The Shift to an Efficient Suburbia:

Strategies for Encouraging Energy-Efficient Design Techniques in Suburban Minnesota

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Introduction

Since the 1980's when fuel prices plummeted, houses have become increasingly larger and more energy demanding. According to the Department of Energy, residential buildings now account for 21% of the primary energy consumption and 20% of the carbon emissions in the United States[1]. Due to low fuel prices over the past 30 years, conventional construction practices have focused on aesthetics upgrades instead of performance and efficiency upgrades. In the past few years, rising fuel costs coupled with increasing public awareness of human causes of global climatic change have started a shift in the way Americans build houses. Fueled by changes in the commercial sector and an economic recession, the residential housing sector is now beginning to adopt innovations in the conventional building practices that have dominated the industry for the last 30 years. These changes will prove to have lasting effects on the quality of our environment in the future, as roughly half of the homes that the US will require by 2030 have not yet been built[2]. Many environmental and government agencies are now recognizing that the increase of energy efficient design techniques in the residential construction sector could provide one of the quickest and most cost-effective means of reducing our national carbon emissions.

The state of Minnesota has recently adopted stricter energy codes in the hope of producing more efficient houses, and energy-efficient technologies have become increasingly available and affordable. Unfortunately, these regulations and better technologies are not proving to be effective by themselves. Current barriers to the wide scale implementation of these technologies in suburban houses include: lack of confidence in third-party certification programs, misguided consumer desires, lack of builder willingness to make changes that are not consumer demanded, failure of realtors to properly market efficient technologies, and short-sighted cost-benefit analyses from both consumers and builders. These barriers all stem from one main issue: the lack of sufficient and accessible information. In order to

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[1] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008).
[2] Built Environment Team, "RMI Built Environment Team," Rocky Mountain Institute, http://bet.rmi.org/ (accessed September 6, 2009).

encourage the wide-scale implementation of energy-efficient homes in suburban Minnesota, more emphasis needs to be placed on the availability of information and the education of consumers, builders and realtors.

The Twin Cities Parade of Homes

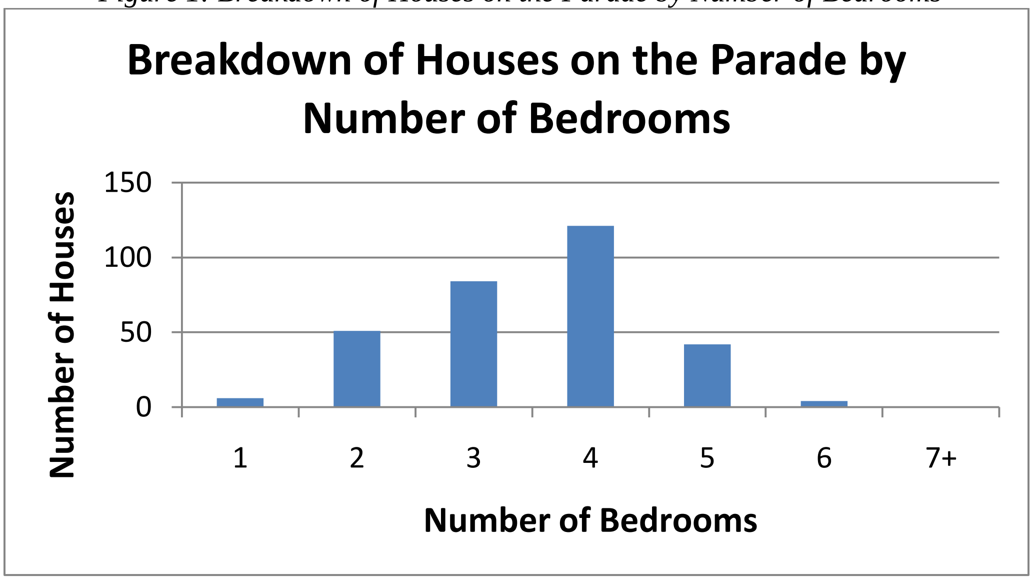
In order to determine how and where education efforts need to be focused, a study was conducted of the technologies being incorporated in new houses in suburban Minnesota. This study primarily focused on a visual checklist of 15 energy-efficient technologies in an attempt to establish which technologies are currently being incorporated in new houses and which ones are not. More importantly, what are the reasons behind the decisions to incorporate certain technologies in new homes, and what lessons can we learn from why these decisions are being made that might lead to a better understanding of the culture of builders, consumers, and realtors in this industry? This study focused on a survey conducted of the *Fall 2009 Twin Cities Parade of Homes*. The Parade of Homes is a bi-annual model home showcase, where for the past 61 years, builders from around the country display their newest suburban home designs. It was chosen because of the availability of a large number of diverse designs all having open houses at the same time, but more importantly for its reputation. The Parade of Homes is a marketing event that is meant to showcase what builders think consumers want, and for that reason, it can help provide evidence of where the building trends in new home design will be moving towards in coming years, as well as an idea of the current culture of consumerism. This year 152 local and national builders displayed 308 model homes throughout the Minneapolis-St. Paul Metropolitan Area for four weeks.[3] In order to establish an accurate selection of houses, a representative cluster sample was determined from the Parade of Homes. Each house was then visited during open house hours, on-site builders and realtors were interviewed, and a visual checklist of 15 energy-efficient technologies was filled out.

[3] Builders Association of the Twin Cities, "Parade of Homes," Builders Association of the Twin Cities, http://www.paradeofhomes.org/index.aspx (accessed September 7, 2009).

Creating a Sample

This research consisted of visiting a representative cluster sample of typical single-family homes on the Parade. As made visible in figure 1 below, the 308 model homes were first sorted by number of bedrooms, and the median number of bedrooms was determined to be four. Accordingly, the rest of the sampling process focused only on four bedroom houses.

Figure 1: Breakdown of Houses on the Parade by Number of Bedrooms [4]

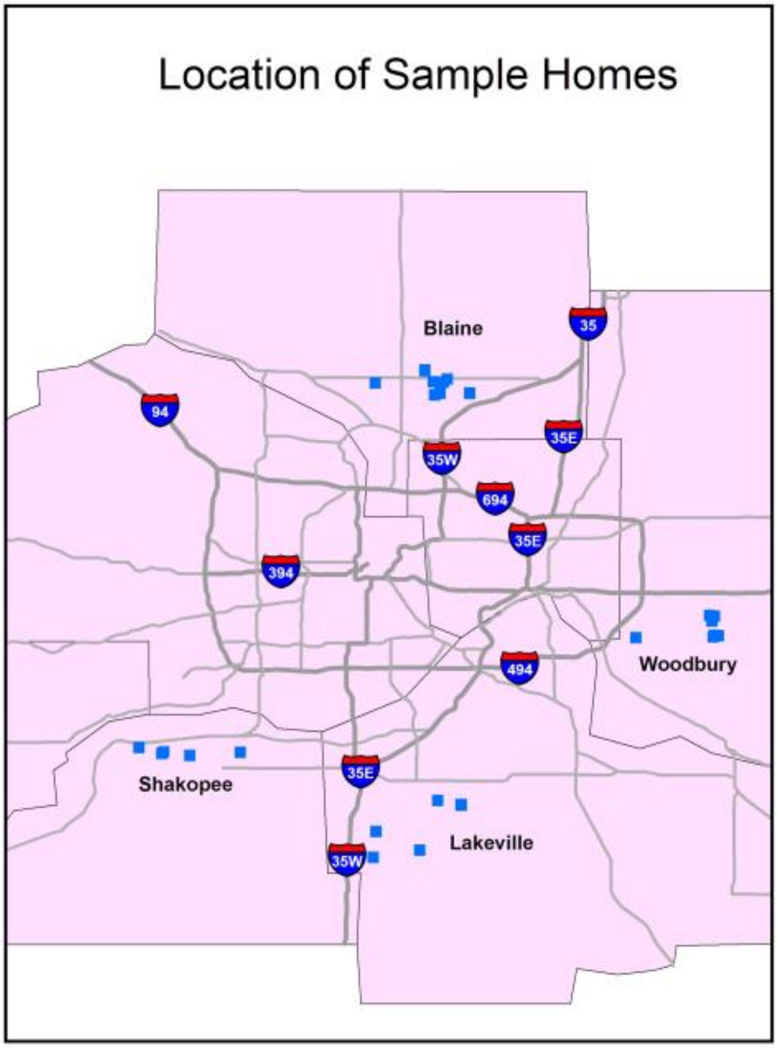


The average price of four bedroom houses was $565,295, and the average square footage was 3,152. A range was determined within one standard deviation of the mean for both price and square footage. Those two ranges were then overlapped and the sample was narrowed to 86 homes that fell within both ranges. Finally, a cluster sampling process was used to pick homes from the four suburbs with the largest concentration of homes within both ranges. This provided the sample with the following distribution: ten houses in the city of Blaine, eight houses in Lakeville, seven houses in Woodbury, and five houses in Shakopee for a total of 30 houses. Figure 2 below shows the distribution of the 30 sample houses; these clusters were spaced out in different parts of the Minneapolis-St. Paul Metropolitan area, with Blaine being in the north, Lakeville to the south, Woodbury to the east, and Shakopee to the

[4] Builders Association of the Twin Cities, "Parade of Homes," Builders Association of the Twin Cities, http://www.paradeofhomes.org/index.aspx (accessed September 7, 2009).

southwest.[5]

Figure 2: Location of Sample Homes[6]



Conducting Research

A list of 15 energy-efficient building technologies and products were selected, and a checklist was filled out after visiting each home during open house hours. The checklist was designed to include visible technologies that could be easily observed in a finished home. The 15 energy-efficient technologies chosen for the checklist in this study were the following:

- Size
- Space Heating

[5] Ibid.

[6] GIS Map courtesy of Dr. Jean Lavigne, St. John's University.

