; Internet; accessed 14 July, 2007.

Definitions of Terms

Advanced Wood Framing: Design and construction techniques that significantly reduce the amount of wood used to frame a home. Advance wood framing includes strategies like placing studs 24 inches on-center, two-stud corners, eliminating wood in non-load bearing walls, and using in-line framing.[1] (See In-Line Framing)

Air Barrier: "The element in an assembly designed and constructed to control air flow between a conditioned space and an unconditioned space. The air barrier is the primary air enclosure boundary that separates indoor (conditioned) air and outdoor (unconditioned) air." [2]

Air Conditioner, Energy Star: An air conditioner with additional energy-efficient features built in. It will use 20 to 40 percent less energy than a standard system, and it includes high-efficiency compressors, variable speed fans, high efficiency motors, and improved heat exchangers.[3]

Air Leakage (Air Infiltration): The "outside air that enters a house uncontrollably through cracks and openings"[4] (See also Ventilation)

Blower Door Test: A test that determines how airtight a home is by measuring how much air can get into or out of a pressurized or depressurized home with windows and doors shut.[5]

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[1] Office of Energy Efficiency and Renewable Energy, *"Advanced Wall Framing"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26449.pdf; Internet; accessed 01/09/06.
[2] Building Science Consulting, *Building Science Glossary*, available from http://www.buildingscienceconsulting.com/resources/glossary.htm; Internet; accessed 15 September 2006
[3] United States Environmental Protection Agency, "*Energy Star Labeled Air Conditioners*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006, pg 1.
[4] Asthma Regional Coordinating Council of New England, *"Groundwater,"* available from http://www.uaf.edu/ces/faculty/seifert/pdf_nuaf/Design_Build.pdf; Internet; Accessed 04 September, 2006, pg 1.
[5] Tool Base Services, *"Making Energy Efficiency Visible to Homebuyers"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.

Building Envelope (Enclosure): The structure that separates inside conditioned space, from the outside[1] and includes the floors, exterior walls, ceiling, roof, doors, and windows. A building envelope is an environmental separator that "controls heat flow, air flow, water vapor flow, rain, groundwater, light, and solar radiation."[2] (See Conditioned Space)

Building Practices: Actions or processes that are used by builders and designers during the planning, designing, and building of a home.

Combined Heat and Power Systems (CHP): Systems designed to produce heat and electricity at the same time. They are about 90 percent efficient compared to 30 to 40 percent for electricity from power plants. One of the reasons for this is that a byproduct of electricity is heat that can then be applied to heating a home.[3]

Conditioned Space: "The part of the building that is designed to be thermally conditioned for the comfort of occupants or for other reasons."[4]

Direct Heat Gain: Solar radiation that directly penetrates a building, typically through windows. Often designers exploit direct gain by designing the space to store the heat in interior materials.[5]

Duct Leakage Test: A test meant to measure the amount of air that leaks through air ducts. The test is performed by sealing off the mechanical ducts and pressurizing the system. The tester measures the leakage rate by using an airflow and pressure gauge.[1]

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[1] Southface Energy Institute, "*Air Sealing: Seal air leaks and save energy,*" 5 March 2002, available from http://www.southface.org/web/resources&services/publications/factsheets/8_airsealing.pdf; Internet; Accessed 23 August, 2006, pg 1.
[2] Building Science Consulting, *Building Science Glossary*, available from http://www.buildingscienceconsulting.com/resources/glossary.htm; Internet; accessed 09/15/06, pg 1
[3] Tool Base Services, "*Combined Heat and Power Systems for Residential Use*", available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.
[4] Building Science Consulting, *Building Science Glossary*, pg 1.
[5] EERE "*Passive Solar Design*", available from http://www.eere.energy.gov/buildings/info/; 09/01/06, pg 1.

Energy Efficiency: Getting the same output from a system while using less energy input.[2]

Energy-Efficient Homes: Similar to energy efficiency, however, it also takes into account comfort, proper lighting, temperature, cost, and health within the home.

Energy Star Label: A program sponsored jointly by the U.S. Environmental Protection Agency and the U.S. Department of Energy that promotes energy-efficient products, buildings, and technologies for consumers and businesses.

Furnace, Energy Star: "Energy star labeled furnaces use 10 percent to 20 percent less energy than standard efficiency models."[3]

Furnaces, Modulating: Combines a modulating gas valve with a variable-speed blower. Both are adjusted until the maximum efficiency is reached.[4]

Heat Pumps: Pumps that take a large amount of low-temperature heat and turn it into a smaller amount of high-temperature heat.[5]

Heat Pumps, Air-source: A heat pump that, in the summer, works just like an air conditioner taking hot air in the house and forcing it outside. In the winter an air-source heat pump extracts warm air from the outside and forces it inside.[6]

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[1] Tool Base Services, *"Making Energy Efficiency Visible to Homebuyers"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.
[2] US Department of Energy "*Energy Efficiency Measures*", available from http://www.eere.energy.gov/de/ee_measures.html; Internet; accessed 01 September, 2006, pg 1.
[3] USU, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/; Internet, Accessed 01 June 2007, pg4.
[4] Tool Base Services, *"Modulating Furnace"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 08/23/06.
[5] "The Builder" *Sunday Times*, 19 February 2006, 48.
[6] Ken Sheinkopf, "Effectiveness of Insulation measured by R-Value," *Tulsa World*, 3 Jun. 2000, pg. 16.

Heat Pumps, Geothermal (Ground Source): A heat pump that absorbs heat in the winter and transfers heat in the summer[1] to and from the ground through vertical or horizontal loops.[2]

Infrared (IR) Thermography Camera: A tool used to detect heat loss and air leakage from a home. An infrared camera is used to take pictures of the exterior shell of a home where the color variations indicate heat and air loss.[3]

In-Line Framing (Stack Framing): A framing method where floor, wall, and roof structural members are lined up vertically to transfer loads directly down to evenly distribute the load.[4] By stacking structural members, some lumber can be removed from the structure, thus allowing more room for insulation.[5]

Insulating Concrete Forms (ICFs): Foam (polystyrene or polyurethane[6]) blocks that act act as concrete forms during construction and remain in place afterwards to serve as thermal insulation.[7]

Lifecycle Energy Cost: The total cost of an item throughout its life. The lifecycle cost of a home would include design costs, land costs, installation costs, construction costs, systems costs, operating costs, and maintenance costs.[8]

Low-E (Low-Emissivity) Window: A window with a special metal oxide[1] coating that allows daylight to enter a building, but reduces the flow of radiative heat.[2]

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[1] Beth W. Orenstein, "The Warmth of Mother Earth," *Morning Call*, 22 September 1996, G.03.
[2] US DOE "*Geothermal Heat Pumps*", available from http://www.eere.energy.gov/; Internet; accessed 01 09, 06, pg 1.
[3] TBS, "*Making Energy Efficiency Visible*", available from http://www.toolbase.org/; Internet; accessed 08/23/06.
[4] EERE, "*Advanced Wall Framing*", available from http://www.eere.energy.gov/; Internet; accessed 09/01/06, pg 1.
[5] Matthew Power, "Optimal Framing," *Builder Magazine*, 01 October 2001, pg 1.
[6] Utah State University, Utah House, *Energy Smarts: Insulating Concrete Forms (ICFS)*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/; Internet, Accessed 01 June 2007.
[7] TBS, *Insulating Concrete Forms*, available from http://www.toolbase.org/; Internet; accessed 23 August, 2006.
[8] Rangel Ruiz, University of Calgary (Canada), "*Energy-efficient Building Design in Cold Climates*" 2003, available from http://proquest.umi.com.erl.lib.byu.edu/; Internet; Accessed 01 June, 2006, pg 11.

Mortgages, Energy-Efficient: Help offset the cost of added construction due to energy improvements.[3] "An energy mortgage increases a consumer's buying power by enabling mortgage lenders to count the monthly energy bill savings that a home's energy efficiency features deliver as additional income."[4]

National Fenestration Rating Council (NFRC): An industry organization in the United States that promotes a voluntary energy rating system for windows, skylights, and doors. The NFRC label rates how well a window keeps heat inside a building, the window's ability to block heat from the sun, how much light passes through a window, and how much heat is gained or lost due to cracks around the window assembly.[5]

Passive Solar Design: A design strategy that "integrates a combination of building features to reduce or even eliminate the need for mechanical cooling and heating and daytime artificial lighting."[6]

Payback Period: The period of time it takes for the energy savings to repay the additional cost of the product or system.[7]

R-Value: Quantitative measure of resistance to heat flow or conductivity. Considered to be the primary or paramount indicator of energy efficiency, it only measures conduction.

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[1] USU, *Energy-efficient Windows*, 07/01/05, available from http://extension.usu.edu/; Internet, Accessed 06/01/07, pg 1.
[2] Regents of the University of Minnesota, *Window Technologies: Low-E Coatings*, available from http://www.efficientwindows.org/; Internet; accessed 7 September 2006.
[3] Southface Energy Institute, "*Energy Efficiency Makes Homes More Affordable,*" 16 July 1998, available from http://www.southface.org/; Internet; Accessed 23 August, 2006.
[4] Steve Baden, "Financing: The key to Unlocking Residential Energy Efficiency," *Home Energy magazine*, available from www.homeenergy.org/consumerinfo/; Internet, Accessed 01 September 2006.
[5] Jennifer Roberts, *Good Green Homes* (Utah: Gibbs Smith), 154.
[6] Office of Energy Efficiency and Renewable Energy, *"Passive Solar Design"*, available from http://www.eere.energy.gov/buildings/info/documents/; Internet; accessed 01 September, 2006, pg 1.
[7] Southface Energy Institute, *Using the Sun to Heat Water*, 30 September 2004, available from http://www.southface.org/web/; Internet; accessed 15 September 2006, pg 2.

Conduction is one of three modes of heat flow (the other two being convection and radiation).[1]

Shear Panel Inserts: Panels used as strengthening devices in advanced framing when studs are spaced 24" on-center. Panel inserts are typically 2x4 panels with plywood faces set into 2x6 walls approximately every twenty feet.[2]

Smoke Tube Test: A test used in conjunction with a blower door test to show where air leakage occurs.

Solar Heat Gain Coefficient (SHGC): "Measures how well a window blocks the sun's heat on a zero-to-one scale. The lower the SHGC, the less solar heat passes through."[3] "SHGC is a measure of the amount of solar energy that a glazing material allows to pass."[4]

Solar Hot Water Systems: Systems that use the sun's energy to heat domestic hot water.[5] "Water (or antifreeze) travels through dark colored pipes that are located in direct sunlight. The sun heats the water in the pipes. Once heated, the water is stored in an insulated tank until needed."[6]

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[1] Building Science Consulting, *Building Science Glossary*, available from http://www.buildingscienceconsulting.com/resources/glossary.htm; Internet; accessed 15 September 2006, pg3)

[2] Matthew Power, "Optimal Framing," *Builder Magazine*, 01 October 2001, pg 2.

[3] Colorado New Home Choices, *Windows More than Just a View*, October 2003, available from http://www.coloradonewhomechoices.org/factsheets/CNHCFS-Windows_2005-01.pdf; Internet; accessed 16 September 2006, pg 2.

[4] United States Environmental Protection Agency, "*High-Performance Windows*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.

[5] US Department of Energy "*Solar Hot Water*", available from http://www.eere.energy.gov/de/solar_hotwater.html; Internet; accessed 01 September, 2006, pg 1.

[6] Southface Energy Institute, *Using the Sun to Heat Water*, 30 September 2004, available from http://www.southface.org/web/resources&services/publications/factsheets/residential_solar_water111804.pdf; Internet; accessed 15 September 2006, pg 1.

Systems Approach: A design approach that takes into account the effects and interactions of all the components of a home, ensuring that the completed system provides the intended energy efficiency benefits and works as planned.[1]

U-Value: A quantitative measure of heat flow or conductivity of windows. It is the reciprocal of R-value."[2]

Ventilation: "Fresh air that enters a house in a controlled manner to exhaust excess moisture and reduce odors and stuffiness."[3] (see also Air Leakage)

Visible Transmittance: Indicates the percentage of visible light transmitted through a window. The higher the visible transmittance, the more light a window transmits.[4]

Window, Double-Glazed: A window with two panes of glass separated by an air space. Compared to single-glazed windows, double-glazed windows significantly reduce heat and sound transmission. Some double-glazed windows contain a gas such as argon or krypton in the air gap to provide additional insulation.[5]

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[1] Aspen Homes of Colorado, *Energy Center*, available from http://www.aspenhomesco.com/index.php?pr=Energy_Center; Internet; accessed 1 September 2006, pg 1.

[2] Building Science Consulting, *Building Science Glossary*, available from http://www.buildingscienceconsulting.com/resources/; Internet; accessed 15 September 2006, pg 3.

[3] Southface Energy Institute, *Using the Sun to Heat Water*, pg 1.

[4] Jennifer Roberts, *Good Green Homes* (Utah: Gibbs Smith), 156.

[5] Ibid, 153.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

This chapter strives to unite and review many of the writings on energy costs and the benefits of energy efficiency. It also presents information regarding barriers to efficient use of energy, and explains energy-efficient building practices and design considerations. Lastly, it presents energy-efficient products that, when coupled with practices and design, can reduce energy use significantly.

Energy Costs

Energy costs play a significant part in the cost of a home, and energy prices are rapidly increasing.[1] Due in part to increased demand, depletion of resources, higher emission standards, and geopolitical instability, prices are expected to continue to rise.[2] Energy price increases can have significant negative effects on home-owners, and by extension, home builders.

> As rising energy costs continue to make headlines, builders and home buyers have become more aware of the need to reduce energy consumption. But overall, the production of

[1] Steven Nadel et al., American Council for an Energy-efficient Economy, *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*, March 2006, available from http://www.aceee.org/pubs/a051.htm; Internet, accessed 1 September 2006, pg iii
[2] Ibid

> highly efficient homes with advanced energy-saving features hasn’t yet saturated the mainstream production home building market.[1]

One of the places we use energy the most is in the home. In fact, the most expensive costs, over the life of the home, aren’t initial building costs; they are energy costs associated with heating, cooling, lighting, and running appliances within the home. Experts say that lifecycle energy costs can be “hundreds of times more expensive than the building was to build.”[2]

In the *Builder’s Foundation Handbook* it says, “In the past, the initial cost and the monthly mortgage payment were the critical criteria considered. Now, with rising energy costs, operating expenses are also a prime consideration.”[3]

Environmental Impact

Another reason energy efficiency is so important is because of the way it effects our environment. As Rangel Ruiz points out, “The need to guide technology and design creativity towards a more sustainable type of architecture has been identified as a key element in the strategy to combat global warming and promote fossil fuel conservation.”[4]

Homes, and the energy they use, have significant impact on the environment. The construction of buildings and their life-time energy costs:[5]

[1] Builder Staff, “Powering Down,” *Builder Magazine*, 01 May 2006.
[2] “'Smart' Materials Revolutionizing Construction -- Windows Can Control Light, Heat, A-C,” *The Commercial Appeal*, 25 October 2004.
[3] John Carmody et al., eds., *Builder’s Foundation Handbook* (Oak Ridge National Laboratory, 1991), pg 2.
[4] Rangel Ruiz, University of Calgary (Canada), *“Energy-efficient Building Design in Cold Climates: Schools as a Case Study,”* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006, pg 1.
[5] Michiana Business Publications, Inc., “Going Green,” *Business People*, 01 Oct. 2004.

- Consume 3 billion tons annually of the earth's raw materials
- Consume more than 65 percent of the electricity in the U.S.
- Account for more than 36 percent of the primary energy use in the U.S.
- Generate 30 percent of the total U.S. greenhouse gas emissions

Energy-efficient homes can significantly reduce negative impact on the environment by reducing waste in construction, reducing the release of green house gas and lowering the utility needs of the house throughout its life.[1]

Benefits to Owners

It is not only beneficial to the environment to "think green." The benefits to owners of having an energy efficient home are as follows:

- Reduced utility, operating, and maintenance costs[2]
- Reduced noise[3]
- A healthier and safer indoor environment[4]
- Improved building durability[5]
- Increased comfort[6]
- Smaller HVAC loads and equipment[7]

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[1] Colorado Energy Star Homes "Facts on Energy Star Qualified Homes in Colorado," 2006, available from http://www.e-star.com/coloradoenergystarhomes/facts.html; Internet; accessed 01 September 2006.
[2] Office of Energy Efficiency and Renewable Energy, *"Whole-House Energy Checklist"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/whole_house_energy_checklist-766.pdf; Internet; accessed 01 September, 2006.
[3] Ibid.
[4] Ibid.
[5] Ibid.
[6] Ibid.
[7] Southface Energy Institute, "*Energy Checklist: Energy-efficient Construction,"* available from http://www.southface.org/web/resources&services/; Internet; Accessed 23 August, 2006.

A study found on the Energy Star website of Colorado found that energy-efficient homes save on average $585.12 per household each year, or $48.76 per month.[1]

Another study by an Atlanta, Georgia community found that energy-efficient homes reduced annual energy bills from $1200 to $800, or 33 percent.[2]

Many energy-efficient homes are more comfortable than less efficient counterparts. This is because most energy-efficient designs and products reduce the energy required for the home while still providing desired comfort.[3]

Another important benefit to owners is that they can qualify for energy-efficient mortgages. Energy-efficient mortgages can offer additional savings to owners.[4] Because home-buyers pay less in utility costs, they are able to afford larger mortgages.[5]

To explain these mortgages, Steve Baden, in an article on financing said, “An energy mortgage increases a consumer’s buying power by enabling mortgage lenders to count the monthly energy bill savings that a home’s energy efficiency features deliver as additional income.”[6]

One of the biggest problems with energy-efficient features is the higher up-front costs; however when the up-front costs are added to a mortgage, the savings can often be immediate and reduce the need to calculate payback.[7]

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[1] Colorado Energy Star Homes “Facts on Energy Star Qualified Homes in Colorado,” 2006, available from http://www.e-star.com/coloradoenergystarhomes/facts.html; Internet; accessed 01 September 2006.
[2] Southface Energy Institute, “*Energy Efficiency Makes Homes More Affordable,*” 16 July 1998, available from http://www.southface.org/web/resources&services/; Internet; Accessed 23 August, 2006.
[3] Ibid.
[4] National Home Builders Association Research Center, *2006 EVHA Winners*, available from http://www.nahbrc.org/evha/winners_climate.html; Internet; accessed 1 September 2006, pg 1.
[5] Southface Energy Institute, “*Energy Efficiency Makes Homes More Affordable,*” pg 2.
[6] Steve Baden, “Financing: The key to Unlocking Residential Energy Efficiency,” *Home Energy magazine*, available from www.homeenergy.org/consumerinfo/finance/financing4.html; Internet, Accessed 01 September 2006.
[7] US Department of Energy “*Geothermal Heat Pumps*”, available from http://www.eere.energy.gov/de/geo_heatpumps.html; Internet; accessed 01 September, 2006, pg 2.

