University of California, Santa Barbara
Donald Bren School of Environmental Science & Management

Waste Today, Wall Tomorrow: Assessment of an Innovative Straw Block for Residential Construction

A Group Project Report
submitted in partial satisfaction of the requirements for the degree of
Master in Environmental Science and Management

by

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As authors of this Group Project, we are proud to archive it on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Donald Bren School of Environmental Science & Management.

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The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) program. It is a three-quarter activity in which small groups of student conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. The final Group Project report is authored by MESM students and has been reviewed and approved by:

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Abstract

The CP Block, developed by Oryzatech, Inc., is a building block made of highly compressed rice straw. Rice straw, an agricultural byproduct, is a rapidly renewable resource which currently goes to waste, either through incineration or to landfills. Oryzatech hopes to utilize this resource to produce an alternative to wood frame construction. Homes constructed with the block will be highly insulated, leading to energy savings for homeowners.

In this study we examined the potential market for the CP Block by analyzing both the demand from homebuyers and the perceptions of builder-developers. We investigated consumer demand through a nationwide survey, and found a large potential demand for the straw block house. We project that at a $10,000 premium, approximately 50% of new home buyers would choose a CP Block over a conventional home. A survey of the building industry professionals allowed us to compare these results with projections from builders themselves. We found that builders are less optimistic, projecting that 25% of new home buyers would choose the straw block home at the same price premium. However, more than 40% of builders stated they would consider using the straw block for projects they work on.

Our consumer research explored the willingness to pay (WTP) for the Block's environmental benefits (such as reduced waste production and less lumber use), and we found that respondents are willing to pay $6,200 for these benefits. Additionally, we investigated the impact that branding or naming has on consumer demand. We found that the WTP for a CP Block rises by $14,500 when the block is not identified as straw.

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LIST OF ABBREVIATIONS

Acronym	Definition
AIA	American Institute of Architects
ASTM	American Society of Testing and Materials
CARB	California Air Resources Board
CDFA	California Department of Food and Agriculture
CMU	Concrete Masonry Unit
CP	Culm-Pressed
CRC	California Rice Commission
CV	Contingent Valuation
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Authority
GDP	Gross Domestic Product
GIS	Geographic Information System
HEED	Home Energy Efficient Design
HEV	Hybrid Electric Vehicle
ICC	International Code Council
KN	Knowledge Networks
LCA	Life Cycle Analysis
LEED	Leadership in Energy and Environmental Design
NAHB	National Association of Homebuilders
RDD	Random Digitized Dialing
SIP	Structural Insulated Panel
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
USGBC	United States Green Building Council
VOC	Volatile Organic Compound
WPC	Wood Products Council
WTP	Willingness to Pay

EXECUTIVE SUMMARY

Problem Statement

The CP Block is a structural and insulating building block made of highly compressed rice straw. Using a rapidly renewable material such as straw in the building industry could lead to many benefits for both homeowners and society. Buildings constructed with the CP Block would provide private benefits, such as reduction in energy costs, and public benefits, such as decrease in energy demand and air pollution. Straw, an agricultural byproduct, has historically been treated as waste. Most states allow farmers to dispose of straw by incineration; however this practice has been banned for over a decade in California. Hence there is great demand to find uses for more than a million tons of rice straw every year. Fortunately, straw has potential for use as an alternative building material.

The CP Block is an innovative and experimental product. Oryzatech, Inc., manufacturer of the block, plans to introduce its product to the green building and mainstream construction markets as a substitute for conventional wood frame and cinder block construction in residential housing. However, since the CP Block is not yet on the market, its potential acceptance by homebuyers and building industry professionals is unknown. In response, this research project investigated the following questions:

- How does the CP Block compare to other building materials in terms of price, physical characteristics, environmental performance, and acceptance in the mainstream construction markets?
- What motivates homebuyers to purchase a straw block home?
- What motivates builders to adopt the block as a construction material?

Significance and Background

The concept of utilizing straw as a building material brings together two distinct subject matters: the demand for green buildings and the need for rice straw disposal.

A nationwide survey conducted by the National Association of Homebuilders (NAHB) shows that builders are reporting shortages of conventional building materials.[1] As a result, rising wholesale prices of building materials have added over $5000 to the cost of building an average new home. Construction delays caused by supply shortages could translate into further cost increases (NAHB 2004). Furthermore, the

[1] Materials include cement, gypsum wallboard, oriented strand board, steel framing and insulating materials.

lumber market is known for its price volatility; it has been historically unstable and regularly shifts to account for changes in demand and supply (Schuler 2003). The increase in the current demand for affordable residential housing coupled with changes in the price of building materials results in increased interest in alternative building materials and methods.

Two private benefits of building with rice straw are the near-absence of toxic chemicals in the material, leading to better indoor air quality, and the reduction in energy costs due to the superior insulating characteristics of the wall system. The decrease in energy demand is also a public benefit because of a decrease in the negative externalities associated with energy production: air pollution, noise generated by power plants, and consumption of non-renewable resources such as natural gas or coal. In addition, because the CP Block will be a substitute for conventional wood frame houses, fewer trees will be harvested for residential home construction.

Rice straw is an agricultural waste product that has brought major environmental and social concerns to California's Sacramento Valley. Traditionally, the two main options for rice straw removal have been either incineration or incorporation into the soil. Unfortunately, rice straw incineration leads to increased levels of air pollution. In 1991, California passed the Rice Straw Burning Reduction Act to phase down the practice. As a result, farmers had to till the rice straw back into the soil which added costs and reduced crop yields. With over 1.2 million tons of rice straw generated every year (CRC 2005), the CP Block is being introduced as a solution to both the problem of rice straw removal and the need for alternative building materials.

Approach

To explore where the CP Block will fit into the current residential housing market, we concentrated on the following three approaches: comparing the CP block to other residential construction materials, analyzing consumer demand, and assessing the building industry's perceptions and potential adoption of the block.

How does the CP Block compare to other materials?

We conducted a product comparison of the CP Block with ten conventional and alternative building materials used in the residential construction market. We produced individual specification sheets for each material describing product characteristics such as construction methods and environmental impacts. In addition, we created a table comparing the materials side by side along factors such as price, physical dimensions, energy efficiency, durability, and product availability. The purpose of the product comparison is to provide builders and homebuyers with a introductory guide and reference tool for standard and alternative building materials. The product comparison appears after page 30 of this report.

What motivates homebuyers to purchase a straw block home?

Our primary goal was to estimate consumer demand for CP Block housing. While doing this we also explored two key perceptions that might influence potential homebuyers. First, since a CP Block house provides both public and private benefits, what portion of the willingness to pay (WTP) would come from the public environmental benefits? Second, what impact would "branding" have: would identifying the CP Block as "straw," rather than just as a "new building material," change consumer demand?

In order to answer these questions, we used the logistic regression model (logit) to estimate the likelihood that a homebuyer would purchase a CP Block house as a function of price and other explanatory variables. To obtain data for the logit model, we developed a contingent valuation survey for the CP Block. Survey respondents were asked to choose between a conventional wood frame home and a CP Block home based on an offered price difference. To allow us to construct a demand curve, the price difference between the two homes was systematically varied across the surveys. The survey also had variations which allowed us to answer our questions about WTP for public environment benefits and the impact of branding the block as straw. Respondents were randomly assigned to a specific version of the survey.

What motivates builders to adopt the block as a construction material?

Because builders make most of the decisions about which materials to build with, we sought to understand builders' perception of the block as an option for housing construction and their likelihood to adopt the block.

To understand industry perceptions, another survey was administered to building professionals. We asked respondents to estimate the percentage of new home buyers in their area who would purchase a CP Block home rather than a conventional home over a range of prices. We used these industry responses to construct an industry-estimated demand curve for straw block housing, which we compared to the demand curve derived from the consumer demand model. Some respondents received a survey which listed the environmental benefits of a CP Block home, while others did not. This allowed us to determine whether builders thought environmental benefits would influence consumer demand.

We also used the survey to elicit which factors builders considered important when deciding to adopt a new building material. The survey asked builders for their own estimates of how the straw block compared to conventional 2x4 framing lumber across a range of factors (e.g. ease of construction, regulatory acceptance, and construction cost). It also asked whether they were likely to adopt the block. These responses were analyzed to evaluate which factors were significant in influencing whether a builder stated they were likely to adopt the block.

Our approach for analyzing the CP Block thus consisted of three primary components: 1) comparison with other building materials; 2) analysis of consumer demand; and, 3) evaluation of building industry perceptions. We view this approach as a general framework that could be used to assess the market potential for any new green or alternative building material.

Results and Discussion

Consumer Survey

The consumer survey was distributed nationwide. We obtained a US Census representative sample of 1,024 responses. Analysis of consumer survey data revealed a downward sloping demand curve. When homes were equally priced, an average of 60% of respondents said they would buy the CP Block home.

The different versions of the consumer survey provided information about the WTP for public environmental goods and the effect of branding the block as "straw." On average, respondents were willing to pay $6,200 for the environmental benefits of owning a CP Block house. There was a large "straw" effect: respondents were willing to pay $14,500 less for the CP Block house when they knew it was made of compressed straw.

Industry Survey

The industry estimates of consumer demand displayed significant variance, with individual estimates of 0% to 100% depending on the price premium. Estimates of consumer demand decreased with increasing price, resulting in a downward sloping demand curve. There was no difference between estimates from builders who saw the environmental benefits and those who did not, suggesting that builders do not think environmental benefits will affect consumer demand.

There was a large gap between the industry estimate of consumer demand and the stated consumer demand. The industry-estimated percentage of straw block home buyers was about 25 percentage points lower at a given price than the demand from the consumer survey. The large gap between the industry's prediction and consumer's own responses can partly be explained by yea-saying, which is a common problem when using the contingent valuation method. Despite this difference in the height of the demand curves, the slopes of the demand curves were very similar. Both surveys estimated a marginal effect of price such that a $10,000 increase in the price of the CP Block home (relative to the conventional home) reduced the probability that a homebuyer would choose the CP Block house by approximately 12-13%.

The primary factors which influenced whether a builder said they were likely to adopt the block were their perceptions of consumer demand and ease of construction. Both effects were in the expected directions: builders which had higher estimates of demand were more likely to adopt the block, as were those who perceived the block would be relatively easier to construct with. When asked about other significant factors in an open-ended format, builders expressed concern regarding how the CP Block might perform on factors such as flammability and susceptibility to moisture.