- Space Cooling
- Heating and Cooling Distribution System
- Water Heating
- Insulation
- Windows
- Orientation
- Daylighting
- Electric Lighting
- Appliances
- Roofing
- Walls
- Renewable Energy
- Energy Certification

The checklist was mostly completed through the aid of visual identifiers; however, because these were finished model homes, certain tests could not be conducted. Blower door or duct blaster tests are used to determine the envelope performance of the buildings, but they require special equipment and trained testers. There is also no way to determine the r-value of ceiling and wall insulation in a finished house, so literature or information from the on-site builder representative was used to complete that section[7]. In addition to speaking with on-site builders and realtors about market trends and consumer desires, interviews were also conducted with a builder who has experience installing ICFs and ground source heat pumps, as well as a builder who demonstrated a blower door test in one of his recently finished Energy Star houses. A meeting with the Green Building Committee of the Central Minnesota Builder's Association was attended, as well as one of their Green Build 101 seminars about ground source heat pumps. The information about energy-efficient technologies and building practices was supported by scholarly sources, as well as the Environmental Protection Agency, the Department of Energy, the US Green Building Council, and other industry sources. The following sections will review each of the 15 technologies in detail, discussing the effects they have on increasing the energy-efficiency of houses, reasons they were selected for the study, and what specific criteria was used to classify each technology as efficient or non-efficient.

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[7] R-value is a unit of measurement for thermal resistance; the bigger the r-value, the better the building insulation's effectiveness.

Technical Aspects of Energy-Efficient Design

Size

Assuming all other aspects are the same, a larger home will consume more energy than a smaller home. Depending on the design and the location of the home, as well as the efficiency of the included technologies, an increase in home size by 100% yields an increase in annual energy use of 15% to 50%.[8] Larger houses are also more expensive to build, as they require more resources and labor to construct compared to smaller houses of comparable quality. Essentially, building a smaller house is one of the easiest and most cost effective ways to reduce electricity and fossil fuel demands, as well as reducing the upfront cost of the home. According to US Census data, the average floor area of new houses has more than doubled in the last 50 years, from 983 ft^2 in 1950, to 2266 ft^2 in 2000[9]. Despite the fact that smaller homes consume much less energy than larger homes, size is a luxury that Americans have not historically been willing to sacrifice.

Using a conservative estimate, as homes double in size they consume roughly one quarter more energy, but it is not fair to assume that all homes are equal. A married couple without any kids living in a two bedroom house is not going to need as much space as a family of seven living in a five bedroom house. Therefore when determining a yes/no value for efficiency based on size, it is important to adjust the cutoff based on the number of bedrooms. Since all the houses in this study are four bedroom houses, we must set a cutoff for square footage that can be applied to all of the homes. Using the US Green Building Council's Home Size Threshold Adjustment (figure 3 below), 2,600 square feet is the neutral cutoff for four bedroom houses. In this system, any house above 2,600 square feet is determined to be larger than is necessary to support four bedrooms. Accordingly, all homes with a square footage below 2,600 square feet were classified as efficient for the purposes of this study.

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[8] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 9.

[9] Rick Diamond and Mithra Moezzi, "Changing Trends: A Brief History of the US Household Consumption of Energy, Water, Food, Beverages and Tobacco," Lawrence Berkeley National Laboratory, Energy Performance of Buildings Group, http://epb.lbl.gov/homepages/Rick_Diamond/LBNL55011-trends.pdf.

Figure 3: Home Size Threshold Adjustment [10]

Maximum home size (ft2) by number of bedrooms					Adjustment to award thresholds*
≤ 1 Bedroom	2 Bedrooms	3 Bedrooms	4 Bedrooms	5 Bedrooms	
610	950	1290	1770	1940	-10
640	990	1340	1840	2010	-9
660	1030	1400	1910	2090	-8
680	1070	1450	1990	2180	-7
710	1110	1500	2060	2260	-6
740	1160	1570	2140	2350	-5
770	1200	1630	2230	2440	-4
800	1250	1690	2320	2540	-3
830	1300	1760	2400	2640	-2
860	1350	1830	2500	2740	-1
900	**1400**	**1900**	**2600**	**2850**	**0 ("neutral")**
940	1450	1970	2700	2960	+1
970	1510	2050	2810	3080	+2
1010	1570	2130	2920	3200	+3
1050	1630	2220	3030	3320	+4
1090	1700	2300	3150	3460	+5
1130	1760	2390	3280	3590	+6
1180	1830	2490	3400	3730	+7
1220	1910	2590	3540	3880	+8
1270	1980	2690	3680	4030	+-9
1320	2060	2790	3820	4190	+10
For larger homes, or homes with more bedrooms, see below.					

Space Heating

According to the *2005 Building Energy Data Book*, space heating accounts for 34% of the energy use in U.S. Homes[11]. Due to the long and cold winters, an efficient residential heating system is especially important in Minnesota. The Minneapolis-St. Paul Metropolitan region is classified as a Cold Climate, meaning it has approximately 9,000 heating degree-days or greater and less than 12,600 heating degree-days[12]. Residential heaters can use a variety of energy sources to produce heat, including fossil fuel combustion, electricity, or the sun. The majority of heaters in Minnesota are natural gas combustion furnaces, and electric heat pumps and solar thermal systems are relatively rare. An Energy Star rated gas furnace, with an Annual Fuel Utilization Efficiency (AFUE) of at least 92%, is often 15% more efficient

[10] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 9.
[11] Ibid., 166.
[12] Lstiburek, Joseph, *Builder's Guide to Cold Climates* (Bloomington, MN: Building Science Press, 2006), xvi.

than a standard furnace[13]. For the purposes of this study, all furnaces with an AFUE of 92% or higher, as well as ground-source and air-source heat pumps were considered energy-efficient space heating systems.

Space Cooling

Space heating is by far the largest single consumer of energy in homes, but space cooling also accounts for 11% of the energy use in U.S. Homes[14]. Although the need for an efficient space cooling system is less in Minnesota than Arizona or Florida, these systems are still important during the intense summer heat. Typical space cooling systems in Minnesota are electric air conditioners, although other efficient options exist including the same geothermal systems that are able to supply heat during the winter. An Energy Star rated central air conditioner, with a Seasonal Energy Efficiency Ratio (SEER) of at least 14, are often 14% more efficient than standard air conditioners.[15] For the purposes of this study, all Energy Star qualified central air conditioners as well as ground-source heat pumps were considered efficient space cooling systems[16].

While the upfront cost of more efficient equipment is higher, the energy savings make it cost competitive in the long run. For example, the estimated cost of a three ton, Energy Star qualified cooling system including installation is $3,413; in comparison, the same size conventional unit costs $2,857.[17] The Energy Star rated system has a SEER rating of 14.5, and the conventional unit has a SEER rating of 13; the higher the SEER rating the more energy-efficient the system is. Annual operating costs for the Energy Star unit is $156, and the conventional unit is more expensive, at $207 per year. Given the upfront costs and factoring in the annual operating costs, the Energy Star unit will have a payback rate of 10.9 years.

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[13] United States Environmental Protection Agency, "Furnaces: Energy Star," United States Department of Energy. http://www.energystar.gov/index.cfm?c=furnaces.pr_furnaces.

[14] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 166.

[15] United States Environmental Protection Agency, "Furnaces: Energy Star," United States Department of Energy. http://www.energystar.gov/index.cfm?c=cac.pr_central_ac.

[16] Energy Star standard for Central Air Conditioners changed in 2006. Before that air conditioners with SEER ratings of 13 or higher were often given the Energy Star label, since 2006, 14 SEER has been the cutoff. Individual SEER ratings were not commonly available for model units, but Energy Star ratings were. Therefore, for the purposes of this study, any Energy Star rated air conditioning unit in a new home will be determined to be efficient (regardless of whether it was rated pre or post-2006 standards).

[17] Ibid.

Heating and Cooling Distribution Systems

Once the heating or cooling is produced, there are only a couple of ways to distribute the hot or conditioned air into the house. The most common in new homes is to force the air through a connected system of ducts. Another less common, but arguably more comfortable option for homes is to use a hydronic system, circulating hot water through convectors, radiators, or radiant surfaces. One issue with radiant heating cited by builders is the fact that you cannot use the same hydronic technology to distribute cool water through the floors.[18] Therefore, houses using radiant floor heating need to have hydronic pipes under the floors to provide heating, as well as a duct system to provide air conditioning. This is an added expense, often between $3 and $7 per square foot, which proves to be cost-prohibitive for most builders.[19] Both of these systems have advantages and disadvantages, but the most important factor in the energy-efficiency of the distribution system is proper design and installation.

"In typical new homes, duct leakage may account for 15% to 25% of total heating and cooling energy use."[20] Failure to seal and insulate ductwork, improper sizing, and placement of ducts in unconditioned space are all factors in heating and cooling loss through the duct system. The best way to test the air tightness of ducts is to conduct a duct blaster test, where a fan is connected to the central return, all the vents are temporarily sealed, and the tightness of the system is tested by either pressurizing or depressurizing the space. Unfortunately, duct blaster data was not readily available in these model homes, so that information was not available for reference in deciding the efficiency of a particular duct system. Another prohibitive factor in determining the efficiency of air distribution systems was that once a house was finished, it was difficult to check for consistent duct installation throughout the entire house. As a result of these factors, visual inspections of the duct system were conducted, most commonly in the utility room where the central return was usually located. For the purposes of this study, duct systems

[18] This is because cool water running through the floor causes condensation, an undesirable byproduct. Newmark Homes Representative, interview by Eric DeLuca, Blaine, Minnesota, 24 September 2009.
[19] Ibid.
[20] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 197.

that were visibly sealed and insulated, and that did not visibly leave the conditioned envelope were determined to be efficient air distribution systems.