> Assume that you are purchasing a home for $325,000 and that it could use $15,000 in energy improvements, (roof insulation, new efficient heating system, air sealing, and new efficient water heater). The projected monthly energy savings is $120. The added monthly principal and interest payments would be $107. The argument would be that the added investment for the improvements is offset by $13 a month in energy savings. This is a better rate of return than investing the $15,000 in a mutual fund.[1]

Benefits to Builders

Building energy-efficient homes benefits builders as much as home-buyers. Some of the benefits to builders include:

- Increased customer satisfaction[2]
- Decreased liability[3]
- Greater design flexibility because of smaller mechanical systems[4]
- Increased sales[5]
- Decreased callbacks and warranty work[6]

One builder has experienced the highest satisfaction rating of any builder in the area and more than a third of new customers are referrals from existing customers. This builder credits much of its success to increased energy-efficient details.7

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[1] Baden, "Financing," *Home Energy magazine*.
[2]Ibid
[3] "Scoring Selling Points," *Big Builder Magazine*, 13 March 2003.
[4] Southface Energy Institute, *"Energy Checklist: Energy-efficient Construction,"* available from http://www.southface.org/web/resources&services/; Internet; Accessed 23 August, 2006.
[5] "National Interest Spurs Energy Efficiency Concerns" *Nation's Building News*, 3 April 2006, available from http://www.nbnews.com/NBN/issues/; Internet; accessed 01 July 2006, pg 3.
[6] Office of Energy Efficiency and Renewable Energy, *"Whole-House Energy Checklist"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/; Internet; accessed 01 September, 2006.
[7] Tool Base Services, *"Tech Practices: Watt Homes of Utah"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.

Barriers to Energy-Efficient Homes

Despite all of the benefits of energy-efficient homes to builders and home-owners, there are many reasons builders don't take on the challenge. Some of the barriers include:

- Difficulty in financing new or unproven techniques
- Fear of change[1]
- Lack of knowledge, experience, information[2]
- Inability to assess technologies and correctly apply them
- Inability to get local building departments to accept new methods
- Sensitivity to initial building costs[3]
- Higher up-front costs[4]
- Fear that technology will not perform as expected
- Unknown performance
- Aesthetics[5]

This list can be summarized by lack of knowledge on the part of builders, designers and home buyers, additional up-front costs associated with energy efficiency, and the affects that energy efficiency has on building aesthetics.

[1] Rangel Ruiz, University of Calgary (Canada), *"Energy-Efficient Building Design in Cold Climates: Schools as a Case Study,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006, pg 28.
[2] Ibid, 22, 28.
[3] NAHB Research Center, *Opportunities for Solar Water Heating* (Marlboro, MA: NAHB Research Center, Inc., January 1998) pg2-3.
[4] US Department of Energy "*Energy Efficiency Measures*", available from http://www.eere.energy.gov/de/ee_measures.html; Internet; accessed 01 September, 2006, pg 2.
[5] Ruiz, "*Energy-efficient Building Design in Cold Climates*", pg 29.

Lack of Knowledge

One of the biggest barriers to building energy-efficient homes is lack of knowledge, experience, or information.[1] Builders and designers are unfamiliar with the tools, products and practices available and home-owners are unaware of many of the benefits of owning energy-efficient homes.[2]

Builders and designers think that energy efficiency is difficult or costly. However, "even lots of little improvements can add up to significantly reduce energy costs".[3]

Studies have shown that building more energy-efficient homes increases customer satisfaction, sales, referrals and perceived value.[4] For builders to capitalize on this they need to educate home buyers about energy-efficient homes. Good educational tools include testimonials, home energy bills, third-party evaluations, and energy performance test results.[5]

Many builders and home buyers wait to build energy-efficient homes because they fear that the technology will not perform as expected.[6] These builders prefer to let others test new products and wait "five to 10 years"[7] before they adopt products or practices that make homes more energy-efficient.[8]

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[1] Rangel Ruiz, University of Calgary (Canada), *"Energy-Efficient Building Design in Cold Climates: Schools as a Case Study,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006, pg 22.
[2] Ibid., pg 29.
[3] Southface Energy Institute, "*Energy Efficiency Makes Homes More Affordable,"* 16 July 1998, available from http://www.southface.org/web/resources&services/publications/factsheets/sav_nrg$.pdf; Internet; Accessed 23 August, 2006, pg 2.
[4] "National Interest Spurs Energy Efficiency Concerns" *Nation's Building News*, 3 April 2006, available from http://www.nbnews.com/NBN/issues/2006-04-03/Green+Building/index.html; Internet; accessed 01 July 2006.
[5] Tool Base Services, *"Making Energy Efficiency Visible to Homebuyers"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.
[6] Ruiz, *Energy-efficient Building,"* pg 28.
[7] Builder Staff, "Eliminating Attic Vents," *Builder Magazine,* 01 January 2006, pg 2.
[8] Pat Curry, "Concern Mounts Over Defect Litigation," *Big Builder Magazine*, 10 May, 2002, pg 1-4.

Up-Front Costs

Aside from builders' uneasiness in using new techniques is the deterrent of the cost of energy-efficient products at the beginning of a project. "Even though the payback in energy savings can be quite significant," higher up-front costs are a big drawback to building energy-efficient homes.[1] Additional up-front costs can be from 1-20 percent[2] and decisions regarding energy efficiency are often based on first cost.[3]

It is important to remember, however, that there are many simple things that can be done to increase energy efficiency that cost only slightly more.[4]

Also, by educating home-buyers on the lifecycle, or long term costs, of a home, they may be more willing to pay the additional up-front costs.[5] For example, in a survey conducted by the National Home Builders Association (NAHB), over half of those surveyed said that they were willing to pay additional costs associated with energy-efficient home features if they saved money on utility bills.[6] If more people were educated on this issue, they would choose more efficient practices.

Another way to combat the higher up-front costs of energy-efficient homes is to focus on products that make the most improvement and sense for the "climate and local equipment pricing. For example, in a [heating]-dominated climate, it may make more sense to invest in higher efficiency [heating] equipment and use standard efficiency

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[1]Jim Cory, "B + A: Ship Shape," *Remodeling Magazine,* 01 May, 2002, pg 1.
[2] Nigel Maynard, "Green Money," *Builder Magazine*, 01 November 2004.
[3] NAHB Research Center, *Opportunities for Solar Water Heating* (Marlboro, MA: NAHB Research Center, Inc.) January 1998 pg1.
[4] Tool Base Services, "*TechPractices: Watt Homes of Utah*", available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.
[5] Ken Sheinkopf, "Effectiveness of Insulation measured by R-Value," *Tulsa World,* 3 Jun. 2000, pg. 16.
[6] "National Interest Spurs Energy Efficiency Concerns" *Nation's Building News*, 3 April 2006, available from http://www.nbnews.com/NBN/issues/2006-04-03/Green+Building/index.html; Internet; accessed 01 July 2006.

[cooling] equipment."[1] While many owners have a hard time seeing the larger picture due to higher up-front costs, education can help them to choose options that will save them in the long-term.

Aesthetics

Aesthetics has a big part to play in energy-efficient homes. Windows, vaulted ceilings, glass doors, and multi-pitched roofs all cut down on the efficiency of the home. "Many guide themselves on the aesthetics of the building, rather than its performance. For some developers, it is more important to spend money on the appearance of the building rather than on energy-efficient measures, since most buyers tend to focus on the former."[2] However, if designers and builders are careful, they can retain the beauty of a home with more energy-efficient products. They can also offset less energy-efficient features such as windows with more efficient features in other areas of the house.

Energy-Efficient Practices

Building and design practices have the most impact on the energy efficiency of a home. Product choices and construction methods determined at the design phase of the project can "drastically change how much a home costs its owners."[3]

More than energy-efficient products, if the home isn't built right (tight), it will never be energy-efficient.[1] Energy efficiency is about "tightening the building shell,

[1] Tool Base Services, *"Considerations for Building a More Energy-efficient Home"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006 pg 3.
[2] Rangel Ruiz, University of Calgary, *"Energy-efficient Builing Design in Cold Climatey,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/; Internet; Accessed 01 June, 2006, pg 29.
[3] Matthew Power, "How-To: Minimize to Maximize," *Builder Magazine*, 01 August 2003, pg 2.

sealing ductwork, and making sensible lighting and appliance choices." To a large extent, it's about "doing things everyone has known how to do for 20 years."[2]

Building Practices

The two building practices that have the most positive effect on the energy efficiency of a home are management practices and building a tighter envelope. Management practices should include teaching energy efficiency and monitoring it throughout the project.

Energy-Efficient Management

Management practices that have the biggest effect on the energy efficiency of the home include analysis of building features before construction, training, and quality assurance and testing.

Proper management includes "analysis of energy efficiency features prior to construction to help determine the most cost-effective [systems]."[3] It also includes analyzing the affect features will have on the "energy performance, durability, and cost of the home."[4] By analyzing the home before construction, builders can make changes, flag potential problems, and assign responsibility for energy efficiency before things are built.[5]

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[1] US Department of Energy *"Window Selection"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/window_selection-777.pdf; Internet; accessed 01 September, 2006, pg1.
[2] Boyce Thompson, "Matter of Energy," *Builder Magazine*, 01 February 2005, pg 1.
[3] National Home Builders Association Research Center, *2006 EVHA Winners*, available from http://www.nahbrc.org/evha/winners_climate.html; Internet; accessed 1 September 2006, pg 8.
[4] Tool Base Services, *"TechPractices: Watt Homes of Utah"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 2.
[5] Michael Baechler et al., *"Building America Best Practice Series: Volume 3,"* August 2005, US Department of Energy, pg 70.

Another important management practice is to select knowledgeable employees and subcontractors and train them in energy efficiency.[1] Most often the breakdown occurs at installation,[2] and poorly installed energy-efficient products don't create energy-efficient homes.[3] Also, many simple steps can be taken on-site if employees and subcontractors know of what to be aware.

Proper management should also include quality control measures that maintain high levels of energy efficiency. Quality controls can include checklists, inspections and tests.[4]

Inspections by management can be as informal as looking at the snow on the roof in cold-weather, or as formal as written inspection reports.[5] Inspections should be conducted regularly, and should at least include a pre-drywall inspection and pre-occupancy inspection. With new and inexperienced employees and subcontractors, inspections should take place more often.[6]

Testing is another quality control measure that can find problems and leaks that would not otherwise appear until much later. Testing "can reduce homeowner energy bills by as much as 40 percent."[7] Several important tests include:

- Blower door and smoke tube test[8]
- Infrared camera energy test[1]

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[1] NAHB, *2006 EVHA Winners*, pg 8.
[2] Pat Curry, "Concern Mounts Over Defect Litigation," *Big Builder Magazine*, 10 May, 2002, pg 2.
[3] Southface Energy Institute, "*Energy Efficiency Makes Homes More Affordable,*" 16 July 1998, available from http://www.southface.org/web/resources&services/; Internet; Accessed 23 August, 2006, pg 4.
[4] NAHB, *2006 EVHA Winners*, pg 3.
[5] Don Hynek, "Snowy and Icy Indicators of Wasted Money," *Home Energy magazine*, available from http://www.homeenergy.org/consumerinfo/roofs/index.html; Internet, Accessed 01 September 2006, pg 1.
[6] Michael Baechler et al., *"Building America Best Practice Series: Volume 3,"* August 2005, US Department of Energy, pg 75.
[7] Kenneth Aaron, "Energy Audit Offers Savings," *Times Union,* 8 Dec. 2002, pg. E.1.
[8] Don Hynek, "Snowy and Icy Indicators of Wasted Money," *Home Energy magazine*, available from http://www.homeenergy.org/consumerinfo/roofs/index.html; Internet, Accessed 01 September 2006, pg 1.

- Full Energy Audit[2]
- Duct Leakage Test[3]

Thus, if managed properly, homes can be built more energy-efficient as employees and subcontractors understand how to monitor and educate using inspections and tests. In this manner, they can also catch problems at appropriate times.

<u>Creating a Tighter Building Envelope</u>

One thing of which builders and owners should be aware is the importance of a tight building envelope. As Thompson, in "Matter of Energy" says:

> Hundreds of penetrations are made in building envelopes during construction. Imagine if every opening for plumbing and ductwork were expertly caulked or sealed, then checked. Imagine if every hole made in an air barrier were taped. What if every joining between framing plates were sealed? That would add up to some real savings.[4]

Tighter building envelopes mean better thermal, moisture and air barriers. Heat, moisture and airflow are the keys to energy loss.

The thermal barrier contributes significantly to a tighter envelope. "Heating and cooling (space conditioning) account for 50 to 70 percent of the energy used in the average American home."[5] Proper levels of insulation, installed correctly, will have the most dramatic effect on reducing energy used in the home.

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[1] Boyce Thompson, "Matter of Energy," *Builder Magazine*, 01 February 2005, pg 1.
[2] Aaron, "Energy Audit Offers Savings," pg. E.1.
[3] Tool Base Services, *"Making Energy Efficiency Visible to Homebuyers"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.
[4] Thompson, "Matter of Energy," pg 1.
[5] Department of Energy, *Insulation Fact Sheet*, October 2005, available from http://www.ornl.gov/sci/roofs+walls/insulation/insulation.pdf; Internet; accessed 11 September 2006, pg1

Benefits of increased insulation include: improved comfort, improved indoor air quality, increased construction quality, lower utility bills, improved resale, uniform temperatures, and better sound absorption.[1]

Causes of reduced effectiveness of insulation include compressed insulation, gaps, and inadequate insulation.[2] Installation also plays a big role in the actual effectiveness of insulation, and poor installation can cut effectiveness in half.[3]

It is important to remember to insulate over the attic access[4] and between conditioned and unconditioned spaces like the attic, crawl space, and basement.

Another important building practice that can greatly increase the thermal barrier of a home is called optimal framing, value-engineered framing, or advanced-wall framing.[5] Optimal framing is a non-traditional framing method that uses fewer wood materials while maintaining the strength and structure of the home. It "increases the thermal resistance of the building envelope without compromising structural integrity by eliminating unnecessary framing members."[6]

Optimal framing incorporates some or all of the following techniques:

- Framing at 24" inches on center[7]
- Using drywall clips and two-stud corners[8]

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[1] United States Environmental Protection Agency, "*Increased Insulation*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006, pg 2.
[2] Canada Mortgage and Housing Corporation, *Insulating Your House*, 4 June 2006, available from http://www.cmhc-schl.gc.ca/en/co/maho/enefcosa/; Internet; accessed 11 September 2006, pg 1.
[3] Southface Energy Institute, "*Insulation Basics,*" 5 March 2002, available from http://www.southface.org/web/resources&services/publications/factsheets/12insulation.pdf; Internet; Accessed 23 August, 2006, pg 1.
[4] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home*, 01 July 2005, available from http://extension.usu.edu/files/publications/; Internet, Accessed 06/01/07, pg 3.
[5] Matthew Power, "How-To: Minimize to Maximize," *Builder Magazine*, 01 August 2003, pg 3.
[6] United States Environmental Protection Agency, "*Value-Engineered Framing*", December 2000, available from http://www.energystar.gov/ia/new_homes/; Internet; accessed 01 September, 2006 pg 1.
[7] Office of Energy Efficiency and Renewable Energy, *"Advanced Wall Framing"*, available from http://www.eere.energy.gov/buildings/info/documents/; Internet; accessed 01 September, 2006, pg 1-2.
[8] United States, "*Value-Engineered Framing*", pg 1.

- Designing homes on 2-foot modules[1]
- Eliminating headers in non-load bearing walls[2]
- Using in-line framing (Stack framing)[3]
- Incorporating shear panel inserts[4]

The purpose is to reduce the amount of wood used in the wall to allow room for more insulation. "The unnecessary use of wood displaces insulation and degrades the thermal efficiency of the building envelope".[5] Wood has a much lower R-Value than insulation.[6] Wood also acts as a thermal bridge and "some heat flows around the insulation through the studs and joists."[7]

In addition to increasing the insulation value of the house, optimal framing "can result in materials cost savings of about [$0.42 per square foot], labor cost savings of between 3 and 5 percent, and annual heating and cooling savings of up to 5 percent."[8] Optimal framing can also reduce lumber costs by more than 15 percent.[9]

Additional benefits of optimal framing include:

- Reduced wood purchase and disposal costs[10]

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[1] Office of Energy Efficiency, *"Advanced Wall Framing"*, pg 1-2.
[2] Ibid.
[3] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 2.
[4] Matthew Power, "Optimal Framing," *Builder Magazine*, 01 October 2001, pg 1.
[5] United States Environmental Protection Agency, "*Value-Engineered Framing"*, December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.
[6] Ibid.
[7] Department of Energy, *Insulation Fact Sheet*, October 2005, available from http://www.ornl.gov/sci/roofs+walls/insulation/insulation.pdf; Internet; accessed 11 September 2006, pg2
[8] Office of Energy Efficiency and Renewable Energy, *"Advanced Wall Framing"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26449.pdf; Internet; accessed 01 September, 2006, pg 1.
[9] Southface Energy Institute, "*Energy Efficiency Makes Homes More Affordable,"* 16 July 1998, available from http://www.southface.org/web/resources&services/publications/factsheets/sav_nrg$.pdf; Internet; Accessed 23 August, 2006, pg 2.
[10] Peter Yost and Ann Edminster, "Optimizing Wood Framing," *Building Safety Journal*, May 2003, available fromhttp://www.buildingscienceconsulting.com/resources/articles/optimizing_wood_framing.pdf; Internet; accessed 16 September 2006, pg 1.

- Reduced environmental impact[1]
- Reduced thermal bridging[2]
- Improved thermal performance (insulation material replacing lumber)[3]
- Lower material and labor costs[4]

The thermal barrier isn't the only part of creating a tighter building envelope. Airflow control is also important. Leaky homes decrease comfort, bring in moisture, increase cold drafts, are noisy, and have lower indoor air quality. Air leakage also "accounts for between 25[5] percent and 50[6] percent of the energy used for heating and cooling in a typical residence."

Reducing infiltration and leakage "can significantly cut annual heating and cooling costs, improve building durability, and create a healthier indoor environment."[7] It also helps to reduce the size of heating and cooling equipment.[8]

Creating a continuous air barrier can be done for less than $200 for the average home,[9] does not require specialized labor,[10] and is inexpensive during the construction phase.[11]

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[1] Peter Yost and Ann Edminster, "Optimizing Wood Framing," *Building Safety Journal*, May 2003, available fromhttp://www.buildingscienceconsulting.com/resources/articles/optimizing_wood_framing.pdf; Internet; accessed 16 September 2006, pg 1.
[2] Ibid
[3] Office of Energy Efficiency and Renewable Energy, *"Advanced Wall Framing"*, pg 1.
[4] Ibid
[5] United States Environmental Protection Agency, "*Air Sealing*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.
[6] Office of Energy Efficiency and Renewable Energy, *"Air Sealing"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26448.pdf; Internet; accessed 01 September, 2006, pg 1
[7] Ibid.
[8] Ibid.
[9] Ibid.
[10] Southface Energy Institute, "*Airsealing: Seal air leaks and save energy,"* 5 March 2002, available from http://www.southface.org/web/resources&services/publications/factsheets/8_airsealing.pdf; Internet; Accessed 23 August, 2006, pg 1.
[11] Southface Energy Institute, "*Energy Checklist: Energy-efficient Construction,"* available from http://www.southface.org/web/resources&services/publications/factsheets/cheklist.pdf; Internet; Accessed 23 August, 2006, pg 1.