Recommendations and Conclusions

Conclusions

Our results suggest there is large potential demand for alternative building materials with properties similar to the CP Block. While estimates of demand from the consumer survey were likely inflated by yea-saying, these results may also represent the long-run demand for alternatives material like the CP Block after full market penetration is achieved. Further, even the more conservative industry estimates of demand suggest that a significant portion (10-20%) of new home buyers might purchase a CP Block house.

Both survey techniques found a marginal effect of price such that if the relative price of a CP Block home rises by ~$800 then a potential buyer is about 1% less likely to purchase the CP Block house compared to a wood frame house. The fact that this effect was the same across two separate survey groups suggests that the result is robust and reflects the slope of the actual demand curve.

Perceptions of the CP Block will be critical to its market acceptance. Concerns about susceptibility to moisture, fire, and pests will have to be addressed. In addition, building professionals want to know that there is consumer demand and the Block is easy to work with before they will adopt it for projects they build.

Geographic analysis identified the major hotspots for CP Block housing in the Southwest US. These are centered in major urban centers. Intriguingly, one of the major hotspots is the Sacramento area, which is close to where the majority of California rice is grown.

The profit-maximizing price for a CP Block home is $15,000 more than a wood frame house. Depending on the labor costs associated with building straw block walls, this corresponds to a price of $6.28 to $10.85 per CP Block. Projections from the industry-estimated demand curve result in 12% of the new home market being CP Block homes if they cost $15,000 more on average than wood frame homes. If this market penetration was achieved in California it would represent nearly 18,000 homes annually, which would require about one-third of the rice straw produced in California each year.

<u>Recommendations for Oryzatech</u>

Our results provide Oryzatech with information they can use to reach out to homebuyers and the building industry. Based on our consumer survey, we recommend that in approaching potential homebuyers Oryzatech should:

- Highlight the environmental benefits of building with straw
- Seek to quantify and tout the potential health benefits of building with straw
- Strive to demonstrate that compressed rice straw is a viable and durable building material, and not overemphasize the fact that the CP Block is straw
- Focus on local demand, particularly in Sacramento

The building industry has been reluctant to adopt alternative or green building methods and materials in the past. In order to gain acceptance within this typically conservative industry, Oryzatech should:

- Provide demonstrations on the ease of straw block construction, perhaps through workshops or the erection of test homes
- Begin to demonstrate demand for their product
- Seek certification with a standards board such as the International Code Council (ICC)
- Seek green certification with a program such as LEED or Energy Star

These recommendations should help Oryzatech to maximize their chance for success in bringing a new green building material onto the residential housing market.

PROBLEM STATEMENT

Oryzatech, Inc. hopes to turn the excess rice straw in Northern California into a successful building material. Oryzatech's product, the Culm-Pressed Block[2], or CP Block, is an insulating, structural building block made out of highly compressed rice straw. Homes constructed with CP Blocks will be highly insulated, leading to energy savings for homeowners. Further, while straw bale homes have not broken into the mainstream, the characteristics of the CP Block make it more likely to be adopted by the construction industry. The blocks are modular and smaller than bales; standardized production methods allow the blocks to be engineered to be uniform in size, shape, and weight; and it will be possible to have the CP Block tested and certified as a standard building material.

In addition, there are several environmental benefits associated with the CP Block. Rice straw is a rapidly renewable resource; every year over 1 million tons are produced in California, enough for more than 50,000 CP Block homes. Straw is also an agricultural byproduct, if left unused it is treated as a waste. A common method of rice straw removal has been incineration. However, rice straw burning was banned in California in 1992 because it increases levels of air pollution. Therefore, utilizing straw as a building block either diverts material from the waste stream or reduces air pollution in regions where rice straw is still burned.

These physical and environmental aspects of the CP Block seem to make it a viable contender as a new residential building material. However, the CP Block is a novel and experimental product. In this report we investigate the potential market for the CP Block in the residential building industry. In order to thoroughly explore where the CP block will fit into the current residential housing market, we answer the following questions:

<u>How does the CP Block compare to other wall materials?</u>
How does the Block compare in terms of price, physical characteristics, environmental performance, and acceptance in the mainstream construction markets?

<u>What motivates homebuyers to purchase a straw block home?</u>
How might the block be perceived by potential home buyers? Will they value it for its private benefits such as insulation and energy savings? Will they value the public environmental benefits, such as lumber conservation or

[2] Culm refers to the rice plant's stem (the straw), the source material for the CP Block.

reduced waste, associated with the block? Will home buyers be deterred by the notion of living in a house made of straw?

What motivates builders to adopt the block as a construction material?
While consumer demand is an important factor in the potential market for new wall materials, home buyers often do not build homes; they purchase a home as a package, already built. Builders make most of the decisions about which materials to build with. What is the industry's perception of consumer demand for straw block houses? Do builders view CP Blocks as a realistic option for wall construction? Are they likely to build homes with the CP Block?

Our research provides insight into how the residential construction market will react to the CP Block by comparing the CP Block with other conventional and alternative wall materials already on the market, by estimating potential consumer demand, and by analyzing how the professional building industry thinks the CP Block will perform in the residential building market.

Report Organization

This report is divided into four chapters. Chapter 1 introduces the current market for green goods and provides background summaries of the nationwide green building industry and California rice straw problem. The CP Block is then introduced with a complete description of its characteristics and environmental benefits. Chapter 2 outlines our methodology. First, we assess the potential of the CP Block in the building industry by through a comparison with other building products. We then describe our theoretical model for deriving consumer demand, and our approach to the two surveys. Results of the consumer and industry research are discussed in Chapter 3. Further discussion, recommendations, and conclusions are presented in Chapter 4. Complete versions of the surveys and other data are included in the appendices.

CHAPTER 1: INTRODUCTION

1. A. Market for Green Goods

The market for green goods is growing rapidly. In recent years, people have increasingly chosen to purchase products and services which have better environmental performance characteristics. These "environmentally friendly" characteristics include resource-efficient production, incorporation of recycled materials, and the absence of toxins. Consumers may prefer these "green" goods because they are better for the environment; frequently, however, consumers prefer green goods because they are perceived to be healthier or better than their conventional counterparts. These "private benefits" can be an important factor in consumers' decisions. For example, if a home appliance uses less electricity than a comparable product, the private benefit to consumers would be the savings on their electrical bill. The "public benefits" are the set of environmental benefits accruing to society as a whole, such as the reduction in air pollution from electrical generating power plants. This combination of benefits frequently leads to a price premium for green goods. Consumers may be paying more for what they perceive to be a superior product, or they may be willing to pay to reduce the environmental impact of their purchase.

More consumers are paying this green premium. One recent study reported that about 9% of consumers are willing to pay price premiums for green products (Murphy 2003). A prime example is organic foods. Organic foods are a quintessential green good, associated with numerous private and public benefits[3]. What was once considered to be a niche market is now a booming industry even though organic foods are, on average, more expensive than conventional goods. Sales of organic foods increased from nearly $1 billion in 1990 to $7.8 billion in 2000 (Natural Foods Merchandisers). Certified organic cropland in the US doubled between 1992 and 1997, and continues to rise. The proliferation of organic products is not relegated just to natural foods markets or direct-to-consumer markets. The year 2000 marked the first time that sales of organic food in conventional supermarkets eclipsed other outlets (Dmitri and Greene 2002).

[3] As a private good, organic foods benefit the consumers by meeting food safety concerns and promoting healthy lifestyles. In the United States, organic foods and livestock products are certified to be virtually free of synthetic chemicals such as herbicides and pesticides as well as antibiotics and hormones. In addition, many public benefits are associated with organic food production including improvements in water quality, biodiversity, and worker health.

The automobile industry also witnessed the rising importance of green goods in the market for hybrid electric vehicles (HEVs). Sales of these highly fuel-efficient vehicles have more than doubled from 2004 to 2005, rising to around 187,000 vehicles (Business Week 2005). Some consumers buy HEVs simply because they want to use less gasoline and reduce their carbon footprint, whereas others are hoping to capitalize on the savings recouped from higher fuel efficiency. Most of the major automobile manufacturers have introduced or are introducing an HEV of their own, and the consumer demand for HEVs remains high despite the fact that the payback period for the price premium may be several years or even beyond the car's lifetime (Estudillo et. al. 2005).

However, as with many new products, the diffusion of most green products into the mainstream market can be slow. According to product diffusion theory, most products start out slowly, with sales accelerating once the product has been established in the market, which may take years. While there has been a demonstrated demand for green products, the demand drops if consumers believe that they will have to trade comfort or confidence for environmental benefits (Murphy 2003).

Two other factors which determine the success of a green good are branding and distribution. Branding is an important aspect of any product in any market. For example, the reason that organic wine makers do not promote the fact that they are selling an organic product is simple: when organic wines first hit the market, wine drinkers found them inferior to conventional wines. Sales were low, and as a result many producers eventually the removed the term "organic" from their labels (Silverman and Lamphar 2003). Despite improvements in the quality of organic wine, the current market for organic wine remains small. In addition to branding, suppliers, distributors, and other intermediaries in the supply chain can sometimes be the determining factor in whether a good is successful. For example, while several studies showed consumers had an increased WTP for lumber which had been certified as sustainably grown (Ozanne and Vlosky 1997; Anderson and Hansen 2004), certified lumber did not become widely used until large distributors such as Home Depot and IKEA made it company policy to sell only certified lumber (Social Funds 2005).

In this report we examine a specific green product, the CP Block, within the residential housing market. Although alternative and green materials are not yet widely used in residential housing, the term "green building" is becoming widespread, and the green building industry is burgeoning.

1. B. Green Building Industry

History of green design

Green building is "the practice of 1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and 2) reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal—the complete building life cycle" (Office of the Federal Environmental Executive 2003).

Green design principles have been around for centuries (Kats 2003). The oldest buildings existing on earth today are of earthen construction, adobe and rammed earth, both typical green building materials (King 1996). The earliest modern green building on record is London's Crystal Palace, completed in 1851, which used a passive energy system to warm and cool the building interior. The Crystal Palace utilized designs that incorporated roof ventilators and underground air-cooling chambers to control indoor air temperature with natural conditions like sunlight and wind.

Early green building techniques were simple and required little or no investment. For example, passive energy from the sun can be controlled with architectural design and building materials to save energy. Buildings constructed with thick stone or adobe slowly collect heat during the day and gradually release it at night. For passive energy designs, attention is given to building location and solar orientation. For instance, in the southern hemisphere, the north face of a building should allow maximum sunlight in the winter whereas the western face should be screened from the hot afternoon sun in the summer. Furthermore, the location and natural surrounding of building can contribute to energy efficiency. Deciduous trees can provide additional shading during the summer and in winter, when their leaves fall, can expose the house to sun. (Givoni 1994)

In the 1930s, passive green design techniques were supplanted by the urban building model that arose with the advent of cheap fossil fuel. This modernist building movement was centered on industrialism and utilitarianism, bypassing the environmental concerns of buildings systems (Lacayo 2002).