Water Heating

The process of heating domestic water is also a large consumer of energy in a house, with as much as one-third of a home's total energy bill being spent on heating water.[21] In Minnesota water is typically heated in an insulated tank using natural gas or electricity; however more efficient methods exist including gas condensing tank systems, air-source heat pumps, on-demand gas heaters, and solar thermal heaters. One of the most common cost saving options in Minnesota is to use cheap, off-peak electricity at night to heat a substantially larger tank[22]. These off-peak tanks are not always more efficient, but can substantially reduce operating costs because of the lower rates. The ultimate benefits from high efficiency water heaters are that they can reduce energy demands by 10% to 50% and save the homeowner between $30 and $290 annually.[23] Figure 4 below shows the average annual savings of the five energy-efficient water heater technologies. While Energy Star certification is provided for all water heater systems, the criteria vary depending on the specific technologies[24]. Therefore, only water heaters that were Energy Star certified were deemed efficient water heaters for the purposes of this study.

[21] Ibid., 210.
[22] Electric water heaters capable of using off-peak rates, typically have a storage capacity larger than 100 gallons.
[23] Ibid.
[24] For example, gas water tanks need to have a nominal input of 75,000 BTU/hr or less, and a storage capacity of 20-100 gallons. On-demand gas water heaters need to have a nominal input between 50,000 BTU/hr and 200,000 BTU/hr with a storage capacity of 2 gallons or less. United States Environmental Protection Agency, "Residential Water Heaters: Energy Star," United States Department of Energy. http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters.

Figure 4: Average Annual Savings of Energy-Efficient Water Heater Technologies[25]

Water Heater Technology	**Average Annual Savings***
High-Efficiency Gas Storage	$30
Gas Condensing	$110
Whole-Home Gas Tankless	$115
Solar	$220
Heat Pump	$290

Insulation

Regardless of the efficiency of the distribution system or the major utilities, around one-quarter of a home's heat losses and gains is through its insulated thermal envelope (exterior walls, floor, and attic).[26] There are many different types of insulation and many different ways to install insulation, but according to Chad Carlson, a certified home energy auditor for Lumber One in Avon, MN, the two most important energy saving aspects of insulation is that it is installed properly and has a high r-value.[27] In order for insulation to work properly, it is important to avoid gaps, voids, and areas of compression. Unfortunately, the quality of installation cannot be tested once the house is finished and builders do not usually admit if they installed the insulation carelessly. The r-value, on the other hand, can be accounted for in all new homes. The state of Minnesota's new Residential Energy Code, which is stricter than the International Energy Conservation Code (IECC) most commonly used throughout the U.S., determines the minimum required levels of insulation in new homes. As of June 1, 2009, the minimum required level of insulation

[25] Savings are for an average household of 2.6 people. United States Environmental Protection Agency, "Residential Water Heaters: Energy Star," United States Department of Energy, http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters.
[26] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 182.
[27] The r-value is the measurement used to evaluate the thermal effectiveness of insulation; the higher the r-value, the higher the resistance of heat flow (from both directions) through the insulation. Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.

in the walls was r-19 and the minimum required level of insulation in the ceiling was r-44.[28] Since the state of Minnesota already requires an efficient amount of insulation, one of the strictest in the country according to the Central Minnesota Builder's Association, all new homes in compliance with the minimum r-value requirements of the most recent Residential Energy Code were deemed as having efficient insulation.

Windows

Windows and doors are not included in insulation statistics, because they are essentially holes in the thermal envelope. In cold climates such as Minnesota, windows can cause between 10 to 25 percent of a home's heat loss during the winter and heat gain during the summer.[29] Compared to basic single-pane windows, the US Department of Energy estimates that Energy Star qualified windows in Minnesota can save $352 a year in utility costs[30]. In order to maximize energy-efficiency and the effectiveness of the thermal envelope, windows need to be properly selected for their performance and installed carefully and correctly. While many different types of windows can be efficient, the style of window is important in regards to air leakage and effective natural ventilation. For example, fixed-pane windows are typically more air tight than sliding or double-hung windows are. Window technologies that are typically found in high-efficiency windows include some or all of the following: double or triple paned; low-e glazing; solar control coating; argon or krypton gas fill; heat absorbing or reflective glass; efficient spacers; and weather stripping. Energy Star qualification requirements for windows are regionally different based on climate zones and levels of solar radiation, but for the most part they include windows with at least two panes, reflective coating such as low-e, and argon or krypton gas insert. For the purposes of this study, only

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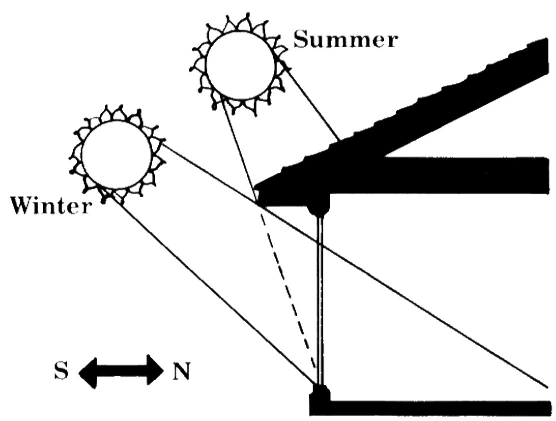
[28] Builders Association of Minnesota, "Field Guide to the Residential Energy Code Including Radon Requirements," Builders Association of Minnesota. http://www.bamn.org/documents/EcodeFG_0509_TEXT.pdf.
[29] Building Technologies Program (U.S.), Whole-house Energy Checklist: 50 Steps to Energy Efficiency in the Home, Washington, D.C.: Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Dept. of Energy, http://purl.access.gpo.gov/GPO/LPS106712, 2000.
[30] Energy Star Windows are estimated to save $75 a year compared to double-pane windows with clear glass. United States Environmental Protection Agency, "Save Money and Energy- Choose Energy Star Qualified Windows, Doors, and Skylights," United States Department of Energy, http://www.energystar.gov/index.cfm?c=windows_doors.pr_savemoney.

regionally certified Energy Star windows for Minnesota's climate zones were deemed as efficient windows.

Orientation

An energy-efficient window is largely dependent on the direction it is facing in order to maximize its effectiveness. Due to the positioning of the sun in the Northern Hemisphere, a south-facing orientation for a house can play a role in reducing the mechanical heating and cooling demands of the building. During the winter, when the seasonal solar position is lower on the horizon, the south-facing orientation helps to maximize direct and indirect solar gains that reduce the demand on the space heating system (figure 5 below). Because the sun is at a higher angle in the summer, it is not as able to penetrate the overhangs above south-facing windows as well, which ultimately reduces the demand on the air conditioning system. Below is a basic diagram of seasonal variations in solar exposure that displays how southern exposure maximizes solar gain during the winter and minimizes solar gain during the summer.

Figure 5: Seasonal Variations of Solar Direction in Northern Hemisphere[31]



Additional efforts can be made to help encourage energy-saving, passive solar techniques such as: adding thermal masses for heat storage; properly sizing roof overhangs to shade summer sun; selecting energy-efficient windows; applying different glazes for different sides of the house; using natural ventilation to reduce cooling needs; and implementing certain landscaping techniques that provide shade

[31] Solar4Power, "Solar power and construction techniques," Advanced Energy Group, http://www.solar4power.com/solar-power-construction.html.

in the summer but not in the winter.[32] Unfortunately, many of these passive solar techniques are relatively ambiguous and hard to accurately measure. Therefore for the purposes of this study, only houses with the high-use side of the home orientated to within 30 degrees of magnetic south were considered to be designed using an efficient orientation.[33]

Daylighting

Not only can the intentional use of the sun provide passive solar heating and cooling in the house, but it can also provide natural light that reduces the demand of the electrical lighting system. The abundant placement of large, low-e coated windows on the south, as well as high-VT glazing on the east, north, and west windows all contribute to the effective use of daylighting in a house. The selection of high-efficiency windows with proper glazing, as well as the appropriate placement of windows both play a role in the ability of a house to allow natural light inside, thus reducing some of the demand for electric lighting. For the purposes of this study, only houses that have Energy Star rated windows placed properly throughout the house were determined to be using energy-efficient, daylighting techniques.[34]

Electric Lighting

Interior and exterior lighting typically accounts for between 5% and 15% of a new home's total energy use.[35] Many homeowners still use incandescent light bulbs, an archaic technology that has hardly improved since the days of Thomas Edison. High-efficiency light fixtures, such as Compact Fluorescent Lamps (CFLs) or Light-Emitting Diodes (LEDs), consume 23% to 7% of the energy and last ten to 40 times longer than standard incandescent bulbs[36]. In a US EPA comparison of CFL and incandescent bulbs, the cost savings of Energy Star rated light fixtures becomes apparent. CFLs often have an upfront cost of around $3 more than incandescent bulbs, but they save $6 a year in energy costs. The life cycle

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[32] Building Technologies Program (U.S.), "Whole-house Energy Checklist: 50 Steps to Energy Efficiency in the Home," Washington, D.C.: Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Dept. of Energy, http://purl.access.gpo.gov/GPO/LPS106712, 2000.

[33] A compass was used on site to determine this measurement.

[34] Building Technologies Program (U.S.), "Whole-house Energy Checklist: 50 Steps to Energy Efficiency in the Home," Washington, D.C.: Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Dept. of Energy, http://purl.access.gpo.gov/GPO/LPS106712, 2000.

[35] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 214.

[36] Ibid.

cost of one CFL bulb is around $17, and the life cycle cost of one incandescent bulb is $86; that equates to a $69 difference in total cost per bulb, which means that the payback rate for the more expensive CFL bulb is only 0.3 years[37]. Additional technologies such as dimmers, motion activated lights, and time-delayed systems can also reduce electric demand from the lighting system. The Energy Star program does provide their label to light bulbs and fixtures, but not all CFL bulbs are Energy Star rated and it is often difficult to visually determine a bulbs rating. Therefore, for the purposes of this study, houses incorporating CFLs or LEDs in more than half of the fixtures will be deemed to be using efficient lighting systems.