The key to an airtight house is to make sure that cracks in the building envelope are caulked, sealed, and weather-stripped. It is also important to identify potential infiltration paths and assign responsibility for sealing holes.[1] In many homes there are "hidden spaces and holes" where air can move from conditioned spaces to unconditioned spaces. These should also be identified.[2] Tools to create a continuous air barrier include: include: caulks, foams, weather-stripping, gaskets, and door sweeps.[3]

Some of the spots that are consistently leaky include: the attic hatch, ceiling fans, windows, wall outlets, light switches, plumbing stacks, floor drains, the basement slab, the area in between the foundation wall and the floor system, and connections to the attic and crawl space.[4]

Areas to remember to seal, caulk, tape or gasket are:

- Below bottom plates[5]
- Around bathtubs[6]
- Above dropped ceilings and soffit[7]
- Around electrical and plumbing penetrations[8]
- Behind mechanical room closets

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[1] Southface Energy Institute, "*Energy Checklist: Energy-efficient Construction,"* available from http://www.southface.org/web/resources&services/publications/factsheets/cheklist.pdf; Internet; Accessed 23 August, 2006, pg 1.
[2] United States Environmental Protection Agency, "*Locating Ducts Within Conditioned Space"*, December 2000, available from http://www.energystar.gov/ia/; Internet; accessed 01 September, 2006, pg1.
[3] United States Environmental Protection Agency, "*Air Sealing"*, December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.pg 1.
[4] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home,* 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/; Internet, Accessed 01 June 2007, pg 3.
[5] Office of Energy Efficiency and Renewable Energy, *"Whole-House Energy Checklist"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/whole_house_energy_checklist-766.pdf; Internet; accessed 01 September, 2006, pg 2
[6] Southface Energy Institute, "*Energy Checklist,"* pg 1.
[7] Tool Base Services, *Seven Steps to a ZEH*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 01 September, 2006.
[8] Tool Base Services, *"Considerations for Building a More Energy-efficient Home"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 2.

- Above and below baseboards on exterior walls[1]
- Between conditioned and unconditioned spaces
- Building or house wraps[2]
- Drywall on exterior walls[3]

"The more complicated a house becomes…the more difficult it is to create a continuous air barrier. Careful attention to details becomes the key."[4]

Another key part of an airtight house is to provide proper ventilation of outside air to avoid poor indoor air quality.[5] Venting is an important part of building energy-efficient homes.[6] It is important to rely on controlled ventilation rather than air leakage because controlled ventilation maintains constant, clean air, and keeps moisture out of the structure.[7] Tool Base Services advises on this issue that it is not good enough to let natural ventilation alone do the job.

> One problem with relying on natural air infiltration is that it is often driven by wind and the difference in temperature between indoors and out. There is more air infiltration during the most extreme outdoor conditions and little air infiltration in mild weather. Another problem in relying on air infiltration alone is that air may be forced through building cavities which can lead to condensation in the walls.[8]

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[1] Tool Base Services, "*TechPractices: Watt Homes of Utah*", available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 2

[2] National Home Builders Association Research Center, *2006 EVHA Winners*, available from http://www.nahbrc.org/evha/winners_climate.html; Internet; accessed 1 September 2006, pg 1, 3.

[3] Utah State University, Utah House, "*Overall House Design Guidelines,*" available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 4.

[4] Arnie Katz, "Ingredients for an Energy-efficient Home," *Advanced Energy*, available from http://www.advancedenergy.org/buildings/knowledge_library/systems_approach/ingredients_for_an_energy_efficient_home.html; Internet; Accessed 01 September 2006, pg 2.

[5] Tool Base Services, "*Whole-House Mechanical Ventilation Strategies*", available from http://www.toolbase.org/Techinventory/; Internet; accessed 01 September, 2006.

[6] Arnie Katz, "Ingredients for an Energy-efficient Home," pg 1.

[7] Office of Energy Efficiency and Renewable Energy, "*Air Sealing*", available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26448.pdf; Internet; accessed 01 September, 2006, pg 1. (Tool Base Services, "*Whole-House Mechanical Ventilation Strategies*", available from http://www.toolbase.org/Techinventory/; Internet; accessed 01 September, 2006.)

[8] Tool Base Services, "*Considerations for Building a More Energy-efficient Home*", available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 3.

To some extent, the key to controlling moisture in the home is to control air movement because air brings moisture with it wherever it goes.[1] Once a proper air barrier has been made, the next step is to stop capillary action.

"Capillary rise through footings is typically ignored."[2] In order to create a break between the footing and foundation, a builder may damp-proof, or install a membrane to the top of the footing.[3] Another way to stop capillary action is to put a plastic break under any interior slab-on-grade component.[4]

Making sure the landscape is graded away from the house and that proper damp-proofing and footing and foundation drainage is in place will also stop moisture.

Energy-Efficient Design Practices

The way that a house is designed can have a significant impact on the relative energy efficiency of the home. Often, energy savings can be designed into a house without having any additional impact on the building costs.[5] In fact, research has shown that "energy savings in the order of 10 to 50 percent may be obtained without adding to the capital cost in a building."[6] Often, simple changes can "yield big savings."[1]

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[1] Building Science Consulting, *Air Barriers vs. Vapor Barriers*, available from http://www.buildingscienceconsulting.com/resources/walls/air_barriers_vs_vapor_barriers.htm; Internet; accessed 15 September 2006, pg1

[2] Office of Energy Efficiency and Renewable Energy, *"Whole-House Energy Checklist"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/whole_house_energy_checklist-766.pdf; Internet; accessed 01 September, 2006, pg 2.

[3] Asthma Regional Coordinating Council of New England, *"Groundwater,"* available from http://www.uaf.edu/ces/faculty/seifert/pdf_nuaf/Design_Build.pdf; Internet; Accessed 04 September, 2006, pg 1.

[4] Asthma Regional Coordinating Council of New England, *"Groundwater,"* pg 1.

[5] Rangel Ruiz, University of Calgary (Canada), *"Energy-efficient Builing Design in Cold Climates: Schools as a Case Study,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006, pg 28.

[6] Rangel Ruiz, *"Energy-efficient Building Design in Cold Climates,"* pg 28.

In other cases, energy savings can be designed into the house and increase the cost of the house an additional 2- 5 percent, but have a return on investment (ROI) of far greater consequence.[2]

Some of the key design practices that relate to making houses more energy-efficient are System Design, Passive Design, Mechanical Design, and Landscaping Design. System Design considers how products and practices interrelate to create energy efficiency, and Passive Design considers using natural energy from the environment including the sun and the wind. Landscaping Design considers using landscaping to reduce heating and cooling loads, and finally, Mechanical Design right sizes HVAC equipment and puts ducting in conditioned spaces.

__System Design__

According to Rangel Ruiz,

> Buildings are an interaction of materials, environmental control systems, building automation systems, occupants and equipment. Energy-efficient design is dependent not only on energy-efficient equipment, but also on how building systems are interrelated and respond to local climate conditions.[3]

The basic idea of System Design is to consider how products work together as a system and not as stand-alone components.[4] System Design "takes into account the

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[1] Southface Energy Institute, "*Energy Efficiency Makes Homes More Affordable,*" 16 July 1998, available from http://www.southface.org/web/resources&services/publications/factsheets/sav_nrg$.pdf; Internet; Accessed 23 August, 2006, pg 2.

[2] Rangel Ruiz, University of Calgary (Canada), *"Energy-efficient Building Design in Cold Climates: Schools as a Case Study,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006, pg 28.

[3] Rangel Ruiz, *"Energy-efficient Building Design in Cold Climatesy,"* pg 1.

[4] Michael Baechler et al., *"Building America Best Practice Series: Volume 3,"* August 2005, US Department of Energy.

effects and interactions of all the components of the home."[1] It recognizes that energy-efficient techniques are more effective when studied within the scope of the whole house.[2]

Key factors considered in System Design include: [3]

- Project site
- Building envelope
- Mechanical HVAC systems
- Occupants
- Materials
- Building automation systems
- Equipment

One study found that in designing an energy-efficient house, "success was not so much based on the selection of energy-efficient equipment, but on improved integration."[4]

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[1] Aspen Homes of Colorado, *Energy Center*, available from http://www.aspenhomesco.com/index.php?pr=Energy_Center; Internet; accessed 1 September 2006, pg1

[2] Office of Energy Efficiency and Renewable Energy, *"Whole-House Energy Checklist"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/whole_house_energy_checklist-766.pdf; Internet; accessed 01 September, 2006, pg 1.

[3] Southface Energy Institute, "*Energy Checklist: Energy-efficient Construction,*" available from http://www.southface.org/web/resources&services/publications/factsheets/cheklist.pdf; Internet; Accessed 23 August, 2006, pg 1.

[4] Rangel Ruiz, University of Calgary (Canada), *"Energy-efficient Builing Design in Cold Climates: Schools as a Case Study,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/pqdweb?did=76526657&sid=1&Fmt=2&clientld=9338&RQT=309&VName=PQD; Internet; Accessed 01 June, 2006.

Passive Design

Including Passive Design components into a home is very important to creating energy-efficient houses. Although many design components may "have a higher first cost," they save money over the life of the home.1

> Research…has shown that, by working with technologies that exploit natural processes, a significant drop in the amount of fossil fuels used in heating, cooling, ventilation, lighting, and hot water, can be achieved. However, special attention must be directed to the challenge posed by climatic conditions.[2]

Passive Design components do the following:

- Properly orient the building[3]
- Maximize winter heat gain and summer heat loss[4]
- Select different glazing for different sides of the house[5]
- Add thermal mass[6]
- Use natural ventilation[7]
- Use natural lighting[8]

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[1] Office of Energy Efficiency and Renewable Energy, *"Passive Solar Design"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/29236.pdf; Internet; accessed 01 September, 2006, pg 1.
[2] Rangel Ruiz, University of Calgary (Canada), *"Energy-efficient Builing Design in Cold Climates,"* 2003, available from http://proquest.umi.com.erl.lib.byu.edu/ Internet; Accessed 01 June, 2006.
[3] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 1.
[4] Ibid.
[5] Office of Energy Efficiency and Renewable Energy, *"Passive Solar Design"*, pg 1-2.
[6] Office of Energy Efficiency and Renewable Energy, *"Whole-House Energy Checklist"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/whole_house_energy_checklist-766.pdf; Internet; accessed 01 September, 2006, pg 1.
[7] Arnie Katz, "Ingredients for an Energy-efficient Home," *Advanced Energy*, available from http://www.advancedenergy.org/buildings/knowledge_library/systems_approach/ingredients_for_an_energy_efficient_home.html; Internet; Accessed 01 September 2006, pg 1.
[8] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_3.pdf; Internet, Accessed 01 June 2007, pg 1

- Clear southern exposure[1]
- Minimize wall space and windows on the west side of the home[2]

As one can see from this list, windows play an important part of Passive Design because of their ability to let in heat and light. Landscaping should be used to shade the house. A design should avoid west-facing windows and protect south facing windows with shading.[3]

Daylighting, using windows and skylights to light a house, is another part of Passive Design.[4] "Daylighting optimizes the use of natural light rather than artificial light and thus can be an important part of energy-savings."[5] "A single skylight can provide as much light as a dozen or more lamps."[6]

"South-facing windows are most advantageous for daylighting,"[7]so rooms most used during the daylight should be on the south end of the house to allow for as much natural light as possible.[8]

North-facing, east-facing, and west-facing windows aren't as ideal because of the glare they produce and the heat they generate in the summer and lose in the winter.[9]

In heating climates, reduce windows on the north side and face major glass areas "south to collect solar heat during the winter when the sun is low in the sky."[1]

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[1] Tool Base Services, "*Considerations for Building a More Energy-efficient Home*", available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 1.
[2] Tool Base Services, *Seven Steps to a ZEH*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 01 September, 2006
[3] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home,* 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_3.pdf; Internet, Accessed 01 June 2007, pg 1.
[4] Office of Energy Efficiency and Renewable Energy, "*Efficient Lighting Strategies*", available from http://www.eere.energy.gov/buildings/info/documents/; Internet; accessed 01 September, 2006, pg 2.
[5] Utah State University, Utah House, *Energy Smarts: Lighting,* 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_5; Internet, Accessed 01 June 2007, pg 2.
[6] Ibid
[7] Office of Energy Efficiency and Renewable Energy, "*Efficient Lighting Strategies*, pg 2.
[8] Utah State University, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home,* pg 2.
[9] Office of Energy Efficiency and Renewable Energy, "*Efficient Lighting Strategies*, pg 2.

Other Passive Design elements include putting unheated areas (such as the garage) in the path of winter winds to act as buffers,[2] minimizing outside surfaces,[3] and using vestibules or air-locks[4] on entrance doors to protect the house from outside temperatures.

It is important to "select, orient, and size glass to maximize solar heat gain in winter and minimize it in summer, with different glazings usually selected for different sides of the house (exposures)."[5]

Even with all of the recommendations concerning windows, a very easy way to immediately improve efficiency is to minimize window area on a house.[6]

Landscaping Design

Landscaping design can also contribute to an energy-efficient home. Properly designed landscaping can reduce watering needs and decrease home energy costs. Creating "water-use zones" allows home-owners to water plants according to needs and reduces overall watering needs.[7]

Good landscaping design can also reduce home energy costs. Interior heating and cooling loads can be reduced by planting deciduous trees that shade the house in the

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[1] US Department of Energy *"Window Selection"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/ ; Internet; accessed 01 September, 2006, pg2.
[2] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_3.pdf; Internet, Accessed 01 June 2007, pg 2.
[3] Matthew Power, "How-To: Minimize to Maximize," *Builder Magazine*, 01 August 2003, pg 3.
[4] Utah State University, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home*, pg 4.
[5] American Council for an Energy-efficient Economy, *Consumer Guide to Home Energy Savings*, September 2005, available from http://www.aceee.org/consumerguide/windo.htm; Internet; accessed 15 September 2006, pg3
[6] Tool Base Services, *"Considerations for Building a More Energy-efficient Home"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 1.
[7] Utah State University, Utah House, *Water-Wise Landscape*, available from http://extension.usu.edu/cooperative/utahhouse/files/plantlist.pdf; Internet, Accessed 01 June 2007, pg 1.

summer and warm it in the winter.[1] Evergreen trees can act as wind breaks against winter winds.[2]

<u>Mechanical System Design</u>

In order to have an energy-efficient HVAC system the designer must properly size the equipment. "Size is one of the most important factors affecting efficiency."[3] Systems that are too big or too small cost more and don't run efficiently.[4] The Southface Southface Energy Institute warns not to rely on rules of thumb; sizing should be based on ASHRAE guidelines and calculated with Manual J.[5]

Systems should also be designed in different zones, so that areas of the home, with different uses, can be regulated to meet the demand.[6]

Heating and Air Conditioning ducts can be a major source of heat loss. Heat loss can be as high as 20-35 percent due to leakage and conduction.[7] HVAC ducts should be insulated to a minimum of R-7 wrapped and sealed with mastic.[8] However, even with insulation and mastic, if ducts are located in unconditioned spaces heat loss can still be as high as 7-12 percent.[9]

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[1] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home*, 01 July 2005, available from http://extension.usu.edu/files/publications/; Internet, Accessed 06/01/07, pg 1
[2] Ibid, pg2.
[3] United States Environmental Protection Agency, "*Energy Star Labeled Air Conditioners*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006, pg 1.
[4] Southface Energy Institute, "*Energy Checklist: Energy-efficient Construction,*" available from http://www.southface.org/web/resources&services/; Internet; Accessed 23 August, 2006, pg 4.
[5] Tool Base Services, "*Considerations for Building a More Energy-efficient Home*", available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg 3
[6] Utah State University, Utah House, "*Overall House Design Guidelines,*" available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 4.
[7] Tool Base Services, "*HVAC Equipment and Duct Installation within conditioned Space*", available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.
[8] Utah State University, Utah House, "*Overall House Design Guidelines*", pg 3.
[9] Tool Base Services, "*Considerations for Building a More Energy-efficient Home*", pg3

Keeping ducts in conditioned space should be an integral part of an energy-efficient home.[1]

> Ductwork in unconditioned space "faces a much higher temperature difference than a typical indoor-outdoor temperature difference. As a result, when a home is being heated with delivery air of 130 degrees Fahrenheit, the other side of that R-6 insulation might be 15 degrees Fahrenheit. Under these conditions, consider an example in which ducts in an attic are insulated to R-6 and the ceiling is insulated to R-38. In this case while the heat is on, the amount of energy being lost from just 20 linear feet of 12-inch ductwork in the attic is greater than the amount of energy lost from over 1000 ft2 of ceiling area![2]

Obviously, all types of design must be considered when planning for a comfortable, energy-efficient home.

Energy-Efficient Products

Introduction

In this next section, the researcher presents information on energy-efficient building products. Although products can significantly reduce energy costs, they should be employed after "extensive energy conservation strategies."[3] "It is more cost effective

[1] United States Environmental Protection Agency, "*Duct Sealing*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006, pg1.
[2] Tool Base Services, "*Considerations for Building a More Energy-efficient Home*", available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg3.
[3] Green Builder, "*Solar Hot Water, Heating and Cooling Systems,*" available from http://www.greenbuilder.com/sourcebook/heatcool.html; Internet, Accessed 01 September, 2006, pg 2.

to invest in making your home more energy-efficient."[1] Many of these building products work best when combined with other energy efficiency measures.[2]

<u>Insulated Concrete Forms</u>

"Foundation or basement walls…have the highest initial cost, coupled with the greatest impact on long-term energy costs."[3] "Uninsulated, conditioned basements may represent up to 50 percent of the heat loss" in a home.[4] One way to better insulate basement walls and reduce long-term energy costs is to use Insulated Concrete Forms (ICFs).

Not only can Insulated Concrete Forms be used to form basement walls, they can also be used to replace all exterior walls in a home, replacing wood framed walls.

ICFs are thermally superior to other common foundation and wall framing products.[5] Their insulation values range from R-17 to R-26 where many wood walls range from R-13 to R-19.[6] They also have a lower air filtration.[7] "ICFs average about half as much infiltration as wood-frame homes."[8]

ICFs create a large thermal mass which gives them "the ability to smooth out large temperature swings. They keep the walls warmer when the outdoor temperature

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[1] Tool Base Services, *"Solar Water Heating,"* available from http://www.toolbase.org/ToolbaseResources/level4DG.aspx?ContentDetailID=3615&BucketID=4&CategoryID=9; Internet; accessed 01 September, 2006, pg1

[2] US Department of Energy "*Geothermal Heat Pumps*", available from http://www.eere.energy.gov/de/geo_heatpumps.html; Internet; accessed 01 September, 2006, pg 1.

[3] Matthew Power, "How-To: Minimize to Maximize," *Builder Magazine*, 01 August 2003.

[4] John Carmody et al., eds., *Builder's Foundation Handbook* (Oak Ridge National Laboratory, 1991), pg 3.

[5] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 2.

[6] Tool Base Services, *"Insulating Concrete Forms (ICF)"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.

[7] Utah State University, Utah House, *Energy Smarts: Insulating Concrete Forms (ICFS)*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_4.pdf; Internet, Accessed 01 June 2007, pg 1

[8] Portland Cement Association, *Technology Brief No. 1: Concrete Homes Save Energy*, available from http://www.cement.org/homes/brief01.asp; Internet, Accessed 10 August, 2006, pg 1.

hits its coldest extreme and cooler when the outdoor temperature is hottest…which contributes about 6 percent of the needed energy to the house for free."[1]

Other Benefits of ICFs include:

- High wind resistance[2]
- High seismic resistance[3]
- Moisture resistance[4]
- Greater durability than traditional wood framing products[5]
- Less attractive to pests and termites[6]
- Higher thermal mass[7]
- Noise abatement[8]
- Reduced air leakage[9]

The biggest problem with ICFs is the up-front cost. Initial cost for ICFs can be two to seven percent more than traditional wood framing.[10] However, "houses built with ICF exterior walls require 44 percent less energy to heat and 32 percent less energy to cool than comparable frame houses."[11] Also, because of the higher efficiency, ICFs

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[1] Portland Cement Association, *Technology Brief No. 2: Building a Better House with Concrete*, available from http://www.cement.org/homes/brief02.asp; Internet, Accessed 10 August, 2006, pg 1.
[2] Tool Base Services, *"Insulating Concrete Forms (ICF)"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006
[3] Ibid.
[4] Ibid.
[5] Ibid.
[6] Ibid.
[7] Utah State University, Utah House, *Energy Smarts: Insulating Concrete Forms (ICFS)*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_4.pdf; Internet, Accessed 01 June 2007, pg 1.
[8] Ibid.
[9] Ibid.
[10] Tool Base Services, *"Insulating Concrete Forms (ICF)"*
[11] Portland Cement Association, *Technology Brief No. 1: Concrete Homes Save Energy*, available from http://www.cement.org/homes/brief01.asp; Internet, Accessed 10 August, 2006, pg 1.

require smaller heating and cooling equipment. The decreased mechanical load can cut construction costs by up to 50 percent.[1]

Insulation Products

There are a wide variety of insulation materials available, such as fiberglass, mineral wool, cotton, cellulose, polystyrene, polyisocyanurate, polyicynene, polyurethane, bat-type, loose fill, rigid foam panels, and spray-type insulation.[2] Some materials act only as thermal barriers while others can also be vapor and air barriers. "The right insulation system can save you money, reduce the amount of energy you use and make your home more comfortable."[3]

Although the majority of insulation being used today is fiberglass, other products are making inroads due to their better insulation capabilities, and there additional built-in air and vapor barriers. Some of these include rigid exterior insulation, open and closed cell foam, and combo systems.