Later, in the 1960's, the environmental movement began to influence American politics and culture, culminating with the first Earth Day celebration on April 22, 1970. The public was becoming more concerned about environmental degradation and public health. Meanwhile, the Environmental Protection Agency (EPA) was established and laws like the Clean Air Act were enacted by American legislators. In

1973, the environmental movement captured the attention of the greater American public when war broke out in the Middle East between several Arab states and Israel. American support for Israel resulted in an Arab oil embargo against the United States, leading to instantaneous tripling of oil prices (including heating oil for homes). Americans began to question their dependence on fossil fuels and looked for means to reduce energy use. This confluence of a burgeoning environmental awareness and the energy crisis in the 1970s challenged the dominant paradigm of modern building design. New building technologies emerged, promoting environmentally responsible and cost-efficient places to live and work.

Advantages of green buildings

Green buildings have several advantages over their traditional counterparts, including long-term financial savings associated with increased efficiency and improved building health. The California Sustainable Building Task Force reported that minimal upfront cost increases (less than 2% of construction costs) to support green designs result in lifetime savings of over ten times the initial investment due to greater energy efficiency, more efficient waste disposal, and lower water, operation, and maintenance costs. These quantitative benefits have been conservatively estimated from precise measurements and prolonged monitoring of green buildings. For example, in 2002, a study found that with each added sustainable feature, short-term costs increased, but the long-term cost decreased significantly (David and Lucille Packard Foundation 2002). Another study found that modifying three standard buildings to meet the United States Building Council's Leadership in Energy and Environmental Design (LEED) standards resulted in a 15% savings due to the use of salvaged materials and improved energy and water efficiency (Xenergy Inc. and S. Architects 2000). In the end, the comprehensive California's Sustainable Building Task Force study found the total financial benefits of green buildings to be ten times the average initial investment needed to design, construct, and maintain a green building (Kats 2003).

There is also increasing evidence that green buildings carry advantages for those who occupy them in terms of possible health benefits and increased productivity. Some studies have attempted to assess the effect of certain green building features like the incorporation of daylight and natural ventilation to improve health and indoor air quality. Though hard to quantify, studies show that students in classrooms with more daylight performed almost 20% better than those in classroom with little to no daylight (Heschong Mahone Group 1999). The quality of indoor air, a medium often thought to transfer air-borne pathogens and trigger asthma can be improved with certain green building technologies like ventilation and breathable walls. A study executed by the Lawrence Berkeley National Laboratory found that businesses can save over $58 billion in unused sick time and over $200 billion in increased worker performance if indoor air quality in the workplace is improved (Fisk 2000). Although most qualitative benefits to green buildings are difficult to measure, there seem to be subtle health benefits derived from living and working in green buildings.

Current market trends

Based on the recognition that green building technologies have many private and public benefits, green building began to gain momentum as an emerging trend in the building industry in the mid-1990s.

Green building industry

In 1993, a group of building industry professionals incorporated as the United States Green Building Council (USGBC). The organization set its first goal in creating a sustainable rating system through the American Society of Testing and Materials (ASTM) (Kats 2003). After much trial and error, and the subsequent decision to create a rating system independent of the ASTM, the USGBC introduced the Leadership in Energy and Environmental Design (LEED) Green Building Rating System in 1998. LEED established a common metric for evaluating green building design and has accelerated the adoption of green building technology. The LEED guidelines are a voluntary national standard for developing high-performance sustainable buildings. LEED, and the general green building philosophy, emphasize state of the art strategies for sustainable site development, water savings, energy efficiency, waste reduction through materials selection, and indoor environmental quality based on a credit system. New buildings, existing buildings, and soon residential homes, can be awarded either Certified, Silver, Gold, or Platinum status depending on what resources or technologies are utilized in their design and function. The LEED system has started to transform the $315 billion national design and construction industry (Kats 2003) and interest is growing. The results of a recent survey published in the Building Safety Journal demonstrate the rising interest in green building technologies and the LEED system. About 85% of respondents anticipated their firms would pursue LEED certification at least occasionally, and 60 percent indicated that they would do so “frequently” or “somewhat frequently” (Novelli 2004).

Regulatory support

Regulators have shown support for green building materials by providing incentives to encourage their use. Development plans in cities such as Austin, San Francisco, and Seattle include codes requiring city and some commercial buildings to meet LEED standards. These programs frequently offer financial assistance to building owners and developers who incorporate sustainable building goals early in the design process. Other states have recognized the financial and environmental benefits to green design and include provisions for alternative building technologies in their state legislature. For example, Oregon established the 35% Business Energy Tax Credit for sustainable building, which is based on LEED certification levels. The LEED Silver rating is the minimum standard to obtain the tax credit, as increasing levels are attained, the amount of the tax credit increases. In New York, the state Energy Research and Development Authority (ERDA) offers incentives for energy efficiency measures that reduce the use of electricity. The ERDA provides low interest loans of 4% below the market rate for measures and building materials that meet LEED or other generally accepted green building standards. As well, there are currently over 20 bills that encourage buildings to adhere to green building standards. For example, bills AB1356 and SB274 in New Jersey provide tax incentives for developers and owners who design and build green (Lipper 2005). (Cassidy 2003)

Corporate support

Corporations such as Steelcase, Herman Miller, Johnson Controls, Interface, IBM, PNC Financial Services, Southern California Gas Company, Toyota, and Ford Motor Company have embraced green building design principles in the construction of their offices and factories nationwide (Kats 2003). In addition to the previously described cost benefits, green buildings can strengthen brand image and provide positive press coverage for corporations. Large firms can market their forward thinking as bringing value to the community at large (Johnson 2000).

Obstacles for residential green building

Despite their apparent benefits, green building technologies have been slow to penetrate the mainstream residential housing market. The U.S. Department of Commerce reports that less than 1% of the 1.3 million new US residential homes built per year employ natural housing technologies, such as adobe, rammed earth, and straw bale. Most homes use conventional wood frame construction or masonry (US Department of Commerce 2000). Barriers to a broad adoption of alternative technologies are high initial costs as well as the lack of knowledge or education about the technologies.

Even though the financial benefits yielded from green building technologies can significantly exceed the initial costs, the “green premium” deters many potential adopters. The average premium for green buildings is just under 2%, or $3-5 per square foot (Kats 2003). Though payback from energy savings could absorb the initial increase in cost, there is no guarantee. It could take many years for the energy savings to equal the initial cost. Consumers with a tight budget might not be able to afford the upfront cost, the time to amount to payback, or the overall financial risk.

Furthermore, the lack of knowledge about the green building industry by the general public could hinder its acceptance into mainstream building and construction. Consumers often purchase products that they know, or that they know someone else has purchased. Due to this dependency, it is often difficult to “motivate an individual to change to production/consumption of alternative ‘green’ products” (Janssen and Jager 2002). Lack of awareness about green building technologies can be a hindrance to their acceptance into the mainstream building industry.

In addition to uncertainty about the payback and lack of consumer knowledge, the building industry is generally reluctant to adopt alternative or green building methods and materials unless they exhibit clear cost or quality advantages (NAHB 1994). Even if consumers are knowledgeable about alternative buildings, they will have a difficult time penetrating the market if the supply of willing builders is limited.

Emerging trends based on the housing market

Though green buildings remain a small percentage of the new homes built in the U.S., an emerging interest in green building has been triggered by the rising interest in green goods as well as three additional components of the housing market:

- the current housing demand in the United States
- the fluctuating cost of lumber
- the rising costs of home heating and cooling

The United States housing market is large, and it will continue to get bigger. According to the National Association of Home Builders (NAHB 2005), in 2002, the housing industry accounted for over 16% of the U.S. GDP. Housing construction and remodeling creates millions of jobs each year and generates billions of dollars in tax revenue. Approximately 1.3–1.5 million new homes will be constructed over the next 10 years to accommodate the nation’s projected population increase of 30 million people In addition, the U.S. Commerce Department reported that housing starts in the US states jumped 4.7 percent in January 2005 to reach the highest residential construction pace in 21 years (NAHB 2005).

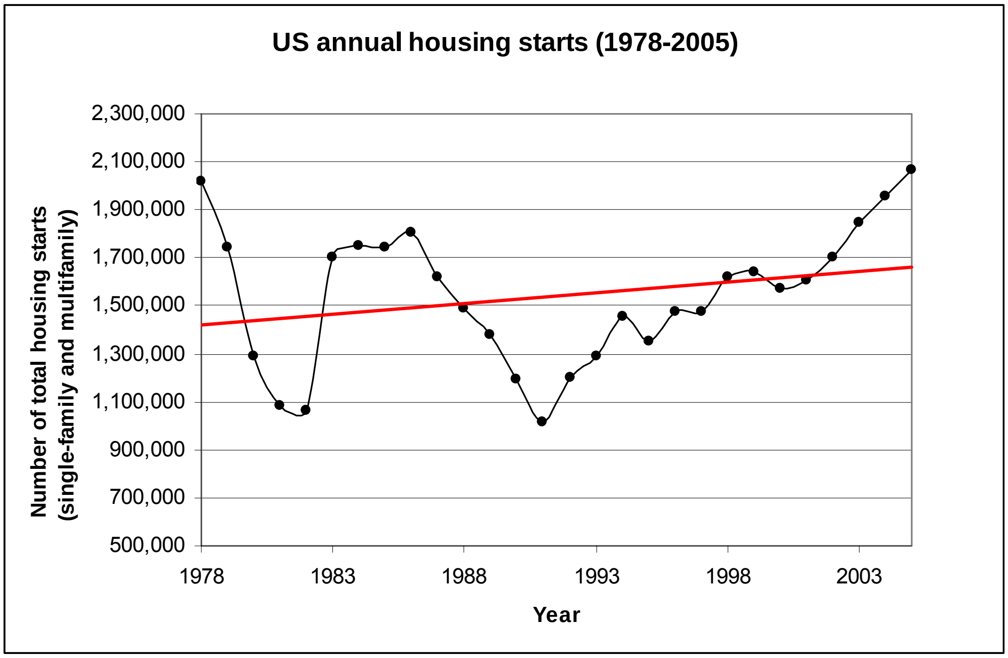


Figure 1.1: US annual housing starts (1978-2005) (Source: US Census Bureau)

According to David Seiders, Chief Economist at NAHB, "the single-family market, in particular, is crying out for supply" and builders are struggling to meet the demand. The demand for building and the related boom in construction also drives other industry sectors like lumber, concrete, and steel. (NAHB 2005)

Another factor which is driving the adoption of green building materials in US residential construction is the fluctuating lumber market. As mentioned above, the majority of homes are built with standard wood-frame construction (US Department of Commerce 2000). However, the lumber market is historically unstable and regularly shifts to account for changes in demand and supply (Schuler 2003). Builders might be concerned with the constantly changing lumber prices and be more apt to switch to a more consistently priced product.