Appliances

Household appliances are used on a daily basis and are responsible for between 20% and 30% of a home's total energy use and about 25% of its indoor water use.[38] Energy Star rated refrigerators, dishwashers, and clothes washers use about half as much energy and water as conventional appliances. While the breadth of this study does not include the environmental factors in regards to water conservation, lower water demands from the appliances leads to lower electricity or fossil fuel inputs required to heat and pump the water. There is no blanket classification for efficiency in this case, as Energy Star certification standards vary depending on the type of appliance. Full size refrigerators that are 7.75 cubic feet or larger are required to be 20% more efficient than the minimum federal government standards (NAECA),[39] standard sized dishwashers are required to consume less than 324 kWh/yr and less than 5.8 gallons/cycle,[40] and standard top and front loading clothes washers are required to have a

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[37] United States Environmental Protection Agency, "Compact Fluorescent Light Bulbs," United States Department of Energy, http://www.energystar.gov/index.cfm?c=cfls.pr_cfls.

[38] US Green Building Council, *LEED for Homes Reference Guide, First Edition 2008* (Washington, DC: US Green Building Council, 2008), 218.

[39] United States Environmental Protection Agency, "Refrigerators & Freezers Key Product Criteria: Energy Star," United States Department of Energy, http://www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators.

[40] United States Environmental Protection Agency, "Dishwashers Key Product Criteria: Energy Star," United States Department of Energy, http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers.

modified energy factor of greater than 1.8 and a Water Factor of less than 7.5.[41] For the purposes of this study, only homes that had an Energy Star rated refrigerator, clothes washer, *and* dishwasher were deemed to have efficient appliances.

Roofing

Roofing products vary greatly depending on durability, climate zone, and aesthetic qualities. Some common roofing materials include asphalt, slate, terra cotta, and cedar, but because they are relatively inexpensive and easy to install, asphalt shingles have become one of the most widely used roofing products in Minnesota. Because standard asphalt shingles are usually dark in color, they absorb heat from the sun, which leads to an increase in the cooling demand of the air conditioning system. In the winter, the opposite would seem to be true as the darker shingles absorb more heat from the sun, which decreases the heating demand of the furnace. However, snow typically covers the roof during the winter, resulting in a negligible heat gain of the darker shingles. So contrary to intuition, it is much more energy efficient in cold weather climates such as Minnesota to have a light colored or highly reflective roofing material, sometimes referred to as a "cool roof."

Metal is one highly reflective roofing material that has proven to drastically reduce cooling demands. Green roofs, a design technique that includes planting vegetation on the roof to reduce cooling demands and conserve water, operate under a different principle but achieve similar results. These two designs techniques, despite their efficiency, are often cited as being too aesthetically unpleasant to be incorporated on a wide scale. More traditional technologies are also available and are proving to be more practical and widely accepted. The same asphalt shingles that we currently use (only painted white) have proven to be highly reflective and reduce peak cooling demand in a house by 10-15%, which can allow the builder to install a smaller and more efficient cooling system for the same price as a larger and less

[41] Water Factor is measured as gallons per cycle per cubic foot. United States Environmental Protection Agency, "Clothes Washers Key Product Criteria: Energy Star," United States Department of Energy, http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers.

efficient alternative.[42] Other techniques such as applying highly reflective coatings to dark products often achieve similar results. Depending on the particular roof product and how it is installed, highly reflective roofs have proven to reduce residential energy bills by up to 50%[43]. The Energy Star certification is given to roof designs that have an initial solar reflectance greater than 0.65 on low slope roofs and an initial solar reflectance greater than 0.25 on steep slope roofs[44]. For the purposes of this study, roofing products that are Energy Star rated were deemed as efficient. Homes with green roofs were also considered to be incorporating energy-efficient roof design.

Walls

Unlike a roof, the efficiency of a wall is not measured in its ability to reflect solar heat, but rather in its ability to trap thermal heat, either from escaping during the winter or from entering the house during the summer. The conventional wall construction method for most homes in Minnesota incorporates wood frames. Properly installed and sufficient insulation and sealing can drastically increase the energy-efficiency of wood frame walls; however, due to the layout of the studs, it is difficult to avoid thermal bridging in wood frame walls. There are currently two efficient wall design technologies that can avoid thermal bridging and that can drastically decrease heating and cooling demands in the house as a result. Insulated Concrete Forms (ICFs) are a relatively new technology, but Structurally Insulated Panels (SIPs) have been around since Frank Lloyd Wright began using them in his Usonian houses during the 1930's and 1940's.

ICFs are essentially "hollow building elements made of plastic foam that are assembled, often like building blocks, into the shape of a building's exterior walls," but two layers of foam cannot support a house on their own, so they are "filled with reinforced concrete to create structural walls.[45]" Houses that use ICF exterior walls will require an estimated 44% less energy to heat and 32% less energy to cool

[42] United States Environmental Protection Agency, "Roof Products: Energy Star," United States Department of Energy. http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products.
[43] Ibid.
[44] United States Environmental Protection Agency, "Roof Products Key Product Criteria: Energy Star," United States Department of Energy, http://www.energystar.gov/index.cfm?c=roof_prods.pr_crit_roof_products.
[45] Lstiburek, Joseph, *Builder's Guide to Cold Climates* (Bloomington, MN: Building Science Press, 2006), 381.

than conventional wood frame houses[46]. SIPs also dramatically reduce energy demands but use a slightly different technology. SIPS are "prefabricated [wall, roof and floor] panels consisting of plastic foam cores sandwiched between two skins; typically orientated strand board or plywood.[47]" While wood framed walls still use insulation between the studs, it is very difficult to stop thermal bridging from taking place along the studs themselves. Since SIPs are prefabricated, they can be produced in much larger sections while utilizing a solid foam core, meaning there are fewer gaps or areas of compression where air can infiltrate. According to the Oak Ridge National Laboratory, SIP houses often have annual energy savings of 50-60% compared to conventional wood frame houses.[48] For the purposes of this study, only houses that incorporate ICFs, SIPs, or both were determined to have energy-efficient walls.

Renewable Energy

Once many of these energy-efficient techniques are incorporated, on-site renewable energy generation can bring the net energy use of an already efficient home to a much lower level. There are many different types of systems available, but it is important to consider that not all energy technologies will work equally as well on every house; systems need to be designed to fit the particular resources available to the house and to meet the particular needs of each individual family. For example, if a builder was considering installing a Wind Energy Conversion System (WECS) on a certain lot, it might be important to know the wind speeds for that particular area at varying heights. Or if a builder was considering installing a geothermal system on a certain lot, it might be useful to know that the lot is situated on top of 300 feet of solid granite, making it very difficult and expensive to drill certain well systems. There are a variety of renewable energy generation technologies, but the most common for residential applications include technologies that capture solar, wind, geothermal, water, or biomass energy to produce on-site heating, cooling, and electricity.

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[46] Insulated Concrete Form Association, "Energy Savings," Insulated Concrete Form Association. http://www.forms.org/index.cfm/Energysavings.
[47] Lstiburek, Joseph, *Builder's Guide to Cold Climates* (Bloomington, MN: Building Science Press, 2006), 405.
[48] Structurally Insulated Panel Association, "Energy Star," Structurally Insulated Panel Association. http://www.sips.org/content/green-building/index.cfm?pageId=32.

At first glance, Minnesota's cold climate does not seem conducive to solar systems, but it has the potential to be an economically viable option if it is properly sized and installed. While Minnesota does not receive as much solar radiation as Arizona or New Mexico, solar photovoltaic cells actually become more efficient in cold temperatures, and the technology has been proving to adapt very quickly in the past few years[49]. There are two main types of solar energy systems. Solar thermal systems use the sun's energy to heat water and/or air, whereas solar photovoltaic (pv) cells convert the sun's energy into electricity. While both of these systems will be able to operate in Minnesota, solar thermal systems are more efficient, versatile, and forgiving than solar electric systems. The Minnesota Department of Commerce estimates that a typical solar water heating system "can provide 50 to 70% of the total energy required for domestic hot water heating" at a cost of $10,000-$15,000 before rebates and tax incentives.[50]

Photovoltaic systems cost slightly more; a typical 2 KW residential system costs somewhere between $17,000 and $20,000 before rebates and tax incentives.[51] There isn't a risk that solar energy will be wasted, as due to Minnesota's net-metering laws, homeowners are guaranteed that their local utility will buy any excess solar electricity they are generating at current retail prices. The main issue with solar pv systems, and this is a similar issue to most renewable energy technologies in Minnesota, is that these systems are very long term investments and do not payback nearly as quickly as other efficient technologies.

Residential wind systems are fairly simple and depending on the size, they can be user installed; however, wind resources vary greatly by region; tower height is critical to efficiency and certain cities have regulations prohibiting WECS construction. Very small turbines can cost as little as $600, but larger turbines cost closer to $10,000 before rebates and tax incentives.[52] In addition to the upfront costs, WEC systems have higher annual maintenance costs than most other renewable generation systems. Unlike

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[49] Derek Larson, "Alternative Energy in Minnesota: Possibilities and Prospects," Minnesota Natural History Lecture Series, Saint John's Arboretum, Saint John's University, 20 October 2009.

[50] Office of Energy Security, "I Want My Own Solar System," Minnesota Department of Commerce. http://www.state.mn.us/mn/externalDocs/Commerce/I_want_my_own_solar_system_100807043158_SolarFAQ.pdf

[51] Ibid.

[52] Derek Larson, "Alternative Energy in Minnesota: Possibilities and Prospects," Minnesota Natural History Lecture Series, Saint John's Arboretum, Saint John's University, 20 October 2009.

solar systems, most turbines cannot be directly mounted onto roofs because the vibrations and movement might cause damage to the structure, so a freestanding tower is usually required in order for the turbine to operate correctly.