Rigid exterior insulation has become more popular because it creates another layer of insulation. It also "minimizes thermal bridging,"[4] and is easy to install.[5]

Open and closed-cell foam is becoming increasingly popular because it "expands to fill all nooks and crannies" creating a continuous thermal barrier better than any other insulation material.[1]

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[1] Tool Base Services, *"Insulating Concrete Forms (ICF)"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.
[2] United States Environmental Protection Agency, "*Increased Insulation*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.
[3] Canada Mortgage and Housing Corporation, *Insulating Your House*, 4 June 2006, available from http://www.cmhc-schl.gc.ca/en/co/maho/enefcosa/enefcosa_002.cfm; Internet; accessed 11 September 2006, pg5
[4] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 2.
[5] Canada Mortgage and Housing Corporation, *Insulating Your House*, pg 3.

Foam creates a tighter house, fills the cracks, is easy to install around wires, boxes, and cables, doesn't sag or compress, acts as vapor barrier, deadens sound, doesn't allow condensation, requires no venting, is an effective air barrier, is a vapor retardant, can be used on cathedral ceilings, and adds stiffness to structural members.[2]

With foam insulation it is "possible to size studs and rafters based on structural loads rather than the amount of space needed for insulation."[3] Closed-cell foam provides more insulation per inch than other materials[4] and also has a perm rating of less than 1.0.[5]

One problem with foam insulation is that it can run 10–15 percent more than fiberglass insulation,[6] but this is offset by the fact that it allows downsizing of HVAC equipment.[7]

Another popular insulation option is to install a combo system of foam and batt together. "Some insulation contractors install foam and batt in the same framing cavity in order to combine the air-sealing and vapor-resistant properties of foam with the economy of fiberglass."[8]

High-Performance Windows

It is estimated that windows comprise as much as 10-25 percent of the exterior wall area of new homes.[9] Windows also account for as much as 25-30 percent of a

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[1] Nigel Maynard, "Hold the Foam," *Builder Magazine*, 01 March 2004, pg 1.
[2] Remodeling Staff, "Reader's Choice Product: Warm Walls," *Remodeling Magazine*, 01 May 2004, pg1.
[3] David Frane, "*Construction Products Review: Spray In-Place Insulation,*" May 2004, available from http://www.architectmagazine.com/industry-news.asp?sectionID=1022&articleID=63452; Internet; accessed 02 September, 2006, pg2.
[4] Charles Wardell, "Bubble Wraps," *Builder Magazine,* 01 September 2005, pg 2.
[5] Ibid.,pg 3.
[6] Nigel Maynard, "Hold the Foam," *Builder Magazine*, 01 March 2004, pg 2.
[7] Nigel Maynard, "Hold the Foam,"pg 2.
[8] David Frane, "*Construction Products Review: Spray In-Place Insulation,*" pg4
[9] United States Environmental Protection Agency, "*High-Performance Windows*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.

home's heat loss or gain.[1] Since windows transfer so much heat and take up such a significant portion of the exterior barrier of a home, it is important to make them more efficient.

In a study by the Efficient Windows Collaborative, new high-performance windows were found to have 27–39 percent savings over single-paned windows.[2] Some of the key features of High Performance windows include:

- Multiple layers of glazing[3]
- Additional dead air space[4]
- Low-conductivity gas[5]
- Low-E coatings[6]
- Thermal breaks or spacers[7]
- Insulated frames[8]
- Better edge sealing technology[9]

Some of the benefits of High Performance Windows include:

- Reduced winter heat loss[10]
- Reduced summer heat gain[11]

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[1] Boyce Thompson, "Matter of Energy," *Builder Magazine*, 01 February 2005, pg 1.
[2] Regents of the University of Minnesota, Benefits: Energy & Cost Savings, available from http://www.efficientwindows.org/energycosts.cfm; Internet; accessed 7 September 2006, pg 1.
[3] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 3.
[4] American Council for an Energy-efficient Economy, *Consumer Guide to Home Energy Savings*, September 2005, available from http://www.aceee.org/consumerguide/windo.htm; Internet; accessed 15 September 2006, pg1-2
[5] United States Environmental Protection Agency, "*High-Performance Windows", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006
[6] Tool Base Services, *"Considerations for Building a More Energy-efficient Home"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006, pg2.
[7] United States Environmental Protection Agency, "*High-Performance Windows*
[8] American Council for an Energy-efficient Economy, *Consumer Guide to Home Energy Savings*, pg1-2
[9] United States Environmental Protection Agency, "*High-Performance Windows"*
[10] Utah State University, Utah House, *Energy Smarts: Energy-efficient Windows,* 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/; Internet, Accessed 01 June 2007, pg 1.
[11] Ibid

- Increased visible light as compared to older tints and films[1]
- Improved comfort due to fewer cold drafts and hot spots[2]
- Reduced fading by blocking UV rays[3]
- Lower utility bills, improved comfort[4]
- Smaller heating and cooling systems required[5]

"In climates with a significant heating season, windows have represented a major source of unwanted heat loss, discomfort, and condensation problems."[6] "Research studies report that windows in heating-dominated climates account for up to 25 percent of a typical house's heating load."[7]

Windows transfer heat in three ways: conduction (non-solar heat), radiation (solar heat), and air infiltration. In cold-weather environments it is important to block conduction but to allow radiation to penetrate windows, especially windows with a southern exposure.[8] The way this is done is by selecting a window with a high U-value and a high SHGC allowing sun light to passively warm the house.[9]

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[1] Colorado New Home Choices, *Windows More than Just a View*, October 2003, available from http://www.coloradonewhomechoices.org/factsheets/CNHCFS-Windows_2005-01.pdf; Internet; accessed 16 September 2006 pg1
[2] United States Department of Energy *"Window Selection"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/window_selection-777.pdf; Internet; accessed 01 September, 2006. pg1.
[3] Colorado New Home Choices, *Windows More than Just a View*, pg1
[4] United States Environmental Protection Agency, "*High-Performance Windows"*, December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.
[5] United States Department of Energy *"Window Selection"*, pg1.
[6] Regents of the University of Minnesota, Benefits: Energy & Cost Savings, available from http://www.efficientwindows.org/energycosts.cfm; Internet; accessed 7 September 2006, pg 1.
[7] United States Environmental Protection Agency, "*High-Performance Windows"*,
[8] Colorado New Home Choices, *Windows More than Just a View*, pg1-2
[9] Regents of the University of Minnesota, Benefits: Energy & Cost Savings, pg 2.

Appliances

According to a survey performed by the Residential Energy Consumption Survey conducted in 1997, lighting and appliances account for about a third of all energy consumed in residences.[1] Appliances also consume additional energy in the cost to cool the heat they generate and the cost to heat the water they use.[2]

Energy-efficient appliances reduce energy costs.[3] For example, Energy Star washers use 50 percent less energy and water per load when compared to similar non-Energy Star models.[4]

It is important to note, however, that "energy efficiency can vary considerably among appliances of similar size and features," so it is important to compare savings.[5]

Most of the energy used in dishwashers and washing machines is for heating water (as high as 80 percent). Models that use less water use less energy.[6] Models that use cooler water also use less energy. Horizontal-axis washing machines use less water, and dishwashers with temperature boosters use cooler water. Both can have a significant impact on the amount of energy used to heat water.[7]

Induction cook-tops are about 90 percent efficient as compared to gas, which is about 50 percent efficient, and radiant electric, which is 60 percent efficient. The time to

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[1] Office of Energy Efficiency and Renewable Energy, *"Energy-efficient Appliances"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26468.pdf; Internet; accessed 01 September, 2006, pg 1.
[2] Ibid.
[3] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home,* 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_3.pdf; Internet, Accessed 01 June 2007, pg 5.
[4] Consumer Federation of America: *Choosing Energy-efficient Products,* available from http://www.buyenergyefficient.org/buy.html; Internet; Accessed 01 September 2006, pg 1.
[5] Utah State University, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home,* pg 5.
[6] Southface Energy Institute, "*Energy Wise Appliances,"* 5 March 2002, available from http://www.southface.org/web/resources&services/publications/factsheets/11appliances.pdf; Internet; Accessed 23 August, 2006, pg 1.
[7] Ibid.

boil water on an induction cook-top is 13 percent faster than gas and 20 percent quicker than radiant.[1] Some important things to remember when considering appliances include:

- Keeping ovens and ranges apart from refrigerators and freezers to reduce heating and cooling costs[2]
- Top freezer modeled refrigerators use approximately 18 percent less energy than side-by-side models[3]
- Keeping appliances cleaned and maintained as per guidelines[4]
- Self-cleaning ovens generally have more insulation[5]

Modulating Furnace

Modulating furnaces combine a modulating gas valve with a variable-speed blower and both are adjusted until the maximum efficiency is reached.[6] The modulating furnace can cost up to three times as much as the least expensive furnaces, but "fuel savings will eventually pay for the extra cost."[7] According to Tool Base Services, "Standard furnaces operate like your car in stop-and-start traffic. A modulating furnace is like highway driving, making slight operating adjustments while achieving maximum efficiency."[8]

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[1] Stephani Miller, "Kitchen Magnets," *Builder Magazine*, 01 June 2006, pg1, 3.
[2] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 5.
[3] Office of Energy Efficiency and Renewable Energy, *"Energy-efficient Appliances"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26468.pdf; Internet; accessed 01 September, 2006, pg3-4.
[4] Ibid
[5] Ibid
[6] Tool Base Services, *"Modulating Furnace"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.
[7] Ibid.
[8] Ibid.

Programmable Thermostats

Electronic, programmable thermostats yield substantive dividends,[1] as high as $100 per year when "programmed and used properly."[2] "A programmable thermostat can pay for itself in energy saved within four years"[3] and "if programmed properly, the heating and cooling systems will operate less frequently, consume less energy, and lower utility bills."[4]

> Space heating and cooling accounts for more than 40 percent of the average home's energy use. A significant amount of this energy is often used to maintain interior temperatures within the comfort zone even when the home is unoccupied or when inhabitants are asleep.[5]

"By turning the thermostat back 10 to 15 degrees for 8 hours, you can save about 5-15 percent a year on your heating bill- a saving of as much as 1 percent for each degree if the setback period is eight hours long."[6]

Water Heating

Energy costs associated with heating domestic water can be up to 25 percent[7] of the annual utility cost and are a high energy factor in most homes.[8] One of the most effective things that builders and home-owners can do to reduce water heating costs is to

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1 National Home Builders Association Research Center, *2006 EVHA Winners*, available from http://www.nahbrc.org/evha/winners_climate.html; Internet; accessed 1 September 2006, pg3

2 Consumer Federation of America: *Choosing Energy-efficient Products*, available from http://www.buyenergyefficient.org/buy.html; Internet; Accessed 01 September 2006, pg 3.

3 United States Department of Energy *"Automatic and Programmable Thermostats"*, March 1997, available from http://www.eren.doe.gov/erec/factsheets/factsheets.html; Internet; accessed 01 September, 2006, pg 2.

4 United States Environmental Protection Agency, "*Energy Star Labeled Programmable Thermostat*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.

5 Ibid.

6 United States Department of Energy *"Automatic and Programmable Thermostats*, pg 1.

7 United States Department of Energy "*Solar Hot Water*", available from http://www.eere.energy.gov/de/solar_hotwater.html; Internet; accessed 01 September, 2006, pg 3.

8 Tool Base Services, *Seven Steps to a ZEH*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 01 September, 2006.

take “steps to use less hot water and to lower the temperature of the hot water.”[1] Some ways to do this include:

- Locating the water heater closer to major use areas[2]
- Wrapping the water heater storage tank with an insulating jacket[3]
- Installing low-flow showerheads and flow restrictors[4]
- Insulating hot water pipes that pass through unconditioned spaces[5]
- Lowering water-heating temperature to 120 degrees[6]

In addition to these important steps, new water heating systems can drastically reduce the amount of energy used. They include Variable Capacity Boilers that can adjust speed and capacity to run at higher efficiency, and new Energy-Efficient (Energy Star) Boilers that use 5-15 percent less energy than standard efficiency boilers.[7] Finally, Solar Water Heaters are another system designed to reduce utility costs.

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[1] Tool Base Services, *“Solar Water Heating,”* available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 01 September, 2006, pg1

[2] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home,* 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_3.pdf; Internet, Accessed 01 June 2007, pg 4.

[3] Southface Energy Institute, “*Energy Efficiency Makes Homes More Affordable,”* 16 July 1998, available from http://www.southface.org/web/resources&services/publications/factsheets/sav_nrg$.pdf; Internet; Accessed 23 August, 2006, pg 4.

[4] Tool Base Services, *“Solar Water Heating,”* pg1

[5] Ibid

[6] Southface Energy Institute, “*Energy Wise Appliances,”* 5 March 2002, available from http://www.southface.org/web/resources&services/publications/factsheets/11appliances.pdf; Internet; Accessed 23 August, 2006, pg 1.

[7] United States Environmental Protection Agency, “*Energy Star Labeled Boilers”*, December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.

Solar Water Heaters (Solar Thermal Systems)

"By using a solar water heating system, residents can typically cut their water heating needs by 40-80 percent and save between $120 – 240 annually."[1] Up-front costs range from $1,000 to $4,500.[2] The typical payback occurs in three to eight years "on a well-designed and properly installed"[3] heater and reduces energy purchased for water heating by 50 percent.[4]

"Solar water heaters are cost competitive in many applications when you account for the total energy cost over the life of the system. Although the initial cost of solar water heaters is higher than that of conventional water heaters, the fuel is free."[5]

The system works well in cold-weather environments, in fact "the colder the water, the more efficiently the system operates."[6] Using solar water heaters in colder climates may "dramatically reduce utility bills"[7]

Geothermal Heating

Geothermal heating relies on the storage capacity of the earth to provide energy.[8] Geothermal heat pumps are more durable than other systems because they have fewer

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[1]Southface Energy Institute, *Using the Sun to Heat Water*, 30 September 2004, available from http://www.southface.org/web/resources&services/publications/factsheets/residential_solar_water111804.pdf; Internet; accessed 15 September 2006, pg1
[2] US Department of Energy *"Solar Water Heating"*, 30 August 2006, available from http://www.eere.energy.gov/states/alternatives/solar_water_heat.cfm; Internet; accessed 01 September, 2006, pg 2.
[3] Ibid
[4] Tool Base Services, *"On the Path" ZEH Demonstration"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 01 September, 2006, pg1.
[5] Tool Base Services, *"Solar Water Heating,"* available from http://www.toolbase.org/ToolbaseResources/; http://www.toolbase.org/ToolbaseResources/; Internet; accessed 01 September, 2006, pg1
[6] Ibid.
[7] US Department of Energy *"Solar Water Heating"*, pg 1.
[8] Tool Base Services, *"Geothermal Heat Pumps"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.

mechanical components and much of the system is protected under the ground.[1] The heat pumps also require little maintenance and are very reliable.[2]

Geothermal heating is a good energy-efficient option because it is twice as efficient as natural gas furnaces, [3]costs one quarter the cost of heating with electrical cables,[4] more efficient than electric resistance heating, gas or oil heating, air-source heat pumps[5] and saves between 30[6] and 70 percent[7] on heating over conventional systems.

"According to the EPA, geothermal systems are the cleanest, most energy-efficient, and most cost-effective HVAC system."[8] According to Natural Resources Canada, geothermal heat pumps are the "most energy-efficient, environmentally clean and cost-effective space conditioning systems available."[9] Geothermal heating is clean, abundant, versatile, natural[10], environmentally friendly, and reduces energy and emissions.[11]

"Ground source systems use less energy than anything we know of; [they are] No. 1 according to the Environmental Protection Agency."[12] For every 1kW of energy

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[1] Beth W. Orenstein, "The Warmth of Mother Earth Geothermal Technology Friendly to Environment," *Morning Call*, 22 September 1996, G.04.
[2] University of Utah, *"Geothermal Energy,"* available from http://www.geothermal.org/GeoEnergy.pdf; Internet; accessed 01 September, 2006, pg5.
[3] Tracy Hanes, "National Energy Award for Port Perry Builder," *Toronto Star*, 25 February 2006, N.02.
[4] Jim Wilson, "Geothermal Snow-Melting in Japan," *Popular Mechanics*, April 1997, 26, pg2.
[5] Tool Base Services, *"Geothermal Heat Pumps"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006.
[6] University of Utah, *"Geothermal Energy,"* available from http://www.geothermal.org/GeoEnergy.pdf; Internet; accessed 01 September, 2006, pg5.
[7] Tool Base Services, *"Geothermal Heat Pumps"*, pg 2.
[8] Jim Cory, "B + A: Ship Shape," *Remodeling Magazine*, 01 May, 2002, pg 1.
[9] Susan Kelly, "Eco-minded Construction," *The Gazette*, 22 February 2006, S.10.
[10] University of Utah, *"Geothermal Energy,"* pg1.
[11] US Department of Energy *"Geothermal Heat Pumps"*, available from http://www.eere.energy.gov/de/geo_heatpumps.html; Internet; accessed 01 September, 2006, Pg 1.
[12] Oklahoma State University, *"Geo-Outlook,"* Vol.3, No.1, 2006, pg9.

required to run a heat pump, geothermal heating generates 4kWs of energy.[1] It "delivers three to four times more energy than it consumes."[2]

The biggest draw back to Geothermal heating is the cost.[3] It requires drilling bore bore holes for the geothermal piping, or laying pipes in vertical trenches. Up-front costs are approximately double other systems like oil and gas,[4] or $4,000 - $11,000 more for a 3-ton GHP.[5]

However, the cost is quickly offset by the savings. In one study by the Pennsylvania Power & Light Company, it was determined that for an average sized house, heating costs would drop from $1,500 to about $500 per year.[6] By reducing the HVAC load it can be even more cost effective.[7]

Geothermal heat pumps can be tied into typical forced air heating and cooling systems, hot water heating, exterior snowmelt, roof heating, and radiant floor heating.[8] They are especially efficient when paired with radiant flooring.[9]

Other important mechanical systems that should be considered in an energy-efficient home include air-source heat pumps, radiant floors[10], Energy Star labeled air conditioners[1], and Energy Star labeled furnaces[2]

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[1] "The Builder" *Sunday Times*, 19 February 2006, 47.
[2] University of Utah, *"Geothermal Energy,"* pg5.
[3] US Department of Energy "*Geothermal Heat Pumps"*, pg 2.
[4] Jim Cory, "B + A: Ship Shape," *Remodeling Magazine*, 01 May, 2002, pg 1. (Beth W. Orenstein, "The Warmth of Mother Earth Geothermal Technology Friendly to Environment," *Morning Call*, 22 September 1996, G.04.
[5] Tool Base Services, *"Geothermal Heat Pumps"*, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006, pg 2.
[6] Beth W. Orenstein, "The Warmth of Mother Earth Geothermal Technology Friendly to Environment," *Morning Call*, 22 September 1996, G.02.
[7] Tool Base Services, *"TechPractices: RBG Residence"*, available from http://www.toolbase.org/ToolbaseResources/; Internet; accessed 23 August, 2006.
[8] NAHB Research Center, *"Measured Performance of Five Residential Geothermal Systems"*, November 1999, available from http://www.toolbase.org/Techinventory/; Internet; accessed 23 August, 2006, pg 2.
[9] Oklahoma State University, *"Geo-Outlook,"* Vol.3, No.1, 2006, pg9.
[10] Utah State University, Utah House, *"Overall House Design Guidelines,"* available from http://extension.usu.edu/cooperative/utahhouse/; Internet, Accessed 01 June 2007, pg 5.