In addition, the recent increase in energy prices might influence consumers to seek out more energy efficient homes. Recent high fossil fuel prices for electricity generators led to higher wholesale power costs. According to the Energy Information Administration (EIA), the average retail price of electricity increased by 3.1 percent in 2004. The chart below details the average retail price of electricity absorbed by residential consumers.

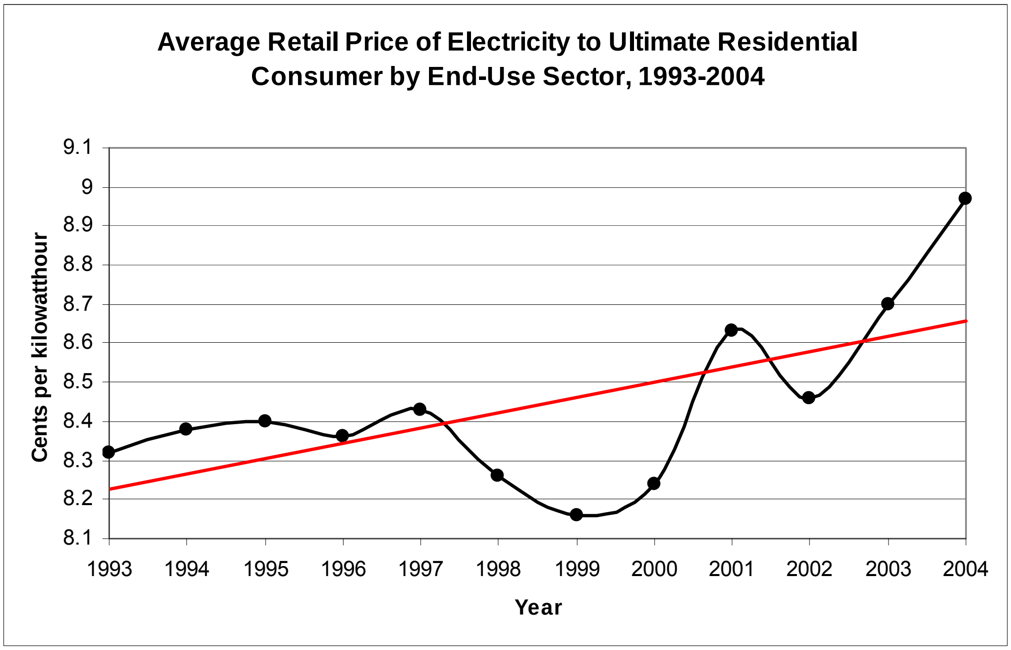


Figure 1.2: Average retail price of electricity to residential consumers, 1993-2004 (Source: Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report")

The recent increase in electricity prices, and the projected slight drop and continued steady increase in the future, is convincing residential consumers to invest in energy saving equipment and adopt more energy efficient practices (EIA 2005a).

Alternatives to lumber are appearing in the mainstream housing market. Buildings made with steel and concrete are enticing consumers who cannot afford wood frame houses or are looking for alternatives. The inconsistency in the building supply market is a great opportunity for green building materials to emerge. Green building materials such as insulated concrete forms, hybrid concrete blocks, structurally insulated panels, and agrifiber materials have the chance to edge their way in the mainstream market.

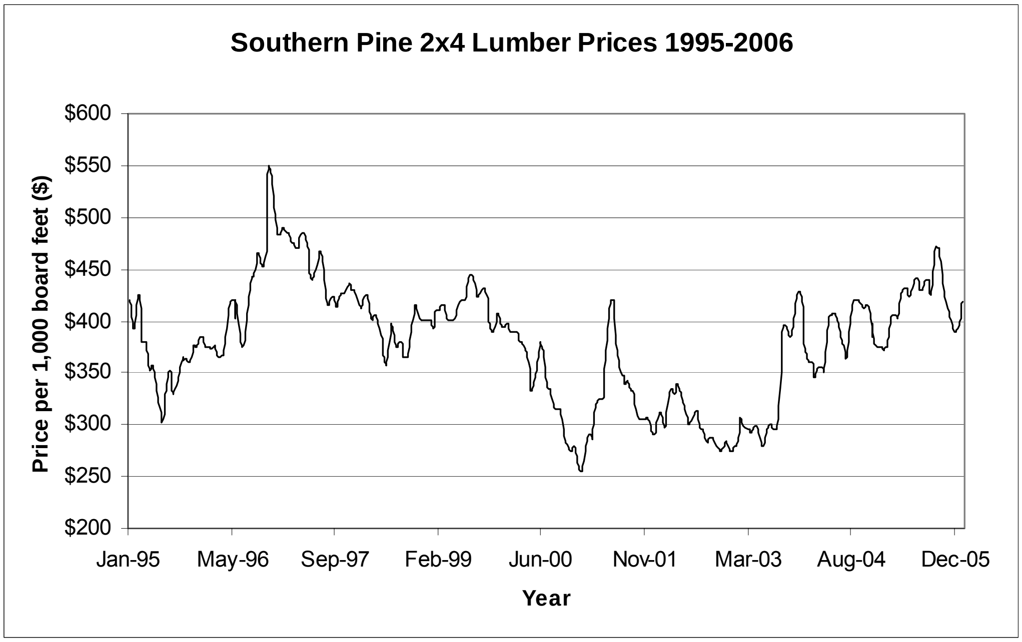


Figure 1.3: Southern pine 2x4 lumber prices 1995-2006 (Source: NAHB Framing Lumber prices, NAHB Web Site, http://www.nahb.org/)

A similar high demand for housing and low supply of lumber affected the Midwestern United States in the mid-1800s when pioneers began to venture into the Midwest and West, aided by the provisions of the Homestead Act of 1862. Settlers built their homes from locally available materials like logs, sod, and straw. In the Midwest, straw was popular because of the large local supply. Also, straw was easily manipulated and baled due to the new technology of horse-powered baling machines that produced a stable building block (Wanek 2003). These houses, built over 100 years ago, were so durable that some are still standing today. Though still in existence, the modern straw bale building industry in the United States is small, mainly due to limitations of construction and local supply of straw. The majority of modern straw bale homes are concentrated in the Midwest and western United States because of the warm and dry climate as well as the proximity to a sufficient supply of straw bales.

1. C. Rice Straw in California

Background

Rice is the most widely consumed grain in the world. While U.S. rice production is largely concentrated in the South, California is the second largest rice-growing state in the nation (Clay 2004). The state's rice industry is clustered around the

Sacramento Valley, where nearly 500,000 acres of rice are harvested annually, contributing around $500 million to California's economy (CRC 2005).

Rice straw is a byproduct of rice production. Once seeds of rice are planted and develop into a mature crop, the grain is collected. Straw, the main stem of the rice plant, is left in the field, as it is essentially a waste material void of any nutrient or seed. The rice straw must be removed before another crop is planted. Disposal options are limited by the great bulk of the material, its slow degradation in the soil, its high mineral content, and the tendency for rice stem diseases to remain in the soil. Traditionally, the two main options for rice straw removal have been incineration and the incorporation of straw into the soil. Because incineration is rapid, economical, and effective at removing disease organisms, it was the most common method for rice straw removal in the Sacramento Valley until the mid-1990s.

Unfortunately, rice straw burning leads to increased levels of air pollution. The Valley is particularly vulnerable to the impacts of air pollution due to its topography, climate, and fast-growing population. Mountains trap the airborne pollutants near the valley floor where people live. High summer temperatures promote ground-level ozone (an atmospheric pollutant), and increasing population levels leads to more cars and other activities which contribute to poor air quality. The degradation to the quality of life spurred state legislature to introduce a plan in 1991 for the gradual phase-down of rice straw burning in the Sacramento Valley. The goal of the Connelly-Areias-Chandler Rice Straw Burning Reduction Act (AB 1378), also known as the Phase Down Act, was to allow time for development of alternative methods of rice straw disposal. The proposed target was to completely phase out the practice, with the exception of the "safe harbor" clause which allows up to 25% to be burned annually for disease control.

In terms of meeting acreage reduction, the phase-down was a success. By 1997, most straw (approximately 99%) was being incorporated into the soil. Although incorporation is detrimental to soil quality, there were no commercially viable uses for rice straw at that time. Because the negative impacts of incorporation continued to increase and the outlook for commercial uses remained bleak, rice growers turned to the California Assembly Board to seek relief. As a result, in 1997 Senate Bill 318 was passed. This bill provided financial incentives to support development of off-field uses. SB 318, The Rice Straw Diversion Plan, required the California Air Resources Board (CARB) to develop an implementation plan and schedule to find uses for 50% of the rice straw from the Sacramento Valley by the year 2000. (Hrynchuk 1998)

Around 500,000 acres of rice were being planted annually in the Sacramento Valley at that time. When rice straw is harvested, an average of 2.25 tons per acre can be removed. With over one million tons of rice straw available for alternative uses, the next challenge was to identify potential uses.

Alternatives to rice straw incineration

Alternative uses and disposal mechanisms for rice straw can be divided into two categories: on-site disposal and off-site use.

On-site disposal

Soil incorporation

As previously mentioned, on-site disposal involves tilling the rice straw back into the earth. The chief concerns to farmers regarding soil incorporation are 1) added costs, 2) physical inability to consistently incorporate large acreage in a timely manner, and 3) crop effects that potentially reduce yield. (van Kessel and Horwath 2000) One study estimated the total costs of incorporation to farmers to be around $37 per acre. (Williams 2001) Compared to the $3/acre cost of burning (CRC 2005), farmers are substantially burdened by the on-site disposal of rice straw.

In addition, an experiment on rice straw management conducted in 1993 suggested that straw incorporation leads to lower yield potential than burning under similar fertilizers and pesticides input. (van Kessel and Horwath 2000) The decrease is likely linked to an increase in stem rot and weed pressure from straw incorporation. Additionally, rice straw has high silica content and decomposes at a slow rate, even in moist soil. While this is an adverse trait for soil incorporation, off-site users may find it to be desirable.