Perhaps the most practical and currently available form of renewable energy generation in Minnesota is a ground source heat pump.[53] Ground source heat pumps take advantage of geothermal energy that is stored in the ground. Below about eight feet, the earth in the Midwest is always at a consistent temperature of about 50 degrees Fahrenheit. Ground source heat pumps don't actually create energy; they use electricity to power the system that essentially accepts or rejects geothermal energy. It uses a specially designed system of water piping that is typically buried into the ground in a vertical well (about 180-200 feet deep) or in a horizontal system that is only a few feet under the ground. Not only can the ground source heat pump provide heat for the house, but the pump can be reversed and begin rejecting heat back into the ground, giving it the ability to also cool the house. Depending on the capacity and the type of equipment, ground source heat pumps are typically 300%-400% efficient; in comparison, the highest efficiency natural gas furnaces on the market are only 95% or 96% efficient.[54]

Ground source heat pumps also have the ability to provide domestic hot water to the house. A Desuperheater attached to the system essentially rejects excess heat during the cooling process and sends it to the water heater tank. This process heats around 70% of the domestic water in a typical home, essentially for free[55]. Ground source heat pumps are one of the most reliable systems for residential heating and cooling, and according to Jeff Rutz, Territory Manager for GeoComfort Geothermal Systems, it is extremely "difficult to find a lot that you couldn't put a geothermal system on."

Geothermal systems often seem cost prohibitive, but the costs must be put into perspective. The heat pump equipment costs practically the same as energy-efficient models of the two major utilities that it replaces: a 95% AFUE natural gas furnace and a 16 SEER air conditioning unit. Since the ground

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[53] Ground source heat pumps are commonly referred to as Geothermal Systems.
[54] Jeff Rutz, "Does Geothermal Make Sen$e," Green Build 101 Seminar, Green Building Committee, Central Minnesota Builder's Association, 27 October 2009.
[55] The only cost is the electricity required to run the small pump of the Desuperheater.

source heat pump uses the same heating and cooling distribution systems that conventional products use, there are not any extra costs on that side either. The only difference is the installation of the wells, which for a four ton system is between $9,000 and $14,000 before rebates and tax incentives. When you factor in fluctuations in fuel prices and monthly usage, Jeff Rutz estimates a typical payback rate of this size system between 3.5 and 7.5 years, after rebates and tax incentives.[56] For the purposes of this study, any house that was incorporating on-site generation systems that captured solar, wind, geothermal, water, or biomass energy to produce heating, cooling, and electricity were determined to be incorporating renewable energy technologies.

Energy Certification

There are currently four main third party certification programs that designate particular houses as being energy-efficient or sustainable. The US Green Building Council's LEED for Homes program incorporates energy-efficiency as well as sustainable site management, building materials, and indoor air quality; the US EPA and DOE's Energy Star program is concerned only with the energy-efficiency of the home; the National Association of Home Builder's Green Building Program is similar to the LEED for Homes program; and the Minnesota Green Star program was designed to take a Minnesota specific approach to similar aspects. While these programs have widely varying definitions of what it means to be energy-efficient, they all incorporate many of these energy saving technologies that this study is concerned with. Figure 6 below outlines the major areas of focus for each of the four certifications, as well as the current cost and availability of each program in Minnesota. The Energy Star certification process is by far the least rigorous and cheapest option, as it is only concerned with the energy performance of the house. These programs all require third party certifications of performance and quality, and they are intended to provide consumers with the confidence that their house was actually built the way the builder says it was built. Although energy certification is not actually an energy-efficient technology it provides proof that these houses are performing efficiently, as a result it has been

[56] Ibid.

included in this checklist. For the purposes of this study, only houses that received one or more of the above certifications were considered.

Figure 6: Energy Certification Comparison

Program	Includes	Certification Cost	Verification Cost	Available in MN
Energy Star	Energy-Efficiency	$50	$800-$1,000	Yes
NAHB Green Building	Energy-Efficiency; Sustainability	$200-$500	$800-$1,000	No
MN Energy Star	Energy-Efficiency; Sustainability	$250-$400	$800-$1,000	Yes
LEED for Homes	Energy-Efficiency; Sustainability	$500-$3,000	$800-$1,000	Yes

Research Results

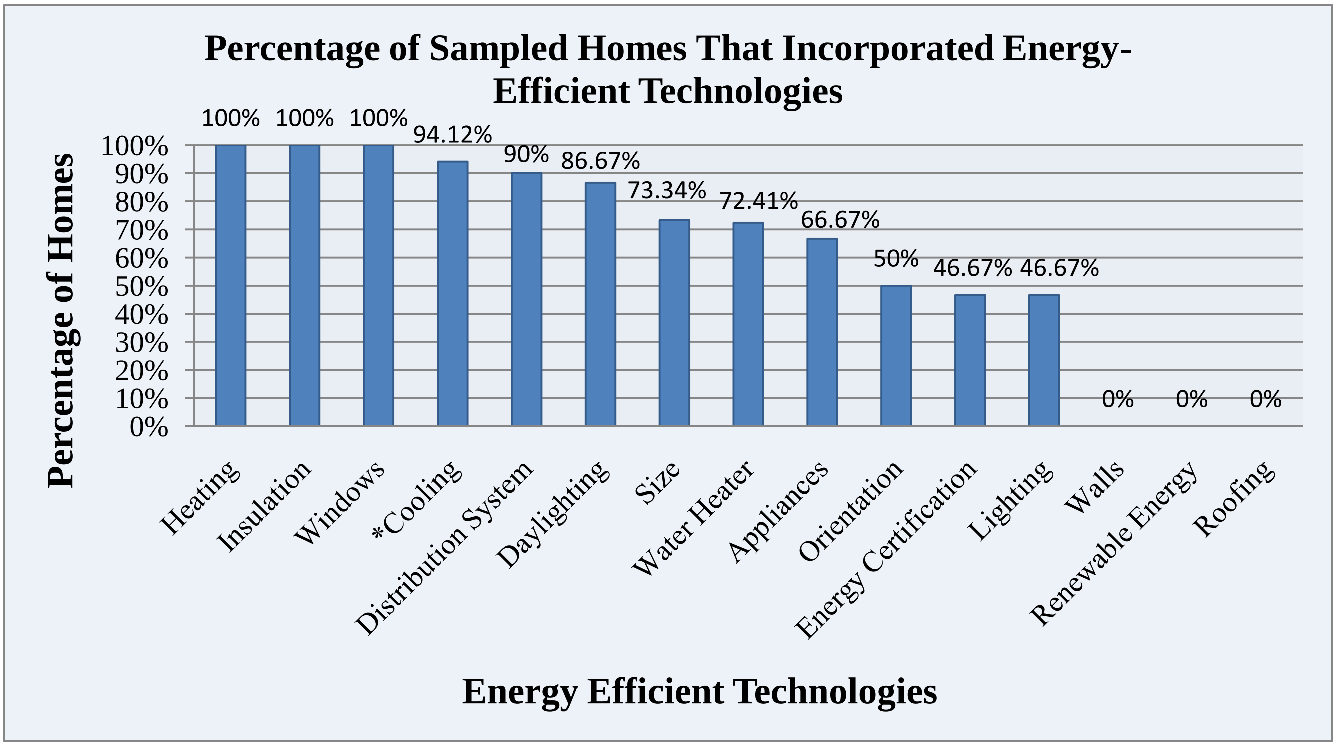
Figure 7 below is a compilation of the results from the checklist for all 30 houses. Certain technologies showed conclusive trends; for example, 100% of the houses were incorporating energy-efficient space heaters, insulation and windows, but 0% of the houses were incorporating energy-efficient walls, roofs, or renewable energy technologies. The rest of the technologies fell somewhere in between: 94% of the houses were incorporating energy-efficient cooling systems[57] and 90% of the houses had well sealed and insulated air distribution systems. Only 72% were incorporating energy-efficient water heaters, but this standard came into question during the research. Five of the houses were using electric water heaters, but they were relatively inefficient systems. The Minnesota Green Star certified house in Blaine, MN, used one of these particular water heaters, and the builder's on-site representative claimed that they received a credit from MN Green Star for having the electric system (regardless of its efficiency). If these non-Energy Star rated electric water heaters are considered to be efficient, then the percentage of homes incorporating efficient systems would be 90%; however, for the purposes of this study, only Energy Star rated water heaters were considered as efficient.

The rest of the results were as follows: 87% were incorporating day lighting techniques; 73%

[57] SEER ratings for cooling systems were only available in 17 of the 30 houses. Because 16 of the 17 houses (94.12%) were using efficient air conditioning units, it is reasonable to assume that this number would be similar if all of the houses had data available.

were below the size threshold for four bedroom houses; 67% were using Energy Star rated appliances; 50% were orientated to within 30 degrees of due south; 47% had received one of the four energy-efficiency certifications;[58] and 47% were using energy saving lighting options. The sample houses were also analyzed individually in order to determine what percentages of these technologies were found in each house. On average the houses in the sample were incorporating 61% of the technologies on the checklist, and interestingly, no houses were incorporating over 80% of the technologies.

Figure 7: Percentage of Sampled Homes That Incorporated Energy-Efficient Technologies



Builders and realtors provided possible explanations as to why some of these technologies are being incorporated. Art Buhs, owner of Art Buhs Construction and founder of the CMBA Green Building Committee, explained that energy-efficient windows have become unofficial industry standards across the board; if a builder does not incorporate these two technologies he/she will struggle to compete with the rest of the builders in the area.[59] This was not the case 20 years ago, but changes in the manufacturing practices as well as builder leadership have fueled the transformation in the window

[58] Out of 14 homes that were third party certified, 13 of them were certified Energy Star houses and 1 was a MN Green Star house. No houses in the sample were certified by LEED for Homes or NAHB Green Building.
[59] Art Buhs, interview by Eric DeLuca, Sauk Rapids, Minnesota, 26 October 2009.

industry. Economies of scale, partly due to similar innovations in the commercial sector, have lowered the cost of manufacturing these windows, and builders began preferring these efficient windows because they tended to be more durable and decrease the builders' liability for faulty products. "We won't, no matter what, compromise our standards on windows and doors," Art explained when talking about his practices in the past ten years, "If we do, we will end up paying for it down the line when they fall apart."[60]

The state of Minnesota has adopted relatively progressive energy codes, which according to Jane DeAustin, Government Affairs Officer for the CMBA, are the first or second most efficient codes in the country. These codes have meant that insulation in Minnesota is already mandated to be extremely efficient. In contrast, an efficient cooling system is not mandated by the energy code, but efficient models are widely available and equate to large electricity savings during the summer months when the price of electricity is higher. Ultimately, no matter how efficient the space heating and cooling systems are, if the distribution system is poorly installed, it will negate many of the benefits of extra efficiency. Builders like Chad Carlson began realizing how much energy the house can save if the contractors are careful to seal and insulate all of the ductwork. In the past builders often designed these distribution systems to go through unconditioned crawl spaces and attics, but the single most important advice Chad gave in regards to the distribution system, was to make sure that every part of the duct work was in conditioned space[61].