Energy-Efficient Lighting

"Artificial lighting consumes almost 15 percent of household electricity."[3] Energy-efficient lighting can reduce lighting costs by 50-75 percent.[4] Energy-efficient lighting practices include:

- Using more compact fluorescent lighting[5]
- Increasing lighting quality to reduce lighting quantity[6]
- Installing task-lighting to reduce ambient lighting[7]
- Using lighting controls[8]
- Maximizing daylighting[9]
- Sealing and insulating lights that recess into unconditioned space[10]

Though energy-efficient lighting may cost more at the outset, when weighing the initial purchasing cost against its energy savings, long life, and reduced replacement and maintenance costs, the newer lighting

[1] United States Environmental Protection Agency, "*Energy Star Labeled Air Conditioners*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006, pg 1.
[2] United States Environmental Protection Agency, "*Energy Star Labeled Furnaces*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006.
[3] Office of Energy Efficiency and Renewable Energy, *"Efficient Lighting Strategies"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26467.pdf; Internet; accessed 01 September, 2006, pg 1.
[4] Ibid.
[5] James Cavallo, "Lighting: An Energy-efficient Future," *Home Energy magazine*, available from http://www.homeenergy.org/consumerinfo/lighting/index.html; Internet, Accessed 09/01/2006, pg 2.
[6] Ibid.
[7] Ibid.
[8] Office of Energy Efficiency and Renewable Energy, *"Efficient Lighting Strategies"*, available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26467.pdf; Internet; accessed 01 September, 2006, pg 2-5.
[9] Ibid.
[10] Ibid.

technologies and techniques are much less expensive than incandescent lighting systems.[1]

The most important energy-efficient lighting practice is to use more Compact Fluorescent light bulbs (CFLs).[2] Although CFLs cost more, they use between 60 and 75 percent less energy and last up to 10 times longer than standard Incandescent light bulbs.[3]

A hybrid system of using CFLs in fixtures that get used more than 2 to 3 hours and incandescent bulbs in all other fixtures can also be very effective.[4]

Another energy-efficient practice is to use lighting controls. Typical lighting controls include dimmers, motion detectors, timers and photo sensors and "can save a great deal of energy."[5] Some lighting controls can reduce energy use by as much as 90 percent.[6]

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[1] Utah State University, Utah House, *Energy Smarts: Lighting*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_5.pdf; Internet, Accessed 01 June 2007, pg6.

[2] Utah State University, Utah House, *Energy Smarts: Checklist to Determine Energy Efficiency of a Home*, 01 July 2005, available from http://extension.usu.edu/files/publications/factsheet/Fact_Sheet_3.pdf; Internet, Accessed 01 June 2007, pg 5.

[3] Consumer Federation of America: *Choosing Energy-efficient Products*, available from http://www.buyenergyefficient.org/buy.html; Internet; Accessed 01 September 2006, pg 2.

[4] United States Environmental Protection Agency, "*High-Efficiency Lighting*", December 2000, available from http://www.energystar.gov/ia/new_homes/features/; Internet; accessed 01 September, 2006, pg1.

[5] Office of Energy Efficiency and Renewable Energy, "*Efficient Lighting Strategies*", available from http://www.eere.energy.gov/buildings/info/documents/pdfs/26467.pdf; Internet; accessed 01 September, 2006, pg 3.

[6] United States Environmental Protection Agency, "*High-Efficiency Lighting*", pg1.

CHAPTER 3

ESSENTIAL FEATURES OF THE METHODOLOGY

Introduction

The purpose of this study was to create energy efficiency benchmarks to overcome inefficiencies of cold-weather, high-end custom homes. It was also to evaluate different products and practices currently in use by Energy Star Builders and in Colorado, Idaho, Utah and Wyoming.

Information was gathered from multiple sources in order to identify and evaluate energy-efficient building practices.

Essential features of the methodology of this project included:

- Developing a list of energy-efficient products and practices
- Forming a committee of experts to explore ideas and create a survey
- Surveying Energy Star builders in Colorado, Idaho, Utah, and Wyoming
- Analyzing surveys and performing pay-back calculations on the products deemed most important by the Energy Star builders.

List of Products and Practices

A list of energy-efficient products and practices was compiled from literature and interviews to compare with energy-efficient products and practices currently practiced by Energy Star builders in the target areas.

The list was developed from four main sources of information. The first was the researcher's background and understanding of the subject. The second was the experience of faculty in the construction management program at BYU. The third was through a review of related literature including books, journals, articles, and websites. And the final method was through the experience of the committee of experts.

Committee of Experts

A committee of experts was formed and consisted of experienced builders in the target areas. Each of the builders had built high-end custom homes and cold-weather construction for many years. The committee helped create a list of the most important energy inefficiencies in building high-end custom homes in the target areas. The committee also helped determine the criteria used to evaluate energy-efficient products and practices. Finally, the committee reviewed the relevance of building practices to be included in the survey. As the survey is presented, the role of the Committee of Experts will be further explained.

Energy Star Builders' Surveys

The Sample Group

The population of interest for this study consisted of Energy Star qualified builders that built high-end custom homes in Colorado, Idaho, Utah, and Wyoming.

It is assumed that Energy Star qualified builders had built one or more energy-efficient homes. It is also assumed that they were knowledgeable on energy-efficient building practices.

An Energy Star qualified builders list was obtained from the government's Energy Star website and was narrowed to builders in Wyoming, Colorado, Idaho, and Utah. A list of 361 builders was obtained. The list was narrowed further to builders within 60 miles of the cities of interest. The cities of interest were Jackson, Wyoming, Vail, Colorado, Sun Valley, Idaho, and Park City, Utah. These are all ski cities that attract many custom home builders and owners.

The Survey

After the sample group was compiled, builders on the list were contacted and asked to participate in an emailed or faxed survey (see Appendix A for a copy of the survey).

- A questionnaire asking participants to evaluate products and practices
- A list of specific inefficiencies with space to write what builders had done to overcome them

The introduction briefly described the purpose and importance of the survey. It had a confidentiality statement and provided the researcher's name and contact information. Lastly, it gave the participant the opportunity to receive a summary of the findings of the survey.

The background questions asked builders to identify where they built homes, the type of homes built, the average cost of homes, and if the homes were energy-efficient.

The questionnaire section of the survey asked participants to evaluate their experiences with various energy-efficient building practices and products. It asked if the builder had used the practice before and if the builder thought it was an important way to reduce energy costs.

The questionnaire was developed from the list of energy-efficient products and practices compiled from the review of literature and interviews. Members of the committee of experts were asked to rate various energy-efficient practices and products as very important to the study, important to the study or not important to the study. The practices the committee found most important to the study were included in the questionnaire.

Finally, several important energy inefficiencies were listed with space for the participants to respond as to how they overcame the inefficiencies. In all, the survey took no more than 15 minutes to fill out.

Purpose of the Survey

The purpose of the survey was to identify energy-efficient products and practices not discovered in the review of literature or through meetings with the committee of experts. It was also to evaluate what Energy Star builders see as important energy-efficient building practices and products and create benchmarks for the industry.

The Specific Treatment of the Data

After the surveys were returned, the data was examined to find general themes, and was broken into subcategories for easy comparison. The data was ordered according to its timing in a general construction schedule.

The information was then compared to find interconnections and any disconfirming evidence.

Payback Calculations

Payback calculations were performed on each of the following products or practices:

- 2x6 framing
- Compact fluorescent lights
- 92 AFUE or greater furnace
- Extra insulation on water heater (insulation jacket)
- Programmable thermostat
- Optimal Value (Advanced) Framing
- 12 SEER or greater AC

The payback calculations were performed in one of two ways. The U.S. DOE and the U.S. EPA have created payback calculators for some energy-efficient products and provide these calculators on the Energy Star website (http://www.energystar.gov). The remainder of payback calculations were performed using the following four steps:

Step 1 - calculate heating BTU's saved using the formula as follows:

$$\text{Annual heating BTU savings} = \frac{(\text{Change in U x area x 24 x degree days})}{(\text{Seasonal efficiency of the heating system})} \qquad (1.1)$$

Change in U is the difference in U value between the products being compared.

Area is the square footage being compared. Degree Days used for the payback calculations in Chapter 4 from a Park City, Utah Radio Station with a base of 65, and the Annual Heating Degree Days are 7981. See page 6 of this thesis for the Annual Heating Degree Days for the other three cities of interest.

Step 2 – Calculate the average annual savings in dollars. Costs for heating units were determined by contacting local suppliers in the Park City, Utah area on October 5, 2007. They include: Natural Gas cost per decatherm (DTH): $7.44667 (Questar); Electricity cost per kilowatt hour (KWH) $.075389 (Rocky Mountain Power).

Step 3 – Determine the additional cost of the energy-efficient product or practice for the same square foot area being compared. Prices were obtained from suppliers and trade contractors in the Park City, Utah area.

Step 4 – Calculate the number of years to payback. After payback periods were calculated, results were compared with results from the surveys.

Conclusion

The purpose of the thesis was to study energy-efficient building practices of high-end custom home builders in cold-weather environments.

Information was gathered from multiple sources in order to identify energy-efficient building practices of builders. Data was obtained through surveys and websites of local Energy Star Builders.

CHAPTER 4

FINDINGS

Committee of Experts Interviews

A committee of experts was formed and consisted of builders in the target areas. Each of the builders was an experienced home builder focusing on high-end custom homes in cold-weather climates.

The builders were interviewed one or more times and they were each asked various questions about energy efficiency in high-end, cold-weather, custom homes. They were also asked the following questions:

1- What aspects of cold-weather custom homes make them less energy-efficient than other homes (production, modular, or semi-custom homes), or custom homes built in warmer climates?

2- What products or practices have you implemented to overcome some of the additional energy costs associated with question one?

3- What criteria do you use when determining whether to use a new product or practice to reduce energy costs?

Finally the builders helped create a list of building practices to be included in the survey sent out to Energy Star Builders.

Committee of Experts – Energy Inefficiencies

Using the answers to the questions listed above, the author created a list of the most important energy inefficiencies in building high-end custom homes in the target areas.

The energy inefficiencies that the experts noted fall into six general categories including: design and layout, space, exterior glass, conditioning, electrical load and building envelope. Here is a summary of what the experts thought were the biggest energy inefficiencies of high-end, cold-weather, custom homes.

Design and Layout

The experts found that builders typically don't have a lot of input in the design of a home, where the greatest impact on energy efficiency is made. They also said that builders don't have a lot of control on building layout, where views dictate home orientation and layout and not maximum solar efficiency.

Space

Many high-end custom homes have taller ceilings, and cathedral vaults. They are also larger, with more square footage and greater interior mass than other types of homes.

Exterior Glass

High-end homes have more exterior glass including more windows, larger windows, sliding glass doors and other exterior glass doors.

Conditioning

Cold-weather custom homes often have exterior snow-melt systems. They have dual heating systems (radiant and forced air systems), and more air conditioning.

Electrical Load

High-end homes have extra electrical load including audio video equipment, spas, steamer units, and exterior eave melt systems.

Building Envelope

High-end custom homes also have increased wiring in exterior walls, reducing the effectiveness of many kinds of insulation and increasing the amount of penetrations in the building envelope.

Many high-end homes with exterior timbers, beams, corbels and knee braces have additional connection details at the exterior envelope that can cause additional air infiltration.

Committee of Experts – Products and Practices

The Committee of Experts was asked to help evaluate the potential of different products and practices to be included in this survey and to suggest other items not previously included.

Committee of Experts – Evaluation Criteria

The committee also helped determine the criteria used to evaluate energy-efficient products and practices. The members were asked what criteria they use to determine whether to use a potentially energy-efficient product. The committee experts responded that they considered the following reasons before using a product:

- Test market results
- Specifications
- Background of the installation company
- References or testimonials of those who have used the product in question
- Initial cost and expected life
- Opinion of the homeowner
- Cost
- Past performance and durability
- Return on Investment calculation
- Initial cost vs. payoff period
- Owner’s ability to pay for more efficiency

Background to the Survey - Part 1

As stated in chapter three, the survey was sent to Energy Star Builders in Colorado, Idaho, Utah and Wyoming. Part 1 of the survey was a background questionnaire that asked builders about where they built, what type of house they built, the average cost of the house built, and if they built energy-efficient homes.

Builders were asked where they built. Table 4-1 shows the number and percentage of respondents by state.

Table 4-1: Number of Respondents by State

State	Number of Builders	Percentage
Colorado	20	42%
Idaho	13	27%
Utah	11	23%
Wyoming	2	4%
Unknown	2	4%
Total	48	100%

As part of the survey, builders were asked in which counties they built, table 4-2 shows the number and percentage of respondents by county.

Table 4-2: Number of Respondents by County

County	Builders	%	County	Builders	%
Ada, ID	9	11%	Albany, WY	1	1%
Unknown, CO	7	8%	Daughter, CO	1	1%
Salt Lake, UT	7	8%	Delta	1	1%
Utah, UT	6	7%	Douglas, CO	1	1%
Canyon, ID	5	6%	Elmore, ID	1	1%
Jefferson, CO	4	5%	Larimer, WY	1	1%
Weld, CO	4	5%	Montrose	1	1%
Summit, UT	4	5%	Morgan, UT	1	1%
Denver, CO	3	4%	Park, CO	1	1%
El Paso, CO	3	4%	Payette, ID	1	1%
Larimer, CO	3	4%	Pueblo, CO	1	1%
Davis, UT	3	4%	Teller, CO	1	1%
Wasatch, UT	3	4%	Unknown	1	1%
Arapahoe, CO	2	2%	Unknown, UT	1	1%
Boulder, CO	2	2%	Unknown, WY	1	1%
Colorado, CO	2	2%	Valley, ID	1	1%
Adams, CO	1	1%			

Builders were also asked to list the type of house they most often build. They were given the option of: Production/Tract, Semi-Custom, Custom, Modular, or Other. Table 4-3 shows the number and percentage of respondents building each type of home.

Table 4-3: Number of Respondents by Home Type Built

Home Type	Number of Builders	Percentage
Production/Tract	8	17%
Semi-Custom	12	25%
Custom	27	56%
Modular	0	0%
Other	0	0%
Unknown	1	2%
Total	48	100%

Builders were asked to list the average cost of houses built. They were given the option of Under 1 Million, 1-2 Million, Over 2 Million, and Over 4 Million. Table 4-4 shows the number and percentage of respondents by average cost.

Table 4-4: Number of Respondents by Cost of Home

Home Type	Number of Builders	Percentage
Under 1 Million	39	81%
1-2 Million	6	13%
Over 2 Million	2	4%
Unknown	1	2%
Total	48	100%

Finally, builders were asked if they built energy-efficient homes. Of the respondents in the survey, 96 percent said that they built energy-efficient homes.

Energy-Efficient Products and Practices - Part 2

Part Two of the survey sent to Energy Star Builders was a questionnaire about building products and practices. Builders were asked if they had tried different products and practices and if they considered them important to increasing energy efficiency.

The survey defined energy-efficient products as follows: products or practices that reduce long term energy costs, had a payback period of less than 10 years, and were durable.

The builders were asked to rate each product or practice in the following way:

- They had **tried** it and considered it an **important** way to increase energy efficiency
- They had **not tried** it and considered it an **important** way to increase energy efficiency
- They had **tried** it and **did not** consider it an important way to increase energy efficiency
- They had **not** tried it and **did not** considered it an important way to increase energy efficiency
- They didn't know if this increased energy efficiency

Questionnaire Results

Table B-1 shows the results of the questionnaire with the number and percentage of the answer for each product or practice.

98 percent of the respondents said that they had both tried and thought it important to have some kind of quality control in place, including inspections, checklists

and tests. It suggests that all companies should have a quality-control system in place in order to improve energy-efficiency.

Another interesting thing to note from this table is that there are eleven items that over 80 percent of the builders surveyed say they have tried and think are important. Based on the builder's experience and their positive ratings, each of these items should be carefully considered as standards that anyone wanting to build this type of energy-efficient house should follow.

The 11 recommended items include quality control checklists, Energy Star appliances, programmable thermostat, low E windows, sealing penetrations, 92 AFUE or greater furnace, duct work sealed with mastic, high efficiency appliances, energy efficiency training, 2x6 framing, and natural ventilation and lighting.

More than 20 percent of respondents had tried and thought that using extra insulation on the water heater, and minimizing north facing windows were unimportant to improving energy efficiency.

More than 30 percent of builders said that, although they hadn't tried triple pane windows, they thought that they were unimportant to improving energy efficiency.

By combining the responses of builders that had tried an item and marked it important with the builders that hadn't, but also marked it important, a table can be created showing the relative importance of an item to energy efficiency. This is illustrated in Table B2.

In addition to the eleven products and practices mentioned before as important, three more are rated as important by over 80 percent of the builders, even if they hadn't used them before. They are compact fluorescent lights, Energy tests, and Zoned systems.

This shows that although builders think that these are important, some of them haven't yet implemented them into their building practices.

There were several products or practices that many of the builders felt they didn't know enough about to evaluate. Table B3 shows the results for each item that was marked "Don't Know" or left the blank.

Almost 40 percent of the builders said that they were unsure if financial payback tests, variable-capacity boilers and open cell foam insulation increased energy efficiency.

Large numbers of respondents left items blank or marked them "Don't Know". Table B4 is an adjusted version of Table B2. By removing the builders that answered "Don't Know" or left an item blank, an adjusted ranking can be created to show the responses of builders who had enough experience to evaluate the products and practices.

In general, by adjusting the results in this fashion, percentages of builders that thought that items were important went up by a few percent. Some of them were virtually unchanged, and some increased dramatically. Tapped house wrap, insulated ducts and pipes, 2x6 Framing, 92 AFUE or greater furnace, using a programmable thermostat, Energy Star appliances, and quality control all changed very little. Most builders were familiar enough with each of these to offer an answer. When the builders understand what the survey items mean, it gives a clearer picture of what many builders think these of items.

When the "Don't Know" responses were eliminated from the statistics, some products changed dramatically in level of importance. These were HVAC balancing checks, compression or magnetic weather stripping, insulated window frames, passive heating and cooling, ROI, open cell foam, and variable capacity boilers each increased by more than 25 percent. This indicates a lack of knowledge of these products or their long-term results, and that of those that do have experience with these products feel they are important.