Off-site uses

The most promising opportunities for farmers to recover the costs they incur from reduced burning involves using straw as a resource instead of disposing of it. Most potential uses of rice straw can be categorized into energy use, erosion control, or manufacturing and construction.

Energy production: ethanol, power generation

- Rice straw is a suitable feedstock for the production of cellulosic ethanol for alternative energy fuels. However, due to remaining technical and economic constraints, however, cellulosic ethanol is not yet a commercial technology.
- Rice straw has been used to produce power through direct combustion processes. Again, there are technical challenges. Most notable are the

impacts of ash melting and slagging (the deposition of solid layers on a boiler tube). (CRC 2005)

Erosion control: catch basins and straw wattles

The demand for straw as erosion control is steady and not likely to decline, but mechanisms for supplying the market (collection, transportation, storage) need improvement (CRC 2005). Some common methods straw erosion control follow:

- Bales are strategically trenched and staked into place to create a catch basin that collects silt and other sediment for a period of time.
- Straw wattles are used to stabilize bare slopes by interrupting the water flow. The cylindrical rolls, 8 - 20" in diameter and 8 – 25' long, also block the flow of sediments from entering storm drains and polluting the water on flat surfaces, such as construction sites, sidewalks and bare lots. (Soil Erosion & Hydroseeding 2003)
- Blankets are a variation of wattles, only manufactured as flat, wide panels to protect disturbed soil surfaces.
- Loose straw can be spread on land to reduce topsoil losses from disturbed sites and serves as a protective cover to enable vegetation to germinate.

Manufacturing and construction: pulp, fiberboard paneling, straw bales construction

- Rice straw can be pulped by a method similar to wood and be used for paper and packaging. Using rice straw for pulp has not been widely accepted due to higher costs by comparison to other sources of pulp and remains a niche market for stationary and art uses. (CRC 2005)
- Thick fiberboard paneling systems made from compressed straw are used in modular wall building systems, while medium density fiberboard, created with a chemical binder, is used in ready-to-assemble furniture.
- Straw bale buildings are energy efficient, well-insulated, and long-lasting. The high silica content (8 to 14%) (Drake et al. 2002) of rice straw is particularly advantageous for building, as it provides strength and durability. Straw bale homes also provide slow natural ventilation of air through the walls and avoid the chemical off-gassing that accompanies many modern building materials.
- Bales are also used to construct sound walls along highways and around planned housing communities for noise attenuation. This provides an added benefit of thermal absorption.
- The use of straw in construction has proven to be technologically and commercially viable. At this point, economic feasibility, market demand and supply methods, appear to be the main barrier to adoption. (CRC 2005)

Incentives and assistance

Although there are many potential uses of rice straw, few of them are currently being used. There are some barriers to usage, including 1) technical constraints, 2) economic feasibility, particularly related to the cost of removing straw from the field, and 3) supply and storage problems. (Hill et. al. 1998)

It is estimated that the acquisition costs of rice straw for off-field use is approximately $25 per ton. In addition, hauling and storage costs can range from $7 to $30 per ton depending on distance to the end-user and the type of storage (CDFA 2000). To offset these costs, a variety of grants, funds, and tax credits have been developed (CDFA 2000; CARB 2003).

Several state agencies hope to motivate potential entrepreneurs and promote the off-field usage of straw with financial incentives. The Rice Straw Utilization Grant Program is an example of this. The program was established by the California Department of Food and Agriculture (CDFA) in AB 2514; it created a $2 million account for businesses that develop new rice straw technologies. Up to $20 per ton of rice straw is provided to end-users, with no single grant exceeding $300,000. The Program gives highest priority to projects that demonstrate the ability to expand use of rice straw in the nearest time frame and utilize the largest quantities on a long-term basis, over and above existing quantities of use (Thomson 2000).

1. D. The CP Block

Oryzatech, Inc.

Our client, Oryzatech, Inc., was the beneficiary of a grant from the CDFA's Rice Straw Utilization Grant Program. Oryzatech is currently developing a building block made out of rice straw for residential and small commercial construction projects. Oryzatech believes a business opportunity exists in transforming an agricultural waste product into a structural green building material. The company views environmental and social stewardship as being core values of its business.

Oryzatech's product, the culm-pressed block (CP Block), is an insulating, structural building block made from resource-efficient, highly compressed rice straw. In the past, rice straw has been used to form boards, panels and composite wood substitute, but only on a small scale. Oryzatech's goal is to introduce the CP Block into the mainstream residential construction market as an alternative to traditional wood frame construction and concrete cinder blocks.

Culm, which is the stalk of the rice straw, is high in silica, and this high silica content contributes to the structural durability and higher fire resistance. The CP Block provides a high level of insulation due to its thickness and natural insulating capacity. Because it is compressed and structurally rigid, it can be used for load-bearing walls.

Description and construction

The CP Block is 12 inches high by 12 inches wide by 24 inches long. The wall will be approximately 13 inches thick (with drywall interior sheeting and exterior plaster), which will result in the house having either a larger footprint or less interior space when compared with a conventional house built with 2x4 framing lumber. The construction costs and labor expertise required is unknown at this point, as a house has yet to be constructed using CP Blocks. However, the construction of a CP Block wall will be similar to that of a cinderblock construction (Figure 1.4).

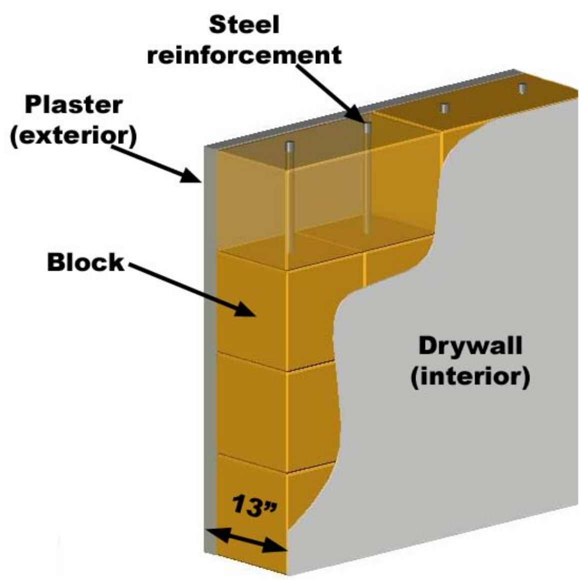


Figure 1.4: CP Block construction diagram

To construct a wall, the blocks are stacked and reinforced with steel rods (rebar). For structural support, 2x6 framing lumber is used for the headers on top of the wall, as well as floor plates to anchor the wall's base to the concrete foundation. On the interior walls, ½ inch drywall interior sheeting (gypsum boards) are attached to the surface of the CP Blocks. The exterior walls of the house will have lath with plaster applied to it. Another option is to use vinyl siding instead of plaster. This wall system does not require plywood or OSB boards for the exterior siding. However, plywood or OSB may be used to significantly improve the shear stress resistance of the CP Block wall system (board and baton construction), which may be a prerequisite to constructing in areas with high wind velocities. Moisture barriers, such as Tyvek, are also unnecessary, because the CP Block is meant to "breathe" in order to regulate temperature and moisture levels. In addition, fiberglass and other forms of insulation are not required, due to the inherently insulating properties of the block.

Characteristics

The high silica content contributes to the structural durability and higher fire resistance of the CP Block. Fire resistance is also higher due to the compressed nature of the block, which reduces the availability of oxygen. The CP Block will also provide a high level of insulation due to its thickness and natural insulating capacity, leading to reduced energy costs. Because the walls are thicker, the sound-blocking properties are higher than that of conventional walls. However, the extent to what the CP Block can block out sounds is difficult to gauge as a house made with CP Blocks has not yet been constructed, but it is expected that CP Block homes will be quieter than conventional homes.[4] Another benefit is the near-absence of toxic chemicals in the walls. Unlike conventional houses, which contain wood products treated with formaldehydes and other chemicals which could off-gas (Brown 1997), CP Block houses do not reduce indoor air quality. One drawback of the CP Block is that it requires low relative humidity. At around 18% relative humidity, fungi spores activate, the straw mildews unless it is treated. (Swearingen 1998)

Environmental benefits

The characteristics described above capture the private benefits of owning a CP Block home. As with other green products, the CP Block provides both private and public benefits. The reduced demand for energy obtained from the lowered need for heating and air conditioning is both a private and public benefit. Lower energy use benefits the environment by reducing the impact of externalities of energy production including acid rain, greenhouse gases, noise pollution, and fuel source extraction. In addition, because the CP Block will substitute framing lumber in wood frame houses, there is a reduced demand for lumber. This results in a public benefit of fewer trees having to be harvested for residential home construction. Much of that lumber would have gone to waste. A typical construction of a 2,000 square foot house generates 1½ tons of wood waste (Toolbase Services 2006). Unlike lumber, straw is a rapidly renewable resource, with new rice crops generating new sources of straw annually. It takes much less time for rice or cereal grains to reach maturity when compared to

[4] Straw bale houses have been shown to be quieter than wood frame houses. (Mas and Everbach 1995) Because CP Block houses are anticipated to have similar characteristics as straw bale houses, it is appropriate to surmise that the trend in soundproofing will be likewise similar.

trees. So much rice is grown that millions of tons of rice straw each year must be disposed of; the view of straw as waste creates an enormous problem. In most states, straw is incinerated, reducing the surrounding air quality. Using straw as a building material will improve air quality, particularly in giant rice production centers like the Lower Mississippi Alluvial Valley (Manley et. al. 2004). The public environmental benefits make the CP Block an intriguing new green building material. In addition, the advantages for homeowners make the block appear an attractive alternative to conventional construction materials. The question is whether the CP Block can realize its potential and gain market acceptance.

CHAPTER 2: CP BLOCK IN THE BUILDING INDUSTRY

2. A. Introduction

The goal of this research is to examine the potential market structure and size for the CP Block. Our research questions and the methods we used to answer them are listed below:

- How does the CP Block compare to other materials?
  To get a better understanding of the potential performance of the CP Block as a structural material, we compared the characteristics of this block with other building materials, both conventional and alternative.
- What motivates homebuyers to purchase a straw block home?
  We investigated the characteristics of a likely CP Block customer. We also researched the effect of branding the product: as a novel building product with private benefits, as a straw block with private benefits and lastly as a straw block with private *and* public benefits. To accomplish this, demand curves were derived, using stated preference techniques for this innovative product.
- What motivates builders to adopt the block as a construction material?
  To investigate potential barriers to utilizing alternative building materials, such as the CP Block, in the current building market, we surveyed building industry professionals on their concerns in regards to adopting the CP Block in their businesses.