Unlike furnaces, which were all powered by natural gas and had AFUEs of 92-95%, water heaters varied greatly between houses. There were four categories of domestic water heaters found in the sample houses: Energy Star rated natural gas tanks, inefficient natural gas tanks, Energy Star electric tanks that could hook up to off-peak electricity, and inefficient electric tanks. The majority of the systems being used by builders in the sample were Energy Star rated gas tanks (55%), both categories of electric tanks were used in 17% of the houses, and only 10% of the houses were using inefficient gas tanks. The size of the tanks also varied greatly, from 50 gallons, which is considered sufficient to 124 gallons, which is

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[60] Art was referring to builders having to "pay" for poor quality windows when they break in the form of warranty payments and a bad reputation for quality. Ibid.
[61] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.

exceptionally large for houses in this size range. Regardless of their efficiency, these extra large water heaters were using energy to heat much more water than most houses need. One of the important findings from this sample was the fact that, unlike furnaces and windows, there is still no industry standard in domestic water heating. Some builders still choose inefficient gas systems to cut costs, some are choose to install massive tanks to appeal to the consumer culture in America, and a few choose to buy extremely efficient electric systems that can heat the tank during off-peak rates which leads to a reduction in energy bills by around 50% over inefficient electric systems[62].

Surprisingly, over 70% of the houses fell below the efficient size threshold for four bedroom houses. There are a couple of possible reasons that so many of these houses are no longer being built extremely large. First, the "suburban mansion" culture of prospective homeowners ten years ago might not be as apparent today. For whatever reason, the ideology of consumers might be shifting away from building the largest house they can afford. The second reason, which was much more widely supported by builders and realtors, is that due to the recent recession in the economy and the instability in the housing market, homeowners are cutting costs across the board. One builder estimated that consumers are spending about $100,000 less on houses then they were three years ago, and another builder told claimed that, "size has decreased in general because price points have decreased across the board." [63] Homeowners are making concessions in every aspect of the house design: size; quality; amenities; and the neighborhood lot.[64]

Valerie Ohman, the chair of the CMBA Green Build Committee, was shocked to find out that only 67% of the houses in this sample were installing Energy Star rates appliances. She claimed that while walking through major appliance retailers in the past few years, it has becoming increasingly difficult to find refrigerators, dishwashers, and clothes washers that are *not* energy star rated. Chad Carlson said the cost is only about $150 more for an efficient refrigerator, but when builders are balancing their budget, that $150 could mean the difference between a black refrigerator and a stainless steel

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[62] Curt Sticha, interview by Eric DeLuca, Lakeville, Minnesota, 2 October 2009.
[63] Mark Gagnon, interview by Eric DeLuca, Blaine, Minnesota, 24 September 2009.
[64] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.

refrigerator[65]. Consumers in Minnesota, no matter what the price point of their new house, are demanding stainless steel appliances; for some of the cheaper houses, that often means sacrificing energy efficiency. When Chad builds a house he sends the homeowners to a supply warehouse to pick out their own appliances, but sometimes they don't make the right choice. "At the end of the day," Chad explained, "the decision [to choose an efficient appliance or not] all comes down to the customer.[66]" However, customers don't always make informed choices about appliances, even when those choices would make financial sense. This doesn't have to be the case. Builders could choose to supply only Energy Star rated appliance; it would mean a couple hundred dollars extra up front, but if the customer understood the quick payback rate on these appliances, the efficient decisions would not likely be resisted.

Despite the passive solar benefits of a south facing orientation, only half of the homes were facing a direction within 30 degrees of magnetic south. The reason that more houses aren't incorporating this energy-saving technique is fairly straightforward. Since most new houses in suburban communities are built in neighborhood developments, as opposed to on an independent lot, the flexibility of house location is restricted. The orientation of a house can be limited by various factors: zoning regulations; the direction the street turns; septic system location; and driveway requirements. Art Buhs explained how many builders, "care about the orientation to the sun, but most of the time our hands are tied.[67]"

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[65] Ibid.
[66] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.
[67] Art Buhs, interview by Eric DeLuca, Sauk Rapids, Minnesota, 26 October 2009.

Figure 8: Orientation of Lakeville Sample House [68]

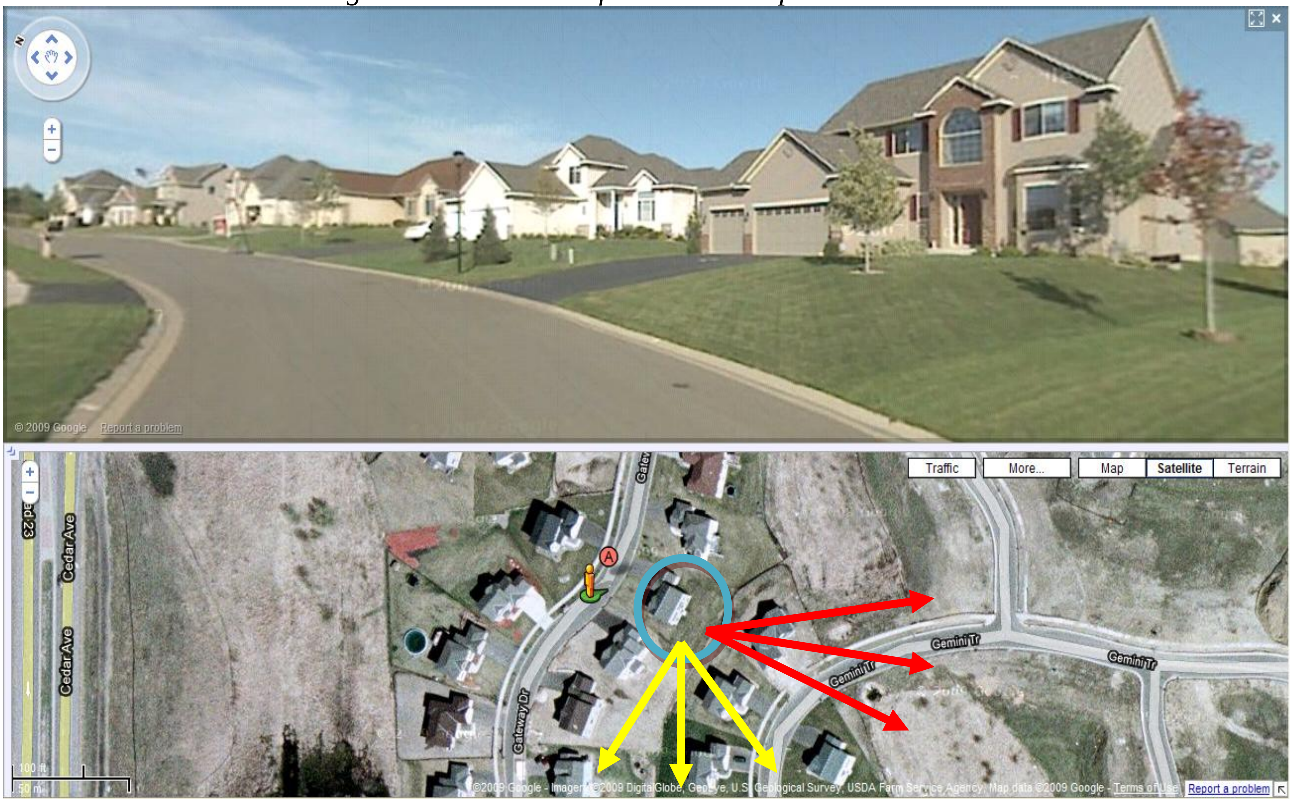

Figure 8 above provides two views of a sample house in Lakeville that did not incorporate efficient orientation. From the street view on the top, it is more obvious how these houses are being designed to face the street, which means that the most useable part of the house is facing directly opposite to the street. This particular model home, the tan building with the brick front elevation, is circled in blue on the bottom aerial picture. The three red arrows represent the direction this house is currently oriented (east), and the three yellow arrows represent the direction this house should be orientated to if it were to maximize the benefits from seasonal solar variations (south). Clearly, the builder does not have much flexibility for the direction of the house on such a small and pre-determined lot.

While a south facing orientation can reduce heating, cooling, and electricity demands in a house, daylighting cannot completely replace the need for electrical lighting systems. Despite dramatic improvements in technology, CFL bulbs were still only incorporated in half of the houses. Builders cited

[68] Google Maps, "20518 Gateway Dr, Lakeville, MN," Google, http://maps.google.com/maps?hl=en&um=1&q=minnesota%20suburban%20development%20aerial%20view&ndsp=21&ie=UTF-8&sa=N&tab=il&start=0.

three main reasons for not installing energy-efficient light bulbs. The first is purely comfort; some realtors claimed that the bright white light emitted from CFLs and LEDs does not provide a warm and relaxing ambience in the model homes. The second is that CFLs are a hazard to dispose of due to dangerous mercury gas that is inside the bulb. The third, and most agreed upon reason was the upfront costs; incandescent bulbs are still slightly cheaper than CFLs and much cheaper than LEDs. Art Buhs describes the evolution of the building industry's attitudes towards energy-efficient lighting: "First it was the color, then it was the mercury, then it was the cost. Now, I think it's just ignorance."[69]

Unlike lighting, the decision about what wall technology to use is largely influenced by the upfront cost and the cost perception. Despite the fact that ICFs and SIPs perform dramatically better than conventional wood framed houses, none of the builders were using these technologies. Chad Carlson believed the reason is fairly straightforward; these technologies are simply not affordable[70]. Art Buhs, who has installed these technologies in many of the homes he has constructed to much success, thought the answer was not that simple. In his experience, ICFs and SIPs have lead to around a 40% savings over conventional designs. He claimed that builders and consumers are looking at in the wrong way; the question should not be, "How much is this system going to cost upfront?" Instead, Art claimed that we need to begin asking ourselves, "How much is this system going to save me."[71]