There were some items where, when the “Don’t Know” responses were eliminated, the percentage of builders that said that the item was unimportant increased significantly. However, there was almost always an equal increase in the percentage of builders that marked the item as important. Items affected this way were open cell foam, variable capacity boilers and front loading washers. Again, the high level of “Don’t Know” or blank responses reflects a lack of familiarity with these items, but the builders that do have experience with them are evenly split as to opinions

Another important finding from this survey was that it showed how much experience builders had with the products and practices listed. Table B5 is an illustration showing the number of builders that have tried each of the products or practices and is ordered from most frequently tried to least.

Programmable thermostats and Energy Star appliances were tried by 100 percent of builders. Quality control practices, Low E windows, high efficiency appliances, and energy tests had been tried by 98 percent of the builders. Because the sample group was Energy Star Builders, it is not unexpected for energy tests and Energy Star appliances to be used by everybody as they are part of the requirements to be an Energy Star Builder.

Triple window panes, geothermal heating, and water source heat pumps have been tried the least by builders with less than 35 percent of builders saying they have tried them.

One of the most important findings in the survey was the experience that builders had with different energy-efficient products and practices. By focusing on items that at least 80 percent of the builders tried, a good list of energy-efficiency benchmarks could be obtained. Table B6 shows the items that at least 80 percent of the builders tried. It is ranked according to importance.

There are 19 items that more than 90 percent of the builders have marked as "important" to energy efficiency. These items should be considered benchmarks for any builder wanting to build energy efficient homes. They include:

- Rigid foam insulation
- Energy efficiency training
- Penetrations: spray foam and caulking
- Duct work sealed with mastic
- Quality control: inspections, checklists and tests
- 92 AFUE or greater furnace
- Low E windows
- Energy Star Appliances
- Energy tests (blower door, duct blaster, infrared)
- Natural ventilation and lighting
- Multiple glazing
- HVAC balancing check
- Compression or magnetic weather strips
- Programmable thermostat
- High efficiency appliances

- Zoned system with separate thermostats
- Compact fluorescent lights
- Foundation insulation
- 2x6 Framing

There are 5 other items that at least 90 percent of builders that have tried them have said were important. However, because less than 80 percent of builders have tried them, it is less conclusive as to whether they can be considered benchmarks for energy efficiency. Table B7 shows the items that less than 80 percent of the builders have tried and is ranked according to importance. Items that would be considered energy efficiency benchmarks if more builders had reported trying them include:

- Passive heating & cooling
- HVAC with variable speed blower
- Landscaping: shading, deciduous trees, wind barriers
- Insulated window frames
- Water source heat pump

Energy Efficiency Questions - Part 3

In the final part of the survey sent to Energy Star Builders, respondents were asked six open-ended questions identified as the greatest energy inefficiencies by the Committee of Experts. Builders were asked what products or practices they had implemented to overcome the following energy inefficiencies of cold-weather, high-end custom homes.

1. Larger home volume (vaulted ceilings, more square footage)
2. More exterior glass (More windows, bigger windows, exterior glass doors)
3. Building envelope limitations (Much more wiring on exterior walls than in a typical home, connection details between exterior timbers and walls, additional penetrations in envelope)
4. Greater electrical load (More AVI equipment, spas, steamer units, exterior eave melt)
5. Additional heating, cooling and venting (Dual heating systems, radiant and forced air, Air conditioning, Exterior snow-melt systems)
6. Less Design control (architect and owner have more control on design and orientation of a home)

Larger Home Volume

Because high-end custom homes are larger than other types of homes there is more space to heat and cool. High-end custom homes also have more ceiling vaults adding to the space that needs to be conditioned. Because of this builders were asked to identify ways to overcome this inefficiency.

Some of the things that builders listed as ways to overcome larger volume include:

- Increasing the thermal mass throughout the house
- Reducing square footage and ceiling heights
- Create more HVAC zones to control heat/cool throughout the home (Mentioned by 8 different builders)

- Use ceiling fans (including Energy Star and energy-efficient fans), air-cyclers, and variable speed blowers to move air and reduce stratification
- Use smaller HVAC units, located in optimum spaces to reduce ducts and maximize efficiency
- Control and condition air at the human height level only. Keep returns, and ducts lower and allow upper air to heat and cool separately

More Exterior Glass

High-end custom homes also typically have more glass doors and windows (both quantity and size), than other homes. Builders were asked about ways to overcome this inefficiency.

The most common answer was to install a high performance window. Some aspects of high performance windows include: Low-E, double or triple paned, gas or Argon filled, insulated, and treated (glazed, heat mirrored, or coated).

Another thing that builders said was an important way to limit the impact of exterior glass was to change the design of the home. Design changes recommended include:

- Putting most of the glass on the southern exposure and limiting glass everywhere else (especially on the West side)
- Design overhangs to protect the windows in the summer
- Incorporate overhangs in southern glass to allow sun in the winter
- Limit oversized glass
- Use different coatings on different sides of the home for optimal efficiency

- High performance exterior doors
- Properly sealed, caulked, and foamed windows and doors
- Casement windows (perform better than other types of windows)
- Hinged glass doors (perform better than sliding doors)
- Shades or blinds with insulation, or exterior mobile insulation

Building Envelope Limitations

High-end custom homes have more building envelope penetrations than other homes. They have more audio, video, and electrical wiring in the exterior walls, and they also have more connection details like chimneys and timber connections. Builders were asked to identify ways to overcome this inefficiency.

The most common answer was to minimize envelope penetrations, and foam, caulk and seal all penetrations including around ceiling can lights and electrical boxes. Builders said that it takes increased effort and advanced sealing practices to seal all penetrations. By using blown-in foam or cellulose insulation, builders can also reduce and seal building penetrations.

Other ideas include:

- Using 2x6 framing and advanced framing to allow more room for insulation to cover the wiring
- Using house wrap (Tyvek) to minimize air infiltration
- Using rigid foam on the exterior of the building to isolate studs and increase the insulation
- Checking penetrations between conditioned and unconditioned spaces

- Using two layers of drywall to create additional thermal breaks and reduced air leakage
- Running wiring through flooring only

Greater Electrical Loads

High-end custom homes have Audio/Video equipment, spas, steamer units, and exterior eave melt systems not common in other homes. This puts a larger demand on the electrical panel and draws more electricity.

One the most important ways to reduce electrical loads on the home is to change the design of a home. Builders suggest that you can eliminate the need for a steam unit by creating an enclosed shower.

You can eliminate eave melt by designing house overhangs differently. By using raised-heal or energy heals, builders can insulate under the eaves of a home and reduce the need for eave melt.

Some of the other things that builders listed as ways to overcome greater electrical loads include:

- Use solar panels (photovoltaic systems) to reduce electrical loads
- Use High Efficiency or Energy Star appliances and fixtures
- Use High Efficiency and compact florescent light bulbs
- Use kill switches and occupancy sensors
- Use domestic hot water heaters
- Use water source heat pumps

- Use hot water thermal collectors for spas
- Design Net-Zero Systems

Additional Heating, Cooling and Venting

High-end custom homes often have additional heating, cooling and venting requirements. This is in part due to the larger size, however, high-end custom homes also frequently have dual heating systems (radiant and forced air), and exterior snowmelt systems.

Several builders recommend avoiding dual systems. They said that if the owner requires AC, then eliminate radiant heat. They also suggested designing HVAC systems for maximum efficiency.

Some other ideas include:

- Use high efficiency HVAC equipment
- Use better insulated duct work
- Increase insulation (including ICFs and SIPs) to reduce the size of HVAC equipment
- Keep HVAC equipment and duct work in conditioned spaces
- Use split systems for different floors to maximize HVAC equipment

Less Design Control

The final question asked to Energy Star builders was how to overcome the lack of design control often encountered by high-end custom home builders.

The key, according to many of the builders, is to get involved in the planning as early as possible. Set design standards before plan design starts, including deciding the level of energy efficiency. Incorporate as many energy saving features as possible, and help orient the house for maximum efficiency. Spend time early in the project thinking about energy and placement.

Some builders suggested that the key to mechanical efficiencies is to include it into the earliest designs (usually floor plans) and include designed systems into the initial budget.

Builders stated that they have to build according to the wishes of the owner, but suggest that they can help, advise, teach, encourage, and work closely with owners, giving recommendations wherever possible.

It is important to:

- Help the owner orient the house for energy efficiency
- Help the owner understand tradeoffs and ways to compensate for owner selected energy inefficiencies
- Show owners payback for additional investments
- Use an in-house architect
- Exert greater onsite oversight
- Teach the architect about energy efficiency and help him be part of the solution

General Suggestions

In addition to answering the specific questions asked, builders also gave lots of general ideas to increase the energy efficiency of the home.

The most common suggestion was to increase the insulation in the building to offset for the inefficiencies listed above. It is also important to build a tight building envelope. By spending more money for better insulation and a tighter building, builders can spend less on HVAC and electrical systems.

Builders also suggest:

- Wrapping the home with rigid foam for added insulation and thermal breaks
- Use gable vents for cross ventilation in attic trusses

Summary of Responses

There are many significant things that builders can do to overcome the energy inefficiencies of cold-weather, high-end custom homes. They include using more heating and cooling zones, using higher performance glass, using higher quality products, and more efficient equipment

The most frequently repeated by the survey participants and most often mentioned as most important are summarized as follows:

- Building a tighter home by minimizing penetrations and using advanced sealing practices
- Be involved as early as possible in the design of the home
- Increasing the amount and quality of insulation

Because of the frequency that each of the respondents mentioned these, they should also be considered energy efficiency benchmarks and incorporated into general building practices.

Payback Calculations

After the surveys were complete, payback calculations were performed for several of the items in the study. Payback was calculated for the following energy saving practices: 2x6 framing, Optimal Value Framing, and extra water heater insulation. See Appendix C for complete payback calculations on all benchmark items.

A payback calculation was performed on an R10 Water Insulation Jacket. It was calculated for the Park City area with a 90% furnace and a 5,730 square foot house. A payback calculation revealed that this item had a payback of 6 years and 10 months. It also has an average annual savings of $3.27. This energy upgrade will have a very minimal impact on the overall energy of the house, but it does pay for itself quickly.

A payback calculation was performed comparing conventional 2x4 framing with conventional 2x6 framing. Where each method framing occurred 16" on center and used a double top plate, however the insulation in 2x6 framing was increased from R13 to R19. It was calculated for the Park City area with a 90% furnace and a 5,730 square foot house. The pricing was calculated for 32 square feet of wall and annual savings is per 32 square feet. It took 11 years and 10 months for the energy savings to pay for the additional costs. The annual savings per 32 square feet is $1.11, so for a 5,730 square foot house, savings after the payback period can be significant.

A payback calculation was performed comparing conventional 2x4 framing with Optimal Value Framing. 2x4 framing consisted of wall studs spaced 16 inches on center with a double top plate. Optimal Value Framing consisted of 2x6 framing with wall studs spaced 24 inches on center, a single top plate, and inline framing. As with previous calculations, it was calculated for the Park City Area using 5,730 square foot house and a 90% efficient furnace. It was also calculated per 32 square feet of exterior wall.

The payback for Optimal Value Framing was much quicker than for conventional 2x6 framing. The payback period was 3 years and 3 months. The annual savings per 32 square feet was $1.11. As said before, for a 5,730 square foot house the additional energy savings would be significant.

The Energy Star website provides payback and energy savings calculators for various Energy Star and energy saving devices. Among the calculators they provide are calculators for compact florescent lights, furnaces, air conditioners, electronic thermostats, and appliances. The following paybacks were calculated on this site.

A payback was calculated for compact fluorescent lights. This was again based in Park City, Utah and compared 13 watt CFLs to 60 watt incandescent bulbs. The life of the 13 watt bulbs is 8,000 hours verses 1,000 for the incandescent bulb. It was calculated for an average use per day of 1 hour and 3 hours. The payback period for fixtures used 1 hour per day was almost five months and for fixtures used an average of 3 hours per day the payback was just less than two months.

A payback calculation was performed on air conditioning in Park City, Utah. A 12 Seer unit was compared with a 13 Seer unit. The payback period for the energy upgrade was more than 14 years. One of the biggest reasons for such a long payback period is the short cooling season in Park City. The payback is even longer in colder climates.

A payback calculation was performed on gas furnaces. Based on a 5,730 square foot home in Park City the payback period to go from an 80% to a 90% furnace was 3 years 11 months. To go from an 80% to a 92% furnace, the payback period becomes 6 years and 9 months. In contrast to the cooling season, the heating season is long, and it makes sense to upgrade to a more efficient furnace.

A pay back calculation was performed comparing an electronic thermostat to a conventional thermostat. Using an electronic thermostat yielded annual savings of $128 and paid for itself in 6 months.

Thus we see that many of the benchmark products or practices have very practical applications. In a matter of a few short years, and in some cases, months, many products and practices will have paid for themselves. By using payback calculations, builders could better inform and educate their clients to the fact that it is cheaper in the long run to build with energy efficiency in mind.

CHAPTER 5

CONCLUSIONS

Introduction

The purpose of this study was to create energy efficiency benchmarks for cold-weather, high-end custom homes and to evaluate different products and practices.

A list of energy-efficient products and practices was developed through a review of literature and help from experienced custom home builders. Specific energy inefficiencies of cold-weather, high-end custom homes were also identified.

A survey was created from the list of energy-efficient products and practices and sent to Energy Star Builders. Builders were also asked to identify specific tactics used to overcome energy inefficiencies identified.

Energy-Efficiency Benchmarks

Based on the review of literature, the interviews with building experts, the survey, and the payback calculations, builders interested in constructing energy-efficient homes should incorporate all of the following 22 products and practices:

- Add rigid foam insulation
- Participate in energy efficiency training
- Seal penetrations with spray foam and caulking
- Seal duct work with mastic

- Initiate quality control, including inspections, checklists and tests
- Use 92% AFUE or greater furnace
- Use Low E windows
- Use Energy Star Appliances
- Energy tests (blower door, duct blaster, infrared)
- Use natural ventilation and lighting
- Use multiple glazing on windows
- Perform HVAC balancing checks
- Use compression or magnetic weather strips
- Install programmable thermostat
- Use high efficiency appliances
- Design zoned system with separate thermostats
- Install compact fluorescent lights
- Install exterior foundation insulation
- Incorporate 2x6 Framing
- Build a tighter home by minimizing penetrations and using advanced sealing practices
- Be involved as early as possible in the design of the home
- Increase the amount and quality of insulation

It was discovered through the review of literature that each of these items was important to reducing energy costs. It was further discovered, through the survey, that a significant portion of Energy Star Builders had tried each of these. Additionally, a vast majority of those surveyed said that these were important in increasing energy efficiency.

Finally, where possible, payback calculations were performed to support the findings of the survey. Each of these items should be considered benchmarks for energy efficiency.

Additional Potential Energy Efficiency Benchmarks

The survey also identifies other potential energy efficiency benchmarks. There were some practices and products that 90 percent or more builders said were important but that they hadn't yet tried. The review of literature suggests that these items are important and the majority of builders say that they are important. However, actual experience from builders is lower and answers could change based on experience. These items include:

- Passive heating & cooling
- HVAC with variable speed blower
- Landscaping: shading, deciduous trees, wind barriers
- Insulated window frames
- Water source heat pump

Builders interested in energy efficiency should carefully consider each of these products or practices as potential ways to increase energy efficiency.

Other Findings

Some of the other key findings from the questionnaire include:

- Shows what other builders have and haven't tried
- Shows product evaluations based on builder experience
- Shows product evaluations based on builder lack of experience
- Shows builders' lack of knowledge regarding certain methods

Limitations of the Questionnaire

It was impossible to know whether those who responded to the survey answered honestly. Additionally some builders asked to take part in the survey were unwilling to complete the survey because they perceived that the base level for the survey builders was those who built one million dollar or higher homes and they built less expensive homes. Also, the questions left blank were assumed to be "Don't Know" responses, where that may not have been the case.

From the results of the survey it was impossible to determine the frequency of use of a product or practice. Also, determining relative importance of the items in the survey was difficult because of the limited amount of responses provided.

A significant number of builders gave the same answers to each of the questions in part 3 of the survey. Although the frequency of some of the answers show how important they are to increasing energy efficiency, the questions could have been crafted differently to bring out additional ideas that might be less familiar to builders.

Recommendations for Future Research

Additional studies in the following areas would continue to provide valuable information:

1- Create a scale to better rate the relative importance of each item.

2- Expand the survey to ask about frequency of use of the methods listed in the questionnaire.

3- Allow space for builders to comment on items in the survey and clarify answers given.

4- Determine if the results would be similar if the survey group was expanded to include all high-end custom home builders in Colorado, Idaho, Utah and Wyoming.

5- Ask questions regarding what it would take to get builders and owners to implement more energy-efficient products and practices.

6- Perform payback calculations on more of the items in the survey.

7- Create performance measures for items that don't directly affect the R-Value of a home, but that contribute to the energy efficiency of a home (such as comparing R-19 fiberglass batt to R-19 foam).

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APPENDICES

APPENDIX A

SURVEY

Energy Efficiency Survey; Brigham Young Univ.; Fax (801) 963-6342; joseph_kearl@hotmail.com
Part 1of3 (2 Minutes)

Energy Efficiency in cold-weather,
high-end, custom homes

Part 1:

In what counties do you primarily build?

What type of house do you most often build?

Production/Tract Semi-Custom Custom Modular Other

What is the average cost of house you build?

Under 1 Million 1-2 Million Over 2 Million Over 4 Million

Do you build energy efficient homes?

Yes No

Energy Efficiency Survey; Brigham Young Univ.; Fax (801) 963-6342; joseph_kearl@hotmail.com
Part 2of3 (10 minutes)

Energy Efficiency in cold-weather,
high-end, custom homes

Part 2:

Note: *Based on a survey of local builders, products or practices important to energy efficiency should not only reduce long term energy costs, they should also: have a payback period of less than 10 years, be durable…*

Please rate the following possible energy saving products or practices as either:

- I have ***tried*** this and consider it an ***important*** way to increase energy efficiency

- I have ***not tried*** this and consider it an ***important*** way to increase energy efficiency
- I have ***tried*** this and consider it ***not an important*** way to increase energy efficiency
- I have ***not tried*** this and consider it ***not an important*** way to increase energy efficiency
- I haven't considered this or ***don't know***

	Tried / Important	Not Tried / Important	Tried / Not Important	Not Tried / Not Important	Don't Know
Natural lighting: clerestory windows, solar tubes, skylights	O	O	O	O	O
Roof overhands, light shelves	O	O	O	O	O
Orientation: solar south	O	O	O	O	O
2x6 framing	O	O	O	O	O
Compact fluorescent lights	O	O	O	O	O
Low E windows	O	O	O	O	O
Compression or magnetic weather strips	O	O	O	O	O
Foundation insulation	O	O	O	O	O
Closed cell foam insulation	O	O	O	O	O
Penetrations: spray foam and caulking	O	O	O	O	O
Radiant (Hydronic) hot water system	O	O	O	O	O
92 AFUE or greater furnace	O	O	O	O	O
Passive heating & cooling	O	O	O	O	O
Quality control: inspections, checklists and tests	O	O	O	O	O
Natural ventilation & lighting	O	O	O	O	O
Energy efficiency training	O	O	O	O	O
Multiple glazing	O	O	O	O	O
Rigid foam insulation	O	O	O	O	O
Extra insulation on water heater (insulation jacket)	O	O	O	O	O
HVAC with variable speed blower	O	O	O	O	O
Zoned system with separate thermostats	O	O	O	O	O
Programmable thermostat	O	O	O	O	O
Minimize north facing windows	O	O	O	O	O
Energy tests (blower door, duct blaster, infrared)	O	O	O	O	O
Low window-to-floor area ratio	O	O	O	O	O
Low solar heat gain coefficient (except on south)	O	O	O	O	O
Open cell foam insulation	O	O	O	O	O
Foam gasket under wall plates	O	O	O	O	O
Duct work sealed with mastic	O	O	O	O	O
HVAC balancing check	O	O	O	O	O
Landscaping: shading, deciduous trees, wind barriers	O	O	O	O	O
Financial payback tests (ROI)	O	O	O	O	O
Energy Star Appliances	O	O	O	O	O
High efficiency appliances	O	O	O	O	O
Insulative window frames	O	O	O	O	O
Taped house wrap	O	O	O	O	O
Exterior foam sheeting	O	O	O	O	O

Insulated ducts & pipes	O	O	O	O	O
Tankless or point of use water heater	O	O	O	O	O
Variable-capacity boiler	O	O	O	O	O
Tax incentives, credits	O	O	O	O	O
Optimal Value (Advanced) Framing	O	O	O	O	O
Front loading (Horizontal axis) washers	O	O	O	O	O
Subslab vapor barrier	O	O	O	O	O
Ground source (geothermal) heating	O	O	O	O	O
Water source heat pump	O	O	O	O	O
12 SEER or greater AC	O	O	O	O	O
Whole house ventilation system	O	O	O	O	O
Triple window pane	O	O	O	O	O
	Tried / Important	Not Tried / Important	Tried / Not Important	Not Tried / Not Important	Don't Know

Energy Efficiency Survey; Brigham Young Univ.; Fax (801) 963-6342; joseph_kearl@hotmail.com
Part 3of3 (5 Minutes)

Energy Efficiency in cold-weather,
custom homes

Part 3:

Note: Based on a survey of local builders, the following are the biggest energy inefficiencies of cold-weather, high-end custom homes.