Our approach to each of these questions is discussed in the following sections.

2. B. Product Comparison

This section presents the product comparison of different building materials. The comparison has been designed as a stand-alone document that may be used by building industry professionals and prospective owner-builders, as well as other people who are interested in various green building materials. The section is laid out with an introduction, main product comparison table, a series of spec sheets, and concludes with a summary of the characteristics of the different building products.

PRODUCT COMPARISON

PURPOSE OF PRODUCT COMPARISON

There are many different types of building materials on the current market, both of conventional types (e.g. framing lumber, cinder blocks) and green (e.g. straw panels, Durisol, and straw bales). The goal of the product comparison is to compare the CP Block with these different building materials and provide builders and homebuyers with a useful reference tool for comparing many of the new alternative residential building materials. Each material has different properties and different performance characteristics. The product comparison will show how the CP Block performs better (or worse) than other building products in terms of energy savings, out-of-pocket expenses and environmental performance (including both private and public benefits). Private benefits include indoor air quality and energy savings, while public benefits include reduced energy demand, waste material reduction, and reduction in demand of slowly renewable natural resources (e.g. lumber by substituting an rapidly renewable natural resource such as straw). The materials in the product comparison include traditional construction materials, green technologies, and other innovative approaches to building practices.

The product comparison describes the CP Block and ten other wall systems in terms of:

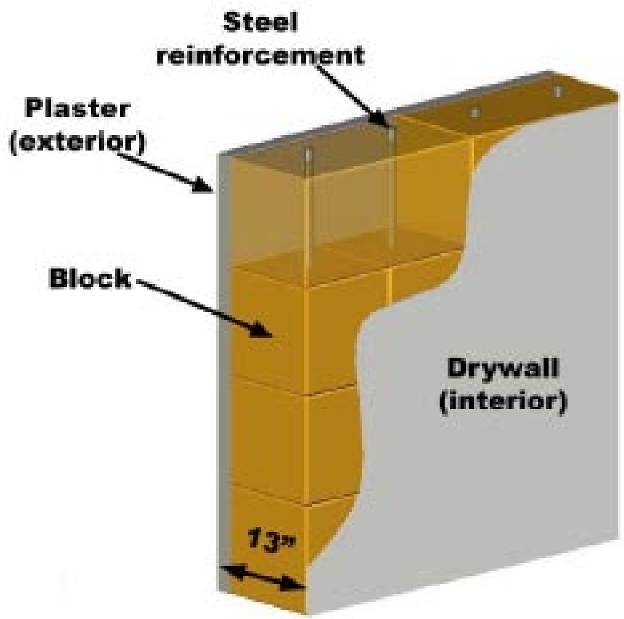
- US Code compliance
- Price per square foot of the material
- Constructed wall thickness
- R-value
- Availability of the product
- Durability of the constructed wall system
- Breathability of the constructed wall
- Energy efficiency of the constructed wall system

Each product characteristic is either listed or the property is rated as either low performing (-), average performing (o), or high performing (+) for each characteristic. For example, a rating of (-) availability corresponds to a product that is not widely obtainable, whereas a product with (+) availability is produced and distributed nation-wide.

In addition, detailed spec sheets were created for each system to provide an overview of the basic physical characteristics of the material, attributes that are unique to the product, as well as information on basic construction of the wall system. Because the labor and construction requirements varied widely across the products, this category was not easily gradable; a short description of each wall system construction process is provided in the product "spec sheet". In addition, environmental effects were difficult to quantify and assign a rating. The additional positive or negative environmental aspects of the manufacture of the product, the construction of the wall system, and end-of-life methods are described in the individual product spec sheets.

CP BLOCK

NOT US CODE COMPLIANT $4/SQ FT 13" WALL THICKNESS R 24



12" x 12" x 24"

Reinforced by rebar

Highly insulating

Above average sound proofing

Fire and pest resistant

Made of compressed rice straw

Rapidly renewable

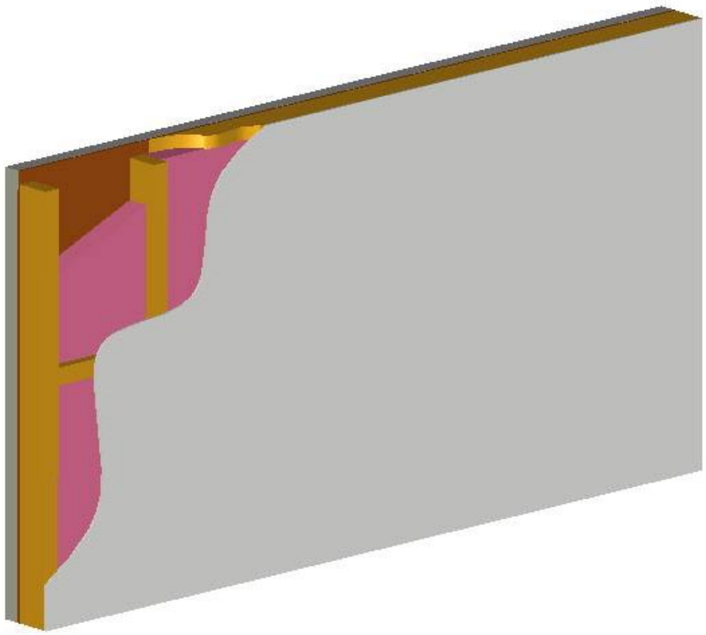
Reduces agricultural waste

CP Block is a modular, insulated block made of compressed rice straw (culm). The blocks are stacked in a manner similar to cinder blocks and reinforced with steel reinforcement (rebar). 2x6 wood is used for the bottom and top plates for additional structural rigidity. Plaster with lath is applied outside on exterior walls, while 1⁄2 inch drywall interior sheeting are used for the inside walls. This construction does not require plywood or OSB for the interior/exterior surfaces. It also requires no fiberglass insulation, due to the thickness of the walls and the natural insulating capacity of rice straw. The moisture resistance of this block, however, is lower than that of 2x4 framing lumber, especially in areas of continuous high humidity (e.g. Gulf Coast) due to the potential susceptibility of mildew. CP Block walls are thicker and contribute to higher noise abatement compared to wood frame walls.

There are a few distinct environmental aspects of the CP Block. For instance, unlike lumber, straw is a rapidly renewing resource. Also, using straw as a building material promotes the use of an agricultural byproduct which, if unused, is treated as waste. This is a benefit for air quality in regions where straw residues on rice fields are incinerated.

2 X 4 LUMBER

US CODE COMPLIANT | $0.50-2/SQ FT | 5" WALL THICKNESS | R 11-18



Standard lumber

2 x 4

Various lengths

Seismic stability

Weatherproof (with Tyvek cover)

Readily available

Douglas Fir, Yellow or Southern

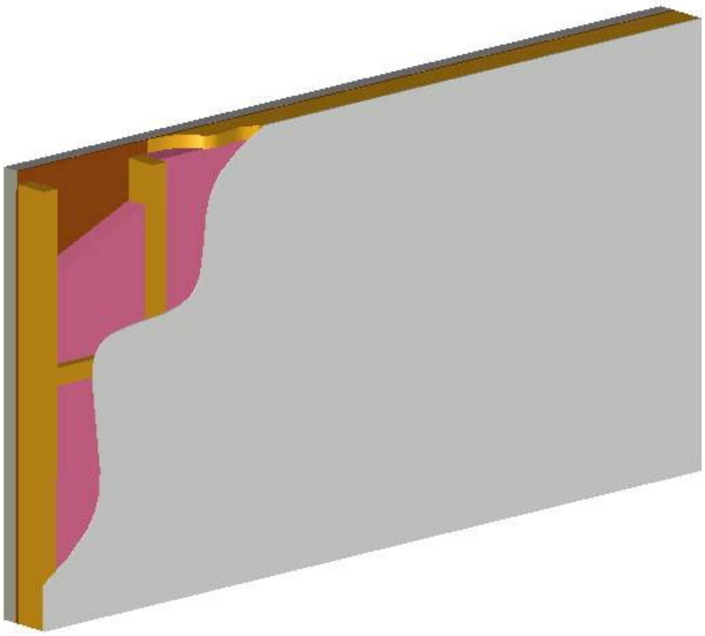
Pine trees

2x4 framing lumber wall systems are the most commonly used for building houses in the United States. The boards are built as a frame: one layer for the floor plate and two layers for the header plates, with vertical studs acting as the load-bearing structural component. The vertical studs are placed 16 inches apart, sometimes diagonal framing is used to strengthen load-bearing walls. Metal braces are used to strengthen joints. On the exterior side of exterior walls, a 1⁄2 OSB wood or plywood is attached for shear and weather protection, while on all interior walls, drywall interior sheeting is used. On exterior walls, standard R-11 to R-18 fiberglass insulation is used, between the vertical load-bearing studs. To make the house "waterproof", a layer of Tyvek is attached to the outside of the OSB or plywood boards. Stucco or plaster is applied to the exterior walls.

In constructing a typical house, up to 50% of the wood ends up as waste. In addition, the wood is treated with chemicals (e.g. formaldehyde) to preserve the wood and prevent dryrot and pesticides are often used to prevent termites. Fiberglass insulation may contain formaldehyde and other chemicals and the Tyvek may keep volatile organic chemical fumes in, increasing indoor pollution. The largest impact from using framing lumber is the harvesting of timber. Certified lumber is now commonplace, to minimize the impacts of poor timber management.