Energy-efficient roofing products can also drastically decrease mechanical utility demands, much like efficient wall systems. Every house in the sample installed 25 or 30-year asphalt shingles, usually grey or dark grey in color. None of the houses were using reflective roofing materials such as metal, and none of the houses applied on-site reflective coatings either. Most on-site builders and realtors did not even realize roofs could be energy efficient, instead they thought of the quality of a roof more in terms of its durability. The builders made it apparent if they were using Landmark or Timberline shingles, two thicker and longer lasting shingle brands, but reflectiveness was never mentioned. Even durability is not quite what it seems in the harsh climate of Minnesota. Due to hail and ice damage, many of these

[69] Art Buhs, interview by Eric DeLuca, Sauk Rapids, Minnesota, 26 October 2009.
[70] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.
[71] Art Buhs, interview by Eric DeLuca, Sauk Rapids, Minnesota, 26 October 2009.

shingles are often lasting half as long as their manufacturer warranty; if 20-year shingles become damaged in ten or 15 years, they will either be replaced by the homeowner's insurance company or the shingle manufacturer. This example illustrates the fact that an investment in more durable shingles does not usually make sense financially in Minnesota's harsh climate; perhaps the homeowner's money would be better spent by investing in reflective roofing materials that both increase the longevity of the roof as well decrease the mechanical heating and cooling demands.[72]

Renewable energy technologies have the potential to contribute some of the largest energy reductions in the residential sector, but they also seem to be the most unlikely to be implemented. Solar systems are expensive to install and usually take a long time before they begin paying for themselves. It also seems counter intuitive to most consumers that Minnesota, with its cold climate and long winters, has the solar potential to make solar pv or solar thermal practical on a residential scale. Wind turbines have high upfront costs and annual maintenance requirements, and similar to solar systems in residential application, they often take decades to pay for themselves. The long payback rate of these technologies has historically been the major barrier to their implementation, but recent government efforts have begun to change that. The most recent federal stimulus package has provided generous tax rebates for renewable energy, and state rebates as well as utility rebates now are providing combined homeowner subsidies of 30%-50% for renewable energy technologies[73]. These rebates, however, are so new that none of the houses have taken advantage of them yet, and while trusted and experienced installers of solar systems and wind turbines on the residential scale are available, they are not yet abundant in Minnesota. In addition, inconsistencies in wind speeds, issues of aesthetics, and city ordinances against installation are also influential factors that are deterring the installation of wind and solar systems.

Geothermal energy is a different story. Ground source heat pumps in Minnesota have proven to be efficient, reliable, healthy, and cost effective. Because these systems have the ability to cool as well as

[72] Shingles often deteriorate as a direct result of intense heat; since reflective roofing materials reduce solar heat gain, they also increase the longevity of the product as a result.
[73] Jeff Rutz, "Does Geothermal Make Sen$e," Green Build 101 Seminar, Green Building Committee, Central Minnesota Builder's Association, 27 October 2009.

heat the air and water, they essentially do the combined work of three different systems. According to Jeff Rutz, the two main reasons why people do not install geothermal systems is they do not understand the technology and they think it is not cost-effective.[74] While the technology of a ground source heat pump is fairly complicated, it has been around for a long time and it has proven to be extremely reliable and dependable. It is fundamentally the same technology as the air source heat pump in a central air conditioning unit, only it uses water instead of air. Geothermal systems have drastically decreased in cost in the past few years, with a new system now costing only around $10,000 more than an efficient furnace and air conditioner combination. Now with advancements in technology, as well as government and utility incentive programs, geothermal energy is becoming increasingly more cost-competitive. The 30% federal rebate for geothermal now covers the distribution system as well, so the same ductwork that is part of the cost of a conventional system, is now subsidized as part of a geothermal system. Because of the incredible efficiency, 300%-400% (compared to 92%-95% in good furnaces), it only takes between 3.5 and 6.5 years for a geothermal system to pay for itself.[75] Similar to Art Buhs' viewpoint on ICFs and SIPs, Jeff Rutz believed that the issue with consumers and builders is that they are looking at the *cost* from the wrong perspective: "A geothermal system is not an expense, it is an investment."[76] The upfront cost might be higher, but if the homeowner is planning to stay in the house longer than about five years, he/she will start making money off of a geothermal system.

Even if builders choose to incorporate many of these energy-efficient technologies into their houses, there is some debate as to whether or not third party energy certification makes a difference. Some builders believed that the extra costs associated with building and certifying an energy-efficient home are not always reflected in higher sale prices[77], whereas some builders were confident that energy-efficient design is the way the future is going.[78] Some of the more encompassing certification programs,

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[74] Jeff Rutz, "Does Geothermal Make Sen$e," Green Build 101 Seminar, Green Building Committee, Central Minnesota Builder's Association, 27 October 2009.
[75] This estimate includes federal and state tax credits as well as cheaper electricity rates and utility rebates. Ibid.
[76] Ibid.
[77] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.
[78] McDonald Construction Representative, interview by Eric DeLuca, Shakopee, Minnesota, 27 September 2009.

such as LEED for Homes or NAHB Green Build, were substantially more expensive which cause them to be cost prohibitive for builders who do not trust the ability of these certifications to recoup the costs during the sale. For starters, all of these certification programs are fairly new and unfamiliar to both consumers and builders, and there is a lack of trust in their merit. It is now evident that developments and innovations in the commercial building industry are helping to provide more confidence in these certification programs. While LEED for Homes is still in its infancy, the USGBC has been much more successful at implementing its LEED certification for new and existing commercial buildings. After a few more years of trusted results in the commercial sector, LEED for Homes might begin to become more credible and more appealing. For now the US EPA's Energy Star program, the cheapest and easiest certification process, is gaining the most merit in Minnesota.

Energy Star certification itself only costs about $50 for an application fee; the only supplemental cost is the field verification of performance. This requires hiring a third party Home Energy Rater, like Chad Carlson, who usually conducts three tests: a blower door test; a duct blaster test; and a visual thermal bypass test. These tests do not take very long and only cost between $800 and $1,000. In addition to added value benefits, the builder also receives a one-time, $2,000 tax credit from the government for achieving certification. So if builders are receiving $2,000 in a tax credit and only spending about $1,000 for the required tests, they are netting about $1,000 in profit just by becoming Energy Star certified.[79] Time is a valuable commodity for most builders on tight schedules, and despite the financial incentive to obtain certification, many of them still see the process as an extra step that is not worth their time and effort.[80]

Where Do We Go From Here?

Chad Carlson explained how the majority of the steps his company takes to qualify for Energy Star certification are being mandated by Minnesota Energy Code. The state code is already one of the most progressive in the country, but there is always room to improve. For example, there is no significant

[79] This calculation doesn't take into account any additional costs of energy-efficient technology compared to conventional technology.
[80] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.

reason why all houses should not be using Energy Star rated refrigerators, dishwashers, and washing machines. In the past few years they have become far too available and far too affordable to be ignored. The code could also place stricter minimum efficiency requirements on space heaters, central air conditioners and domestic water heaters, mandating that builders only purchase Energy Star rated or better. Light colored or reflective roofs might be less popular additions to the code, but they could make a big difference, not only for the energy efficiency of the particular house but in decreasing the heat island affect that occurs in high density neighborhoods. Government regulations could prove to be highly effective, but they would not necessarily be popular amongst builders and realtors.

One possible alternative to unpopular government regulations would be for third party certification programs to become more trusted and inexpensive. As they are today, many of these programs are currently cost prohibitive. Even Energy Star, which costs builders very little if anything, is not always implemented. The other three programs go beyond efficiency to include water conservation, sustainable resource use, construction recycling, waste reduction, and sustainable land-use planning. While these issues are also important and deserve attention in the building industry, from a purely energy-efficiency standpoint, these certification processes are too encompassing and the standards require additional planning and upgrades. For consumers looking to find an energy-efficient home that is well constructed, the Energy Star certification provides the best option. As a result, more builders need to begin certifying their homes. With the exception of maybe three houses in this sample, there was no measurable difference between the amounts of energy-efficient technologies being incorporated in certified houses and in non-certified houses. What this means in practical terms is that 13 additional houses in this sample could have probably received Energy Star certification if they had applied for it; market and social pressures need to be put on the builders in order to encourage them to certify their houses.

Houses would also benefit from more of a systems approach in designing these buildings with energy-efficiency as one of the main goals. For example, builders could design the house so that windows on the south side are large and use proper glazes and coatings in order to take advantage of winter suns; they could also design overhangs intelligently so that they block more of the higher angled summer sun. There are some site aspects that are typically out of the control of the builder. Neighborhoods need to be developed more intentionally, with the sun in mind. If builders are not willing or able to orientate the houses to capture passive solar rays, then the developers should work to redesign the street and lot layouts. What appears to be essential for more efficient designs and neighborhood planning is collaboration between all parties involved.

One of the most notable reoccurring themes among people I spoke with is that consumers, builders, and realtors are all often ignorant of energy-efficient building techniques and preoccupied with maximizing their short-term benefits. Education needs to be one of the first and most important priorities. Consumers especially need to become more knowledgeable in all aspects of building design. It is often startling to hear what many consumers in suburban Minnesota care about when buying a house. Stainless steel appliances, large islands with granite countertops, walk-in closets, and built-in fireplaces are some of the most requested features.[81] Try asking an average prospective homeowner how important a 16 SEER cooling system is and you will get a blank stare (this happened at homes in Shakopee and Lakeville). One woman who was visiting a house in Woodbury told the on-site representative, "Do you know why I am going to buy one of your homes? Because they have all of these cute poems written on the wall. That is such a special touch."[82] One of the major concerns from builders is that consumers do not care enough about energy-efficiency in order for them to want to pay more for it; as a result, they will not be able to recoup their costs on some of the most important upgrades. In order for that to change, consumers need to become more knowledgeable and begin caring more. The housing market has always been consumer driven, so if this energy-efficient car is going to make any progress, consumers need to become better drivers.