What products or practices have you implemented to overcome the following energy inefficiencies of cold-weather, high-end custom homes?

1. Larger home volume (vaulted ceilings, more square footage)
2. More exterior glass (More windows, bigger windows, exterior glass doors)
3. Building envelope limitations (Much more wiring on exterior walls than in a typical home, connection details between exterior timbers and walls, additional penetrations in envelope)
4. Greater electrical load (More AVI equipment, spas, steamer units, exterior eave melt)
5. Additional heating, cooling and venting (Dual heating systems, radiant and forced air, Air conditioning, Exterior snow-melt systems)
6. Less Design control (architect & owner have more control on design and orientation of a home)

APPENDIX B

RESULTS FROM SURVEY: TABLES

Questionnaire Results

Product or Practice	Tried / Important	Tried / Important (%)	Not Tried / Important	Not Tried / Important (%)	Tried / Not Important	Tried / Not Important (%)	Not Tried / Not Important	Not Tried / Not Important (%)	Don't Know	Don't Know (%)	No Answer	No Answer (%)
Quality control: Inspections, Checklists, and Tests	47	98%	1	2%	0	0%	0	0%	0	0%	0	0%
Penetrations: Spray Foam and Caulking	45	94%	1	2%	0	0%	1	2%	1	2%	0	0%
Low E Windows	44	92%	0	0%	1	2%	1	2%	1	2%	1	2%
92 AFUE or Greater Furnace	43	90%	0	0%	2	4%	2	4%	1	2%	0	0%
Programmable Thermostat	42	88%	0	0%	4	8%	0	0%	0	0%	2	4%
Energy Star Appliances	42	88%	0	0%	2	4%	0	0%	1	2%	3	6%
2x6 Framing	40	83%	2	4%	4	8%	2	4%	0	0%	0	0%
Duct Work Sealed With Mastic	40	83%	1	2%	0	0%	1	2%	1	2%	5	10%
Energy Efficiency Training	39	81%	3	6%	1	2%	1	2%	3	6%	1	2%
Natural Ventilation and Lighting	39	81%	2	4%	2	4%	1	2%	2	4%	2	4%
High Efficiency Appliances	39	81%	1	2%	3	6%	0	0%	2	4%	3	6%
Energy Tests	38	79%	1	2%	2	4%	0	0%	4	8%	3	6%

Questionnaire Results – Continued

Zoned System With Separate Thermostats	37	77%	4	8%	2	4%	1	2%	1	2%	3	6%
Compact Fluorescent Lights	36	75%	3	6%	3	6%	2	4%	4	8%	0	0%
Foundation Insulation	35	73%	2	4%	3	6%	4	8%	4	8%	0	0%
Insulated Ducts and Pipes	34	71%	2	4%	6	13%	2	4%	0	0%	4	8%
12 SEER or Greater AC	34	71%	2	4%	4	8%	1	2%	4	8%	3	6%
Rigid Foam Insulation	32	67%	3	6%	2	4%	5	10%	6	13%	0	0%
Multiple Glazing	31	65%	3	6%	3	6%	3	6%	7	15%	1	2%
Foam Gasket Under Wall Plates	30	63%	4	8%	4	8%	4	8%	2	4%	4	8%
HVAC Balancing Check	30	63%	3	6%	1	2%	0	0%	10	21%	4	8%
Compression or Magnetic Weather Strips	29	60%	4	8%	1	2%	3	6%	11	23%	0	0%
Natural Lighting: Clerestory Windows, Solar Tubes, Skylights	29	60%	3	6%	7	15%	4	8%	3	6%	2	4%
Taped House Wrap	28	58%	5	10%	5	10%	6	13%	1	2%	3	6%
HVAC With Variable Speed Blower	28	58%	5	10%	2	4%	3	6%	7	15%	3	6%
Tax Incentives and Credits	28	58%	6	13%	4	8%	0	0%	6	13%	4	8%
Orientation: Solar South	27	56%	11	23%	5	10%	1	2%	2	4%	2	4%
Subslab Vapor Barrier	27	56%	1	2%	5	10%	7	15%	5	10%	3	6%
Whole House Ventilation System	27	56%	4	8%	4	8%	3	6%	7	15%	3	6%
Landscaping: Shading, Deciduous Trees, Wind Barriers	26	54%	10	21%	2	4%	2	4%	6	13%	2	4%
Roof Overhangs and Light Shelves	26	54%	3	6%	6	13%	3	6%	8	17%	2	4%
Closed-Cell Foam Insulation	25	52%	8	17%	3	6%	2	4%	9	19%	1	2%
Optimal Value (Advanced) Framing	25	52%	7	15%	4	8%	1	2%	7	15%	4	8%
Low Solar Heat Gain Coefficient (Except on South)	22	46%	5	10%	6	13%	1	2%	10	21%	4	8%
Insulated Window Frames	21	44%	8	17%	2	4%	2	4%	11	23%	4	8%
Radiant (Hydronic) Hot Water System	20	42%	9	19%	4	8%	6	13%	8	17%	1	2%

Questionnaire Results – Continued

Passive Heating and Cooling	20	42%	12	25%	1	2%	1	2%	13	27%	1	2%
Tank-less or Point of Use Water Heater	18	38%	6	13%	3	6%	10	21%	9	19%	2	4%
Minimize North Facing Windows	17	35%	9	19%	10	21%	7	15%	3	6%	2	4%
Extra Insulation on Water Heater (Insulation Jacket)	17	35%	5	10%	12	25%	8	17%	3	6%	3	6%
Exterior Foam Sheeting	16	33%	6	13%	7	15%	11	23%	5	10%	3	6%
Financial Payback Tests (ROI)	15	31%	11	23%	3	6%	1	2%	15	31%	3	6%
Low Window-to-Floor Area Ratio	14	29%	7	15%	9	19%	4	8%	10	21%	4	8%
Front Loading (Horizontal Axis) Washing Machines	14	29%	3	6%	8	17%	7	15%	13	27%	3	6%
Open-Cell Foam Insulation	13	27%	3	6%	8	17%	2	4%	16	33%	6	13%
Variable Capacity Boiler	12	25%	5	10%	3	6%	10	21%	15	31%	3	6%
Water Source Heat Pump	10	21%	12	25%	1	2%	10	21%	11	23%	4	8%
Triple Window Pane	8	17%	12	25%	5	10%	15	31%	5	10%	3	6%
Ground Source (Geothermal) Heating	6	13%	16	33%	5	10%	7	15%	11	23%	3	6%

Results Ranked According to Energy Importance

Product or Practice	Important (%)	Unimportant (%)	Undecided (%)
Quality Control: Inspections, Checklists, and Tests	100%	0%	0%
Penetrations: Spray Foam and Caulking	96%	2%	2%
Low E Windows	92%	4%	4%
92 AFUE or Greater Furnace	90%	8%	2%
Programmable Thermostat	88%	8%	4%
Energy Star Appliances	88%	4%	8%

Results Ranked According to Energy Importance - Continued

2x6 Framing	88%	13%	0%
Energy Efficiency Training	88%	4%	8%
Duct Work Sealed With Mastic	85%	2%	13%
Natural Ventilation and Lighting	85%	6%	8%
Zoned System With Separate Thermostats	85%	6%	8%
High Efficiency Appliances	83%	6%	10%
Energy Tests: Blower Door, Duct Blaster, Infrared	81%	4%	15%
Compact Fluorescent Lights	81%	10%	8%
Orientation: Solar South	79%	13%	8%
Foundation Insulation	77%	15%	8%
Insulated Ducts & Pipes	75%	17%	8%
12 SEER or Greater AC	75%	10%	15%
Landscaping: Shading, Deciduous Trees, Wind Barriers	75%	8%	17%
Rigid Foam Insulation	73%	15%	13%
Multiple Glazing	71%	13%	17%
Foam Gasket Under Wall Plates	71%	17%	13%
Tax Incentives, Credits	71%	8%	21%
HVAC Balancing Check	69%	2%	29%
Compression or Magnetic Weather Strips	69%	8%	23%
Taped House Wrap	69%	23%	8%
HVAC With Variable Speed Blower	69%	10%	21%
Closed Cell Foam Insulation	69%	10%	21%
Natural Lighting: Clerestory Windows, Solar Tubes, Skylights	67%	23%	10%
Optimal Value (Advanced) Framing	67%	10%	23%
Passive Heating & Cooling	67%	4%	29%
Whole House Ventilation System	65%	15%	21%
Roof Overhangs, Light Shelves	60%	19%	21%
Insulated Window Frames	60%	8%	31%
Radiant (Hydronic) Hot Water System	60%	21%	19%
Subslab Vapor Barrier	58%	25%	17%
Low Solar Heat Gain Coefficient (Except on South)	56%	15%	29%
Minimize North Facing Windows	54%	35%	10%
Financial Payback Tests (ROI)	54%	8%	38%
Tank-less or Point of Use Water Heater	50%	27%	23%
Extra Insulation on Water Heater (Insulation Jacket)	46%	42%	13%
Exterior Foam Sheeting	46%	38%	17%
Water Source Heat Pump	46%	23%	31%
Ground Source (Geothermal) Heating	46%	25%	29%
Low Window-to-Floor Area Ratio	44%	27%	29%
Triple Window Pane	42%	42%	17%
Front Loading (Horizontal Axis) Washers	35%	31%	33%

Results Ranked According to Energy Importance - Continued

Variable-Capacity Boiler	35%	27%	38%
Open Cell Foam Insulation	33%	21%	46%

Least Well Known Products or Practices

Product or Practice	Undecided (%)	Undecided Total	Don't Know	No Answer
Open Cell Foam Insulation	46%	22	16	6
Financial Payback Tests (ROI)	38%	18	15	3
Variable-Capacity Boiler	38%	18	15	3
Front Loading (Horizontal Axis) Washers	33%	16	13	3
Insulated Window Frames	31%	15	11	4
Water Source Heat Pump	31%	15	11	4
HVAC Balancing Check	29%	14	10	4
Low Solar Heat Gain Coefficient (Except on South)	29%	14	10	4
Low Window-to-Floor Area Ratio	29%	14	10	4
Ground Source (Geothermal) Heating	29%	14	11	3
Passive Heating & Cooling	29%	14	13	1
Optimal Value (Advanced) Framing	23%	11	7	4
Tank-less or Point of Use Water Heater	23%	11	9	2
Compression or Magnetic Weather Strips	23%	11	11	0
Tax Incentives, Credits	21%	10	6	4
HVAC With Variable Speed Blower	21%	10	7	3
Whole House Ventilation System	21%	10	7	3
Roof Overhangs, Light Shelves	21%	10	8	2
Closed Cell Foam Insulation	21%	10	9	1
Radiant (Hydronic) Hot Water System	19%	9	8	1
Subslab Vapor Barrier	17%	8	5	3
Exterior Foam Sheeting	17%	8	5	3
Triple Window Pane	17%	8	5	3
Landscaping: Shading, Deciduous Trees, Wind Barriers	17%	8	6	2
Multiple Glazing	17%	8	7	1
Energy Tests: Blower Door, Duct Blaster, Infrared	15%	7	4	3
12 SEER or Greater AC	15%	7	4	3
Duct Work Sealed With Mastic	13%	6	1	5
Foam Gasket Under Wall Plates	13%	6	2	4
Extra Insulation on Water Heater (Insulation Jacket)	13%	6	3	3
Rigid Foam Insulation	13%	6	6	0
High Efficiency Appliances	10%	5	2	3

Least Well Known Products or Practices - Continued

Natural Lighting: Clerestory Windows, Solar Tubes, Skylights	10%	5	3	2
Minimize North Facing Windows	10%	5	3	2
Insulated Ducts & Pipes	8%	4	0	4
Energy Star Appliances	8%	4	1	3
Zoned System With Separate Thermostats	8%	4	1	3
Taped House Wrap	8%	4	1	3
Natural Ventilation and Lighting	8%	4	2	2
Orientation: Solar South	8%	4	2	2
Energy Efficiency Training	8%	4	3	1
Compact Fluorescent Lights	8%	4	4	0
Foundation Insulation	8%	4	4	0
Programmable Thermostat	4%	2	0	2
Low E Windows	4%	2	1	1
Penetrations: Spray Foam and Caulking	2%	1	1	0
92 AFUE or Greater Furnace	2%	1	1	0
Quality Control: Inspections, Checklists, and Tests	0%	0	0	0
2x6 Framing	0%	0	0	0

Adjusted Results Ranked According to Energy Importance

Product or Practice	Adj. Important (%)	Adj. Unimportant (%)	Important	Unimportant
Quality Control: Inspections, Checklists, and Tests	100%	0%	48	0
Penetrations: Spray Foam and Caulking	98%	2%	46	1
Duct Work Sealed With Mastic	98%	2%	41	1
HVAC Balancing Check	97%	3%	33	1
Low E Windows	96%	4%	44	2
Energy Star Appliances	95%	5%	42	2
Energy Efficiency Training	95%	5%	42	2
Energy Tests: Blower Door, Duct Blaster, Infrared	95%	5%	39	2
Passive Heating & Cooling	94%	6%	32	2
Zoned System With Separate Thermostats	93%	7%	41	3
Natural Ventilation and Lighting	93%	7%	41	3
High Efficiency Appliances	93%	7%	40	3
92 AFUE or Greater Furnace	91%	9%	43	4
Programmable Thermostat	91%	9%	42	4

Adjusted Results Ranked According to Energy Importance - Continued

Landscaping: Shading, Deciduous Trees, Wind Barriers	90%	10%	36	4
Tax Incentives, Credits	89%	11%	34	4
Compression or Magnetic Weather Strips	89%	11%	33	4
Compact Fluorescent Lights	89%	11%	39	5
Insulated Window Frames	88%	12%	29	4
12 SEER or Greater AC	88%	12%	36	5
2x6 Framing	88%	13%	42	6
HVAC With Variable Speed Blower	87%	13%	33	5
Closed Cell Foam Insulation	87%	13%	33	5
Financial Payback Tests (ROI)	87%	13%	26	4
Optimal Value (Advanced) Framing	86%	14%	32	5
Orientation: Solar South	86%	14%	38	6
Multiple Glazing	85%	15%	34	6
Foundation Insulation	84%	16%	37	7
Rigid Foam Insulation	83%	17%	35	7
Insulated Ducts & Pipes	82%	18%	36	8
Whole House Ventilation System	82%	18%	31	7
Foam Gasket Under Wall Plates	81%	19%	34	8
Low Solar Heat Gain Coefficient (Except on South)	79%	21%	27	7
Roof Overhangs, Light Shelves	76%	24%	29	9
Taped House Wrap	75%	25%	33	11
Natural Lighting: Clerestory Windows, Solar Tubes, Skylights	74%	26%	32	11
Radiant (Hydronic) Hot Water System	74%	26%	29	10
Subslab Vapor Barrier	70%	30%	28	12
Water Source Heat Pump	67%	33%	22	11
Tank-less or Point of Use Water Heater	65%	35%	24	13
Ground Source (Geothermal) Heating	65%	35%	22	12
Low Window-to-Floor Area Ratio	62%	38%	21	13
Open Cell Foam Insulation	62%	38%	16	10
Minimize North Facing Windows	60%	40%	26	17
Variable-Capacity Boiler	57%	43%	17	13
Exterior Foam Sheeting	55%	45%	22	18
Front Loading (Horizontal Axis) Washers	53%	47%	17	15
Extra Insulation on Water Heater (Insulation Jacket)	52%	48%	22	20
Triple Window Pane	50%	50%	20	20

Products or Practices Tried

Product or Practice	Tried (%)	Untried (%)
Energy Star Appliances	100%	0%
Programmable Thermostat	100%	0%
Quality Control: Inspections, Checklists, and Tests	98%	2%
Low E Windows	98%	2%
High Efficiency Appliances	98%	2%
Energy Tests: Blower Door, Duct Blaster, Infrared	98%	2%
Penetrations: Spray Foam and Caulking	96%	4%
92 AFUE or Greater Furnace	96%	4%
Duct Work Sealed With Mastic	95%	5%
Natural Ventilation and Lighting	93%	7%
12 SEER or Greater AC	93%	7%
2x6 Framing	92%	8%
HVAC Balancing Check	91%	9%
Insulated Ducts & Pipes	91%	9%
Energy Efficiency Training	91%	9%
Zoned System With Separate Thermostats	89%	11%
Compact Fluorescent Lights	89%	11%
Foundation Insulation	86%	14%
Multiple Glazing	85%	15%
Tax Incentives, Credits	84%	16%
Roof Overhangs, Light Shelves	84%	16%
Natural Lighting: Clerestory Windows, Solar Tubes, Skylights	84%	16%
Low Solar Heat Gain Coefficient (Except on South)	82%	18%
Whole House Ventilation System	82%	18%
Compression or Magnetic Weather Strips	81%	19%
Foam Gasket Under Wall Plates	81%	19%
Rigid Foam Insulation	81%	19%
Open Cell Foam Insulation	81%	19%
Subslab Vapor Barrier	80%	20%
HVAC With Variable Speed Blower	79%	21%
Optimal Value (Advanced) Framing	78%	22%
Taped House Wrap	75%	25%
Closed Cell Foam Insulation	74%	26%
Orientation: Solar South	73%	27%
Landscaping: Shading, Deciduous Trees, Wind Barriers	70%	30%
Insulated Window Frames	70%	30%
Extra Insulation on Water Heater (Insulation Jacket)	69%	31%
Front Loading (Horizontal Axis) Washers	69%	31%
Low Window-to-Floor Area Ratio	68%	32%

Products or Practices Tried - Continued

Minimize North Facing Windows	63%	37%
Passive Heating & Cooling	62%	38%
Radiant (Hydronic) Hot Water System	62%	38%
Financial Payback Tests (ROI)	60%	40%
Exterior Foam Sheeting	58%	43%
Tank-less or Point of Use Water Heater	57%	43%
Variable-Capacity Boiler	50%	50%
Water Source Heat Pump	33%	67%
Triple Window Pane	33%	68%
Ground Source (Geothermal) Heating	32%	68%