2 X 6 LUMBER

US CODE COMPLIANT $2-5/SQ FT 7" WALL THICKNESS R 15-18



Standard lumber
2 x 6
Various lengths

Seismic stability
Weatherproof (with Tyvek cover)
Readily available

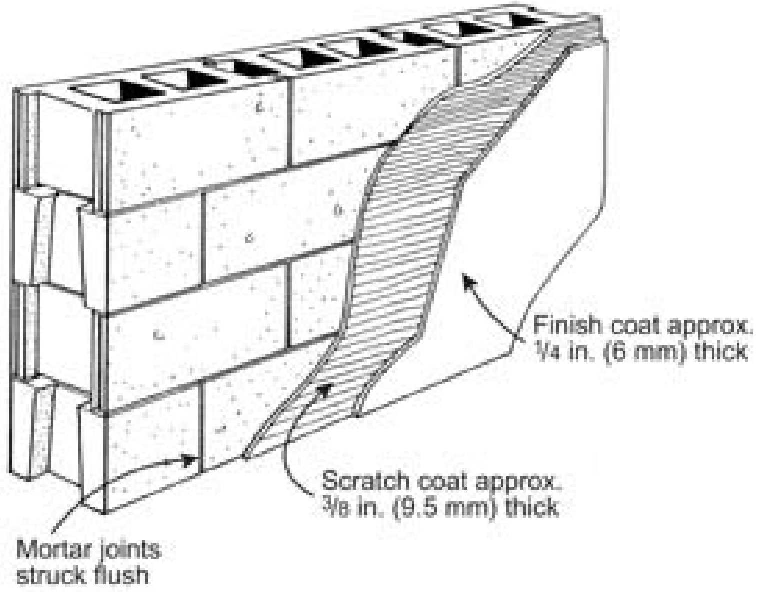
Douglas Fir, Yellow or Southern
Pine trees

The 2x6 wall system has a higher cost than 2x4 framing lumber due to higher cost of thicker insulation and wider framing lumber. 2x6 framing lumber is becoming more common, particularly in colder regions, as it allows for thicker insulation and thus better energy efficiency. The boards are built as a frame similar to 2x4 construction. The vertical studs are placed 16 or 24 inches apart, sometimes diagonal framing is used to strengthen load-bearing walls. Metal braces are used to strengthen joints. On the exterior side of exterior walls, a OSB wood or plywood is attached for shear and weather protection, while on all interior walls, drywall interior sheeting is used. On exterior walls, standard R-15 to R-18 fiberglass insulation is used, between the vertical load-bearing studs. To make the house "waterproof", a layer of Tyvek is attached to the outside of the OSB or plywood boards. Stucco or plaster is applied to the exterior walls.

In constructing a typical house, up to 50% of the wood ends up as waste. In addition, the wood is treated with chemicals (e.g. formaldehyde) to preserve the wood and prevent dryrot and pesticides are often used to prevent termites. Fiberglass insulation may contain formaldehyde and other chemicals and the Tyvek may keep volatile organic chemical fumes in, increasing indoor pollution. The largest impact from using framing lumber is the harvesting of timber.

CONCRETE MASONRY UNIT

US CODE COMPLIANT $3/SQ FT 8" WALL THICKNESS R 17.5



www.cement.org

Standard block

8" x 8" x 16"

Wind resistant

Fire resistant

Termite resistant

Made of Portland cement,

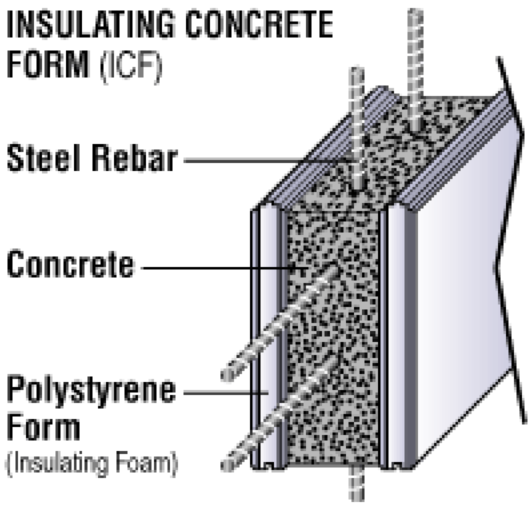
gravel, sand, and water

Concrete Masonry Units are made by pouring concrete into metal molds and curing with steam. There are three basic types of CMUs: hollow non-load bearing, hollow load bearing, and solid load bearing. CMU wall systems are erected with standard architectural block construction. Rebar is passed rebar through the hollow center and the hole is filled with concrete, giving the wall tensile strength. On average, buildings can be erected at a rate of 135 – 215 blocks per day. Labors requirements include basic knowledge of masonry and CMU/brick-laying. CMU homes can last up to 100 years with no maintenance. Aesthetically, pigment and texture can be added to concrete resulting in custom designs and color.

The environmental qualities CMUs include increased energy efficiency and decreased demand for lumber. CMU homes can reduce energy bills 50% when compared to a similar wood frame home. The reduced energy demand reduces the effects of externalities from energy consumption, such as air pollution, noise generated by power plants, and consumption of natural resources. CMUs substitute for conventional wood frame houses, so fewer trees will be harvested for construction and less waste material will be generated from lumber production. CMU production can utilize waste byproducts from electric power plants instead of cement. However, particulate emissions, paint wastes, and plant maintenance wastes are associated with concrete batching.

INSULATED CONCRETE FORMS

US CODE COMPLIANT BY LOCATION $1-4/SQ FT   8-14" WALL THICKNESS   R 7-26



www.cement.ca

Foam forms

Concrete

Rebar

Wind resistant

Seismic stability

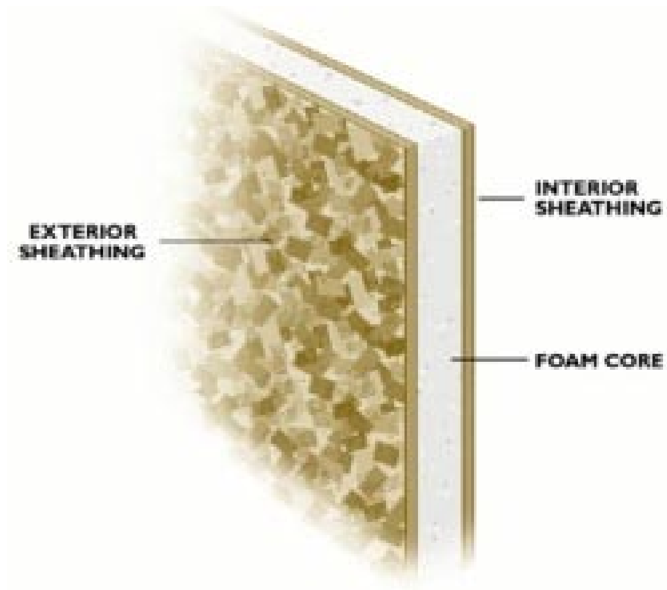
Made of Portland cement, gravel, sand, and water and polystyrene or polyurethane foam

Insulated concrete forms are foam forms that are filled with concrete and rebar to create insulated structural walls. ICFs are set in place, steel rebar is placed where required in the hollow cores and concrete is poured. After curing, standard construction materials are used to complete the roof, floors, and interior walls. Interior and exterior finishes are applied to the foam. Construction is easier and faster that CMU or SIP erection, but require concrete placement equipment like pump truck. Some plastic foams are not accepted by building codes due to the potential for termites.

The environmental aspects of ICFs are increased energy efficiency and decreased demand for lumber. ICF homes can reduce energy bills 42% and the reduced energy demand derived from a lower need of heating and air conditioning is also a public benefit. A decrease in energy demand reduces the effects of externalities from energy consumption, such as air pollution, noise generated by power plants, and consumption of natural resources, such as coal. In addition, because ICFs are a substitute for conventional wood frame houses, fewer trees will be harvested for residential home construction and less waste material will be generated from lumber production.

STRUCTURAL INSULATED PANELS

US CODE COMPLIANT $3-4/SQ FT 4-7" WALL THICKNESS R 14



www.sips.org
Www.toolbase.org
www.ownerbilderalliance.com

Standard panels

Wind resistant

Seismic stability

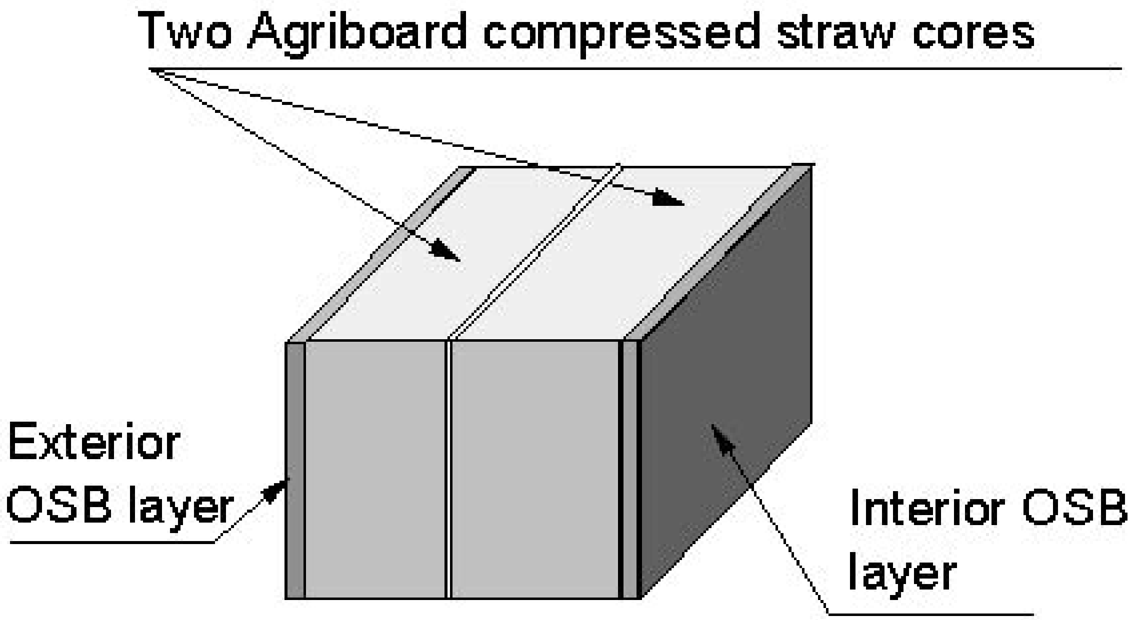
Made of polystyrene or polyurethane foam

SIPs are panels made from a thick layer of foam sandwiched between two layers of oriented strand board (OSB). (Other materials like plywood or fiber-cement board are sometimes used for the outer layers). SIP wall systems require less time to assemble than most techniques, assuming the panels have been pre-fabricated to specific dimensions. Installing wiring and plumbing systems may be complicated by the solid wall, although in some SIPs channels are built into the foam cores to facilitate wiring. Aesthetically, interior or exterior finishes are applied directly to the wall system; stucco brick, siding, etc. can all be used for the exterior.

The environmental qualities associated with SIPs include increased energy efficiency and decreased demand for lumber. ORNL testing showed that under identical conditions, a SIP room used 9% less energy than a wood frame room with 2x6 construction and R-19 insulation. The reduced energy demand reduces the effects of externalities from energy consumption, such as air pollution, noise generated by power plants, and consumption of natural resources, such as coal. In addition, using SIP panel conserve scare timber resources since they provide structural performance while using significantly less lumber. Manufacturers state that the core foam products are environmentally benign.