Despite what most builders will say, the impetus is not entirely on the shoulders of the consumers; the builders also have tremendous power in influencing consumers. Many prospective

[81] Gary Freer, Interview by Eric DeLuca, Woodbury, Minnesota, 26 September 2009.
[82] The poem she was referring to was a painted on the wall in the dining room with a stencil. It said: "Live, Laugh, Love." Ibid.

homeowners looking to design their own home sit down with the builder and discuss their options, often referring back to catalog and speculative homes. Art Buhs explained the problem with builders not knowing or caring about energy-efficient design techniques during this process. "Most builders will only do something if the customer demands it," but customers do not usually know enough about energy-efficiency to demand anything[83]. If consumers are the drivers of the market, then builders are their driver's education instructors. For example, more often than not builders will give the homeowners pre-designed floor plan options and they will choose the one that fits their lifestyle. Then based on the floor plan, the consumer will get a list of standard features that the builder typically incorporates in their houses at that price level. If the consumer does not like something they can fine tune the floor plan and list of features; usually this means upgrading to hardwood floors or adding "his and hers" vanity mirrors. Since the consumers are not usually knowledgeable about domestic water heaters or insulation, those standard features do not usually change. So due to a lack of consumer knowledge, builders often see these technical aspects of a home as an opportunity to cut costs and quality without sacrificing the luxury *feeling* of the house. As a result, standard technical features for most builders are either at or just above code.

What would happen if a builder's standard features were energy-efficient to begin with? What would happen if the standard for new homes was for them to be built extremely efficiently in the first place, and then if the homeowner needs to lower the price point, they cut away the least important features? If energy-efficient *upgrades* weren't seen as upgrades anymore but instead as standards, the lack of consumer knowledge would no longer be a barrier to the implementation of these technologies. In order to understand why this type of thinking has not caught on with more builders, it is important to understand who would be paying and who would be benefiting from these upgrades becoming standard. As mentioned before, many of these energy-efficient upgrades have upfront costs, but end up saving money for the consumers in utility bills down the line. The upfront costs are paid by the builders, but then get passed on in higher ticket prices for the consumers. Consumers can rationalize these costs

[83] Art Buhs, interview by Eric DeLuca, Sauk Rapids, Minnesota, 26 October 2009.

because they will save money down the line, but builders do not see the benefits of efficient technologies, they just benefit from the initial sale of the house. For example, a house that is incorporating many energy-efficient technologies might cost $10,000 more than a conventional home. Even if the upgrades on the more expensive house have a combined payback rate of 3 years, the upfront cost might still be cost-prohibitive compared to the less expensive conventional home. The result of this situation is that if builders are to stay competitive with each other, they have an incentive to keep costs as low as possible, and that means not incorporating many of these technologies. So even if builders have the knowledge and experience to build efficient homes, there is an economic disincentive for them to do so as they risk becoming less competitive as a result.

This example brings up two influential behavioral market failures in regards to energy-efficiency decisions: upfront cost aversion and the principal-agent problem. Standard economic theory presupposes that consumers are rational, taking into account all costs and benefits (long-term and short-term) when making a decision. In reality, this is not the case. Consumers often place more weight or importance on the short-term costs of decisions, and less importance on the long-term costs. In terms of energy-efficiency, the upfront costs often deter consumers from choosing particular technologies, even though the long-term cost-benefit analysis might be much more appealing. The principal-agent problem attempts to explain the market failure that causes technologies that are both cost-effective and energy saving to not be implemented. Adam Jaffe and Robert Stavins explained this problem in terms of energy-efficiency. Even in a situation of perfect information where both the builder (the principal) and the consumer (the agent) understand the benefits of energy-saving technologies, which is hardly ever the case, the consumers are benefiting while the builders are paying upfront.[84] This unequal situation offers little incentive for the builder to make efficiency upgrades. Ultimately, both of these market failures can benefit from more education and access to information for all parties involved. As is made apparent in the principal-agent problem, perfect information cannot always solve the issue. In that case, shared-

[84] Adam B. Jaffe and Robert N. Stavins, "The Energy Paradox and the Diffusion of Conservation Technology," *Resource and Energy Economics*, Volume 16, Issue 2, (May 1994), pg. 91-122.

savings performance based contracts or government incentives to builders might prove to be beneficial.

The last pieces to the puzzle are the realtors. Even if a builder designs an energy-efficient house, it often does not end up mattering to the consumer if the realtor does not talk about it. Chad Carlson spoke about the difficulties he has encountered with realtors on a regular basis. His company is a 100% Energy Star builder, meaning they certify all of their homes with Energy Star, but sometimes he will spend the money to get the certification, only to find out that the realtor did not even show the customer the certificate and did not even mention the house's energy-savings. "Sometimes it makes me wonder what the point is. Getting realtors onboard with this has been difficult. They're the ones who need to convince the consumers that energy efficiency is important."[85] This has the potential to discourage builders from making energy-efficient upgrades and spending the time and money to get certified by a third party. Realtors on the Parade of Homes fit this description well. At least half of the Energy Star certified houses in the sample did not even advertise it; only after reading Parade of Homes literature or consulting Energy Star databases did it become evident that these houses were Energy Star rated. In one of the houses in Woodbury, I saw the Energy Star certification label for the house on the utility box in the basement and I asked the realtor about it. She responded, "What's that?"[86] At the end of the day, realtors need to be concerned about energy-efficiency and to inform themselves about these technologies in order for the efforts of the builders to matter.

Education

The shift to an efficient suburbia is going to require the re-education and intentional, collaborative efforts of consumers, builders, and realtors to initiate the change. Certain energy-efficient technologies, such as space heating, insulation, and windows are already being incorporated in new homes, and technologies such as reflective roofing and renewable energy are not being incorporated at all. It is evident that there is no single barrier to the success of energy-efficient design in suburban Minnesota. Each technology has its own unique challenge, and deliberate efforts that address these particular

[85] Chad Carlson, interview by Eric DeLuca, St. Joseph, Minnesota, 22 October 2009.
[86] Gail Hendrickson, Interview by Eric DeLuca, Woodbury, Minnesota, 26 September 2009.

challenges need to take place. There is not a one-size-fits-all solution to these problems, and each party needs to do their part to influence the process. Ultimately, the barriers to the wide scale implementation of these technologies in suburban houses are: lack of confidence in third-party certification programs; misguided consumer desires; lack of builder willingness to make changes that are not consumer demanded; failure of realtors to properly market efficient technologies; and short-sighted cost-benefit analyses from both consumers and builders. As is evident by this study, the availability or the cost-effectiveness of these technologies are not proving to be barriers to implementation. The solution to these issues should not necessarily be an increase in research and development or even government incentives, but instead an increase in the availability of information and the efforts of educating all the parties involved. Education and information are currently the last missing pieces of the puzzle.

What are the most effective ways to educate consumers, builders, and realtors? Once again there is no one-size-fits-all solution. Consumer education is often the most difficult and the most expensive, but it has the potential to make the biggest difference. For starters, the Twin Cities Parade of Homes is a high-profile event that has the potential to reach a large amount of prospective homeowners twice a year. The official Fall 2009 Parade of Homes brochure, as well as its website, both advocated for the importance of energy-efficient design, but there is much room for improvement. If the parade were to highlight the aspects of energy-efficient houses in their literature, it would inform consumers about the advantages and provide an incentive for builders to receive third-party certification. The Minnesota State Fair is another large-scale event that has the potential to reach a large and diverse consumer audience. The Eco-Experience at the 2009 State Fair featured a “green home” that visitors could tour and learn about green design technologies, and it was a popular exhibit as approximately 350,000 people visited the exhibit over the course of the fair. While it was an educational experience for many consumers, progressive design elements such as green roofs and solar chimneys do not seem practical for the average suburban house. Many consumers who are interested in energy-efficient design techniques do not want to sacrifice conventional aesthetics, so it could be beneficial if easily accessible examples of energy-efficient houses did not look different than conventional houses.

Builder's associations possess some of the greatest potential to educate builders. Monthly publications provide a medium for improvements and advancements in technologies to be made available for builders. The CMBA has recently begun offering free green building seminars, which have been well attended by builders and consumers. Builders associations have the power and authority to reach a large amount of builders, so these types of educational efforts need to become more prevalent and more diverse. The barrier to these efforts becoming more prevalent is that many of the members who contribute to these publications and events do not have the experience necessary to educate their peers. In response to this issue, the CMBA created a green building committee within their association that brings interested and experienced members together. Other builders associations would benefit from the adoption and improvement of similar committees.

Realtors could benefit from similar educational efforts within realtor associations. Out of eight main community education courses being offered by the Minnesota Association of Realtors in 2010, none of them are related to energy efficiency or sustainable design. If realtors are to sell these technologies to consumers, they need to understand how these design elements work. Builders could also take a leadership role in this process. Since the builders hire most of the on-site realtors on the Parade of Homes, the realtors could be encouraged or required to inform themselves about these energy-efficient design elements. Builders such as Chad Carlson, who are discouraged by the lack of realtor education, could take a more proactive role in ensuring their energy-efficiency efforts are passed on to the consumers.

These educational efforts will inevitably take time, but fortunately, many signs are already indicating a shift in the culture of homebuilding. Some builders claim their houses are decreasing in size for the first time since they can remember, and more consumers are placing an emphasis on quality and efficiency. One builder in Lakeville explained how inputs such as, "land, labor and materials have decreased in cost," allowing for cheaper houses without sacrificing efficiency[87]. With the recent increase in the awareness of global climatic change, many consumers are beginning to recognize the social reasons

[87] Anonymous Builder, interview by Eric DeLuca, Lakeville, Minnesota, 2 October 2009.

(on top of the financial reasons) why efficiency in homes is important. The shift to an efficient suburbia in Minnesota might take five years or it might take two generations, but focused efforts to increase the education and the availability of information will help to limit market barriers and speed up that process.

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