Results Based on Experience

Product or Practice	Tried / Important (%)	Tried / Not Important (%)	Tried (%)
Quality Control: Inspections, Checklists, and Tests	100%	0%	98%
Penetrations: Spray Foam and Caulking	100%	0%	96%
Duct Work Sealed With Mastic	100%	0%	95%
Low E Windows	98%	2%	98%
Energy Efficiency Training	98%	3%	91%
HVAC Balancing Check	97%	3%	91%
Compression or Magnetic Weather Strips	97%	3%	81%
92 AFUE or Greater Furnace	96%	4%	96%
Energy Star Appliances	95%	5%	100%
Natural Ventilation and Lighting	95%	5%	93%
Energy Tests: Blower Door, Duct Blaster, Infrared	95%	5%	98%
Zoned System With Separate Thermostats	95%	5%	89%
Rigid Foam Insulation	94%	6%	81%
High Efficiency Appliances	93%	7%	98%
Compact Fluorescent Lights	92%	8%	89%
Foundation Insulation	92%	8%	86%
Programmable Thermostat	91%	9%	100%
Multiple Glazing	91%	9%	85%
2x6 Framing	91%	9%	92%
12 SEER or Greater AC	89%	11%	93%

Results Based on Experience - Continued

Foam Gasket Under Wall Plates	88%	12%	81%
Tax Incentives, Credits	88%	13%	84%
Whole House Ventilation System	87%	13%	82%
Insulated Ducts & Pipes	85%	15%	91%
Subslab Vapor Barrier	84%	16%	80%
Roof Overhangs, Light Shelves	81%	19%	84%
Natural Lighting: Clerestory Windows, Solar Tubes, Skylights	81%	19%	84%
Low Solar Heat Gain Coefficient (Except on South)	79%	21%	82%
Open Cell Foam Insulation	62%	38%	81%

Results Based on Inexperience

Product or Practice	Tried / Important (%)	Tried / Not Important (%)	Tried (%)
Passive Heating & Cooling	95%	5%	62%
HVAC With Variable Speed Blower	93%	7%	79%
Landscaping: Shading, Deciduous Trees, Wind Barriers	93%	7%	70%
Insulated Window Frames	91%	9%	70%
Water Source Heat Pump	91%	9%	33%
Closed Cell Foam Insulation	89%	11%	74%
Optimal Value (Advanced) Framing	86%	14%	78%
Tank-less or Point of Use Water Heater	86%	14%	57%
Taped House Wrap	85%	15%	75%
Orientation: Solar South	84%	16%	73%
Radiant (Hydronic) Hot Water System	83%	17%	62%
Financial Payback Tests (ROI)	83%	17%	60%
Variable-Capacity Boiler	80%	20%	50%
Exterior Foam Sheeting	70%	30%	58%
Front Loading (Horizontal Axis) Washers	64%	36%	69%
Minimize North Facing Windows	63%	37%	63%
Triple Window Pane	62%	38%	33%
Low Window-to-Floor Area Ratio	61%	39%	68%
Extra Insulation on Water Heater (Insulation Jacket)	59%	41%	69%
Ground Source (Geothermal) Heating	55%	45%	32%

APPENDIX C

PAYBACK CALCULATIONS

Extra insulation on water heater (insulation jacket)

	Standard	Upgrade
Jacket	0	10
Inside AF	0.68	0.68
	0	0
	0	0
	0	0
	0	0
	0	0
Total R-value	0.68	10.68
Total U-value	1.4705	0.0936

Costs	Standard	Upgrade
Insulation Jacket		19.98
Total Costs	0	19.98

Delta U	1.3769
Area	1

Delta Costs	19.98

Annual Saved Heating BTUs	293053	BTUs
Annual Therms or KWs Saved	2.93	Therms
Average annual savings	2.91	Dollars
Additional Cost	$ 19.98	
Years to Payback	6.88	Years

General Information

Degree Days	7981
Seasonal efficiency of heating	0.9
Cost per therm (Questar Gas)	0.992
Cost per KW (Rocky Mountain)	0.74467

Product Name:	Therms or KWs:		Therms
2x6 framing			

Materials	Standard	Upgrade
Inside AF	0.68	0.68
Drywall	0.45	0.45
Insulation	13	19
Plywood	0.62	0.62
Airspace	1.01	1.01
Brick	0.44	0.44
Outside AF	0.17	0.17
	0	0
Total R-value	16.37	22.37
Total U-value	0.0611	0.0447

Costs	Standard	Upgrade
Framing Material	20.16	28.44
Insulation		4.8
Total Costs	20.16	33.24

Delta U	0.0164
Area	32

Delta Costs	13.08

Annual Saved Heating BTUs	111587	BTUs
Annual Therms or KWs Saved	1.1159	Therms
Average annual savings	1.1069	Dollars
Additional Cost	13.08	
Years to Payback	11.82	Years

Product Name:	Therms or KWs:		Therms
Optimal Value Framing			

Materials	Standard	Upgrade
Inside AF	0.68	0.68
Drywall	0.45	0.45
Insulation	13	19
Plywood	0.62	0.62
Airspace	1.01	1.01
Brick	0.44	0.44
Outside AF	0.17	0.17
	0	0
Total R-value	16.37	22.37
Total U-value	0.0611	0.0447

Costs	Standard	Upgrade
Framing Material	20.16	28.44
Insulation		4.8
Total Costs	20.16	33.24

Delta U	0.0164
Area	32

Delta Costs	13.08

Annual Saved Heating BTUs	111587	BTUs
Annual Therms or KWs Saved	1.1159	Therms
Average annual savings	1.11	Dollars
Additional Cost	13.08	
Years to Payback	11.82	Years

Products that earn the ENERGY STAR prevent greenhouse gas emissions by meeting strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy.
www.energystar.gov

CHANGE FOR THE BETTER WITH ENERGY STAR

Life Cycle Cost Estimate for 1 ENERGY STAR Qualified Programmable Thermostat(s)

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray boxes or use our default values.

Number of Units	1
Initial Cost per ENERGY STAR Unit (retail price)	$79
Initial Cost per Conventional Unit (retail price)	$21
Unit Fuel Cost (Cooling) ($/kWh)	$0.009
Unit Fuel Cost (Heating) ($/Therm)	$0.74

24 Hour Typical Usage Patterns*

	Weekday	Weekend
Nighttime Set-Back/Set-Up Hours	10	10
Daytime Set-Back/Set-Up Hours	8	8
Hours without Set-Back/Set-Up	6	6

Choose your city from the drop-down menu → City: UT-Salt Lake City

Heating Season*

Typical Indoor Temperature w/o Set-Back	70
Nighttime Set-Back Temperature (Average)	62
Daytime Set-Back Temperature (Average)	62
Heating System Type	Gas Furnace

Cooling Season*

Typical Indoor Temperature w/o Set-Up	78
Nighttime Set-Up Temperature (Average)	82
Daytime Set-Up Temperature (Average)	82
Cooling System Type	Central AC

**All temperatures are in degrees Fahrenheit. Setpoint is defined as the temperature setting for any given time period. Set-back temperature is defined as the lower setpoint temperature for the energy-savings periods during the heating season, generally nighttime and daytime. Set-up temperature is defined as the higher setpoint temperature for the energy-savings periods during the cooling season, generally nighttime and daytime.*

Annual and Life Cycle Costs and Savings for 1 Programmable Thermostat(s)

	1 ENERGY STAR Unit(s)	1 Conventional Unit(s)	Savings with ENERGY STAR
Annual Energy Costs			
Heating Energy Cost	$450	$549	$99
Cooling Energy Cost	$131	$160	$29
Total	$582	$709	$128
Life Cycle Costs			
Energy Costs	$6,465	$7,885	$1,419
Heating Energy Costs	*$5,008*	*$6,107*	*$1,099*
Cooling Energy Costs	$1,457	$1,777	$320
Purchase Price for 1 Unit(s)	*$79*	*$21*	*-$58*
Total	$6,544	$7,906	$1,361
		Simple payback of initial cost (years)	0.5

Summary of Benefits for 1 Programmable Thermostat(s)

Initial cost difference	$58
Life cycle savings	$1,419
Net life cycle savings (life cycle savings - additional cost)	$1,361
Life cycle energy saved (MBTU)-includes both Heating and Cooling	214
Simple payback of additional cost (years)	0.5
Life cycle air pollution reduction (lbs of CO_2)	27,517
Air pollution reduction equivalence (number of cars removed from the road for a year)	2
Air pollution reduction equivalence (acres of forest)	3
Savings as a percent of retail price	1729%

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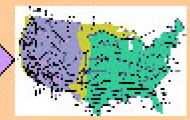
CHANGE FOR THE BETTER WITH ENERGY STAR

Life Cycle Cost Estimate for
1 ENERGY STAR Qualified Central Air Conditioner(s)

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray box using the map.

Full-Load Cooling Hours for Selected Location	800	Follow the link and find your location on the map to determine your cooling load hours, enter this value in the box on the left.



Enter your own values in the gray boxes or use our default values.

Number of units	1	
Electric Rate ($/kWh)	$0.090	
	ENERGY STAR Qualified Unit	**Conventional Unit**
Initial Cost per Unit (estimated retail price with installation)**	$1,426	$1,126
Seasonal Energy Efficiency Ratio (SEER) rating	13	12
Cooling Capacity of Air Conditioner (Btu/hr)	3 ton	3 ton
Use with programmable Thermostat (Yes/No)	No	No

***Prices represent equipment cost only and do not include installation. Customers should contact their contractor for a customized quote.*

Annual and Life Cycle Costs and Savings for 1 Central Air Conditioner(s)

	1 ENERGY STAR Qualified Units	1 Conventional Units	Savings with ENERGY STAR
Annual Operating Costs*			
Energy cost	$220	$238	$18
Energy consumption (kWh)	*2,215*	*2,400*	185
Maintenance cost	$0	$0	$0
Total	$220	$238	$18
Life Cycle Costs*			
Operating costs (energy and maintenance)	$2,321	$2,515	$193
Energy costs	$2,321	$2,515	$193
Energy consumption (kWh)	*31,015*	*33,600*	*2,585*
Maintenance costs	$0	$0	$0
Purchase price for 1 unit(s)	$1,426	$1,126	-$300
Total	$3,747	$3,641	-$107
		Simple payback of initial additional cost (years)†	>14

** Annual costs exclude the initial purchase price. All costs, except initial cost, are discounted over the products' lifetime using a real discount rate of 4%. See "Assumptions" to change factors including the discount rate.*

† A simple payback period of zero years means that the payback is immediate.

Summary of Benefits for 1 Central Air Conditioner(s)

Initial cost difference	$300
Life cycle savings	$193
Net life cycle savings (life cycle savings - additional cost)	-$107
Simple payback of additional cost (years)	>14
Life cycle energy saved (kWh)	2,585
Life cycle air pollution reduction (lbs of CO_2)	3,967
Air pollution reduction equivalence (number of cars removed from the road for a year)	0
Air pollution reduction equivalence (acres of forest)	0
Savings as a percent of retail price	-7%

Products that earn the ENERGY STAR prevent greenhouse gas emissions by meeting strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy.
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CHANGE FOR THE BETTER WITH ENERGY STAR

Life Cycle Cost Estimate for an ENERGY STAR Qualified Gas Residential Furnace

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray boxes or use our default values.

What fuel do you use to heat your home?	Gas	
Gas Rate ($/therm)	$0.74	
What Census region do you live in?	Mountain	Census Region Map
How large is your home? (in square feet)	5,730	Include only heated space
When was your home built?	2000-2004	
When was your existing furnace installed?	New Unit	Select 'New Unit' to compare new furnace options

	New ENERGY STAR Qualified Unit	Conventional or Existing Unit
Installed Cost per Unit (estimated retail price)	$5,500	$5,000
Annual Fuel Utilization Efficiency (AFUE)	90%	80%
Use with programmable Thermostat (Yes/No)	No	No

Annual and Life Cycle Costs and Savings for a Gas Furnace

	ENERGY STAR Qualified Unit	Conventional Unit	Savings with ENERGY STAR
Annual Operating Costs*			
Energy cost	$1,014	$1,141	$127
Maintenance cost	$0	$0	$0
Total	$1,014	$1,141	$127
Life Cycle Costs*			
Operating costs (energy and maintenance)	$12,834	$14,439	$1,604
Energy costs	$12,834	$14,439	$1,604
Maintenance costs	$0	$0	$0
Purchase price	$5,500	$5,000	-$500
Total	$18,334	$19,439	$1,104
		Simple payback of initial additional cost (years)†	3.9

* *Annual costs exclude the initial purchase price. All costs, except initial cost, are discounted over the products' lifetime using a real discount rate of 4%. See "Assumptions" to change factors including the discount rate.*

† *A simple payback period of zero years means that the payback is immediate.*

Summary of Benefits for a Gas Furnace

Initial cost difference	$500
Life cycle savings	$1,604
Net life cycle savings (life cycle savings - additional cost)	$1,104
Simple payback of additional cost (years)	3.9
Life cycle energy saved (MMBtu)	306
Life cycle air pollution reduction (lbs of CO_2)	35,626
Air pollution reduction equivalence (number of cars removed from the road for a year)	3
Air pollution reduction equivalence (acres of forest)	4
Savings as a percent of retail price	20%

Products that earn the ENERGY STAR prevent greenhouse gas emissions by meeting strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy.
www.energystar.gov

CHANGE FOR THE BETTER WITH ENERGY STAR

Life Cycle Cost Estimate for an ENERGY STAR Qualified Gas Residential Furnace

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray boxes or use our default values.

What fuel do you use to heat your home?	Gas	
Gas Rate ($/therm)	$0.74	
What Census region do you live in?	Mountain	Census Region Map
How large is your home? (in square feet)	5,730	Include only heated space
When was your home built?	2000-2006	
When was your existing furnace installed?	New Unit	Select 'New Unit' to compare new furnace options

	New ENERGY STAR Qualified Unit	Conventional or Existing Unit
Installed Cost per Unit (estimated retail price)	$6,000	$5,000
Annual Fuel Utilization Efficiency (AFUE)	92%	80%
Use with programmable Thermostat (Yes/No)	No	No

Annual and Life Cycle Costs and Savings for a Gas Furnace

	ENERGY STAR Qualified Unit	Conventional Unit	Savings with ENERGY STAR
Annual Operating Costs*			
Energy cost	$992	$1,141	$149
Maintenance cost	$0	$0	$0
Total	$992	$1,141	$149
Life Cycle Costs*			
Operating costs (energy and maintenance)	$12,555	$14,439	$1,883
Energy costs	$12,555	$14,439	$1,883
Maintenance costs	$0	$0	$0
Purchase price	$6,000	$5,000	-$1,000
Total	$18,555	$19,439	$883
		Simple payback of initial additional cost (years)†	6.7

** Annual costs exclude the initial purchase price. All costs, except initial cost, are discounted over the products' lifetime using a real discount rate of 4%. See "Assumptions" to change factors including the discount rate.*

† A simple payback period of zero years means that the payback is immediate.

Summary of Benefits for a Gas Furnace

Initial cost difference	$1,000
Life cycle savings	$1,883
Net life cycle savings (life cycle savings - additional cost)	$883
Simple payback of additional cost (years)	6.7
Life cycle energy saved (MMBtu)	360
Life cycle air pollution reduction (lbs of CO_2)	41,821
Air pollution reduction equivalence (number of cars removed from the road for a year)	4
Air pollution reduction equivalence (acres of forest)	5
Savings as a percent of retail price	15%

Products that earn the ENERGY STAR prevent greenhouse gas emissions by meeting strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy.
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CHANGE FOR THE BETTER WITH ENERGY STAR

Life Cycle Cost Estimate for 24 ENERGY STAR Qualified Compact Fluoresecent Lamp(s)

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray boxes or use our default values.

Number of units	24	
Electricity Rate ($/kWh)	$ 0.099	
Hours used per day	3	
	ENERGY STAR Qualified Unit	Conventional Unit
Initial cost per unit (estimated retail price)	$1.66	$0.42
Wattage (watts)	13*	60
Lifetime (hours)	8,000	1,000

**ENERGY STAR wattage is calculated based on the wattage selected for the incandescent unit, user can entire an alternative value if desired.*

Annual and Life Cycle Costs and Savings for 24 CFLs

	24 ENERGY STAR Qualified Units	24 Conventional Units	Savings with ENERGY STAR
Annual Operating Costs*			
Energy cost	$34	$156	$123
Maintenance cost	$0	$92	$92
Total	$34	$248	$215
Life Cycle Costs*			
Operating cost (energy and maintenance)	$211	$1,547	$1,336
Purchase price for 24 unit(s)	$39.92	$9.98	-$29.94
Total	$251	$1,557	$1,306
		Simple payback of initial additional cost (years)†	0.1

** Annual costs exclude the initial purchase price. All costs, except initial cost, are discounted over the products' lifetime using a real discount rate of 4%. See "Assumptions" to change factors including the discount rate.*

† A simple payback period of zero years means that the payback is immediate.

Summary of Benefits for 24 CFLs

Initial cost difference	$30
Life cycle savings	$1,336
Net life cycle savings (life cycle savings - additional cost)	$1,306
Simple payback of additional cost (years)	0.1
Life cycle energy saved (kWh)	9,024
Life cycle air pollution reduction (lbs of CO_2)	13,852
Air pollution reduction equivalence (number of cars removed from the road for a year)	1.21
Air pollution reduction equivalence (acres of forest)	1.72
Savings as a percent of retail price	3272%

Products that earn the ENERGY STAR prevent greenhouse gas emissions by meeting strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy.
www.energystar.gov

CHANGE FOR THE BETTER WITH ENERGY STAR

Life Cycle Cost Estimate for
24 ENERGY STAR Qualified Compact Fluorescent Lamp(s)

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray boxes or use our default values.

Number of units	24	
Electricity Rate ($/kWh)	$ 0.099	
Hours used per day	1	
	ENERGY STAR Qualified Unit	**Conventional Unit**
Initial cost per unit (estimated retail price)	$1.66	$0.42
Wattage (watts)	13*	60
Lifetime (hours)	8,000	1,000

**ENERGY STAR wattage is calculated based on the wattage selected for the incandescent unit, user can entre an alternative value if desired.*

Annual and Life Cycle Costs and Savings for 24 CFLs

	24 ENERGY STAR Qualified Units	24 Conventional Units	Savings with ENERGY STAR
Annual Operating Costs*			
Energy cost	$11	$52	$41
Maintenance cost	$0	$31	$31
Total	$11	$83	$72
Life Cycle Costs*			
Operating cost (energy and maintenance)	$163	$1,194	$1,031
Purchase price for 24 unit(s)	$39.92	$9.98	-$29.94
Total	$203	$1,204	$1,001
Simple payback of initial additional cost (years)†			0.4

** Annual costs exclude the initial purchase price. All costs, except initial cost, are discounted over the products' lifetime using a real discount rate of 4%. See "Assumptions" to change factors including the discount rate.*
† A simple payback period of zero years means that the payback is immediate.

Summary of Benefits for 24 CFLs

Initial cost difference	$30
Life cycle savings	$1,031
Net life cycle savings (life cycle savings - additional cost)	$1,001
Simple payback of additional cost (years)	0.4
Life cycle energy saved (kWh)	9,024
Life cycle air pollution reduction (lbs of CO_2)	13,852
Air pollution reduction equivalence (number of cars removed from the road for a year)	1.21
Air pollution reduction equivalence (acres of forest)	1.72
Savings as a percent of retail price	2507%