AGRIBOARD

US CODE COMPLIANT $5.50-6.50 4-8" WALL THICKNESS R14-25



www.ornl.gov
www.agriboard.com

Standard 3-string bale

About 48"x23"x16"

50-60 lbs

Wind and Fire resistant

Sound resistant

Termite and Mold resistent

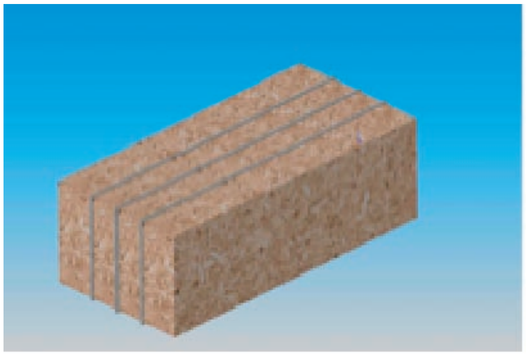
Made of agricultural byproduct

Agriboard are SIPs made with a core of compressed agricultural fiberboard (CAF) sandwiched between OSB. Either one or two core CAF layers can be used, resulting in either 43/8" or 77/8" walls. The CAF is made from wheat straw which is heated and compressed. Agriboard walls require less construction time than most other techniques, assuming panels have been pre-fabricated to the required dimensions (which is recommended). However, heavy construction equipment to set components in place (due the weight of the panels) is required. The panels include prefabbed 1" runners for installing electrical wiring.

The environmental qualities include increased energy efficiency and decreased demand for lumber. Because the building envelope of an agriboard home is 7x higher than a wood frame home, utility savings can reach 40-50% (reported by www.agriboard.com). The reduced energy demand reduces the effects of externalities from energy consumption, such as air pollution, noise generated by power plants, and consumption of natural resources, such as coal. In addition, because agriboard is a substitute for conventional wood frame houses, fewer trees will be harvested for residential home construction and less waste material will be generated from lumber production.

STRAWBALE

NOT US CODE COMPLIANT | PRICE VARIES | 23” WALL THICKNESS | R 25-60



Standard 3-string bale

About 48”x23”x16”

50-60 lbs

Highly sound resistant

Highly fire retardant if plastered

Termite and pest resistant

Rapidly renewable resource

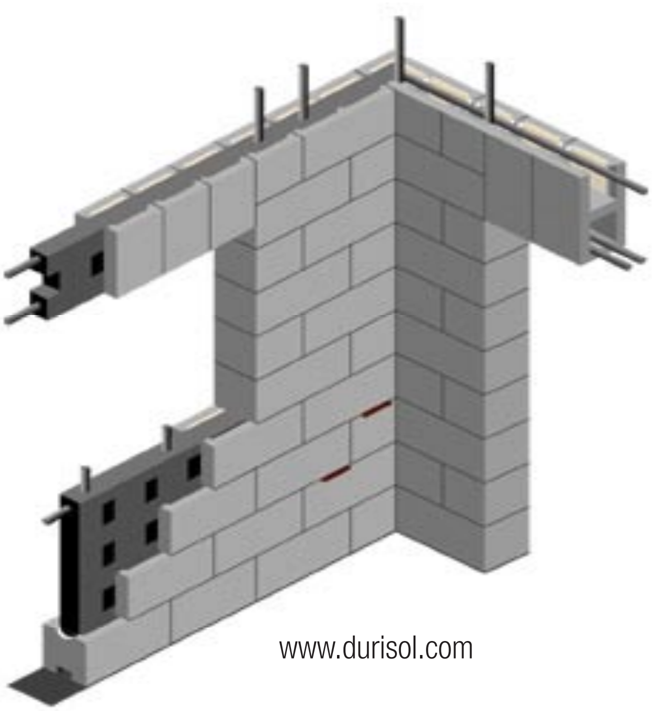
Highly breathable

Straw bales are compressed blocks of straw bound with steel wire or polypropylene twine and stacked on top of one another like masonry blocks. The bales are stacked in a manner similar to cinder blocks and are usually reinforced with straps, wire mesh, or steel pins (rebar). Lumber is often used for the bottom and top wall plates for additional structural rigidity, but straw bale wall construction does not require plywood or OSB. Typically, the outer shell of the wall is made with earthen plasters on top of steel lath.

The use of straw bales provides significant environmental benefits. Straw is highly insulating and reduces energy demand for the homeowner and society. Unlike lumber, straw is a rapidly renewable material and a waste product of another industry. An additional environmental benefit of using straw is the air quality improvements in regions where waste straw is incinerated.

DURISOL

US CODE COMPLIANT | $5-7/SQ FT | 6”-12” WALL THICKNESS | R8-20



12” high x 36” long

Moisture resistant

Mold resistant

Rot and termite proof

STC: 54-72

4 hour fire resistance rating

Durisol is a modular, insulated, concrete forming system made of recycled waste wood that is bonded with Portland Cement. The blocks are dry-stacked and filled with concrete and reinforcing steel to form wall systems. The wall form incorporates rockwool insulation that is positioned towards the exterior of the wall to increase energy efficiency. The insulating properties of Durisol allow winter construction without additional heating and insulation sources being required. The material is light-weight, easily cut, nailed and screwed with simple carpentry tools. Interior and exterior finishes are applied directly to the material. Drywall can be attached anywhere on the surface, though the open texture of Durisol makes it an ideal substrate for plasters and stucco.

The environmental qualities of Durisol include increased energy efficiency and decreased demand for lumber. Durisol homes have lower energy bills. A decrease in energy demand reduces the effects of externalities from energy consumption, such as air pollution, noise generated by power plants, and consumption of natural resources, such as coal. In addition, because the Durisol substitutes for conventional wood frame houses, fewer trees will be harvested for residential home construction and less waste material will be generated from lumber production. In addition concrete is inert and requires no volatile organic compounds. Durisol production can also utilize waste byproducts from electric power plants instead of cement.

RASTRA®

US CODE COMPLIANT $6-7/SQ FT 8-14” WALL THICKNESS R 25-32

www.ornl.gov
www.rastra.com

Standard panels

15”-30” wide 7”-10” long

42-64 lbs

Fire resistant

Frost resistant

Mold and pest resistannt

85% recyclable material

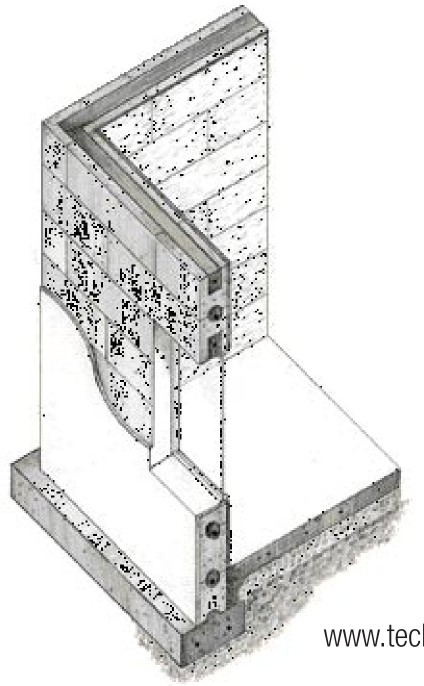
STC: 50+

RASTRA® is a stay in place insulated concrete form (ICF) system. The panels are made of Thastyron (THermo Acoustic STYROfoam Concrete), a mixture of recycled polystyrene beads and a cementitious binder. They can be dry-stacked either horizontally or vertically, creating an internal grid that is reinforced and then filled with concrete. There are two panels: the standard panel is used for straight and curved walls, and the end panel is for corners, wall ends, and window and door frames; the panels can be stapled or glued together. Thastyron can be easily carved, cut, and routed into any shape, and plasters and tiles adhere directly to the blocks. In addition, load capacity can be adapted to fit any requirement by using different strengths of concrete and various amounts of reinforcement.

Rastra's® claims of being a “truly green” building material stem from the production process. Less than 1 kWh is needed to produce each element. In addition, no by-products are released during production; all debris from trimming is used in new product. There are no out-gassing, mold, or condensation issues associated with the product.

TECH BLOCK®

NOT US CODE COMPLIANT $7-8/SQ FT 11" WALL THICKNESS R 48



www.techblock.com

Standard block	Sound resistant	Made of recycled material
16" x 48"	Fire resistant	Impervious to air and moisture
65-85 lbs	Termite and mold resistant	

Tech Block® is made with recycled foam beads, cement, and water. An integrated 3⁄4 inch oriented strand board, OSB, attachment surface is bonded to the block in order to support drywall. The blocks are dry-stacked, forming an internal channel. The channel acts as a hollow grid for the installation of steel rebar and a form for the grout that is poured in from the top of the wall. The exterior of the wall is ready for stucco, brick, or stone without the need for wire mesh. Installation costs are around $2/sq ft more than usual 2x6 wood frame wall construction, and the company cites a "moderate" ease of construction, likely due to the weight of the blocks.

The environmental qualities of Tech Block® include increased energy efficiency and decreased demand for lumber. Recycled polystyrene from the manufacture of other products is used in the production of Tech Block®. The OSB is also prepared from wood left over from the making of framing lumber. Recycling these materials diverts them from landfills.

PRODUCT COMPARISON

PRODUCT COMPARISON SUMMARY

The product comparison provides a snapshot of a few select building materials. It reveals that the unconventional building materials market hold distinct advantages and disadvantages over what is offered by the conventional building market. The following is a summary of the product characteristics that were presented in the comparison table.

- U.S Code Acceptance: Having no prescribed standards of construction in the U.S. Building Codes is perhaps the greatest barrier to entry for most of the alternative building systems. SIPs and TechBlock are both undergoing the certification process and are not currently accepted by general building conventions. ICF and straw bales are also not universally acknowledged by national code organizations, however some localities have adopted the materials in their independent standards assuming certain criteria is met. For instance, jurisdictions may choose to permit straw bale construction only if it is used in a non-load bearing capacity.

- Average cost per square foot: A substantial premium typically accompanies the cost of alternative building materials. The average cost per square foot of materials other than wood frame is approximately $5, excluding straw bales which are highly variable. In comparison, 2 x 4 wood studs are estimated to cost between $0.50 and $2 per square foot.

- Wall Thickness: In general, the unconventional building materials have thicker wall systems. On average, the alternative wall systems have 10" thick walls. The thickest wall system, made of straw bales, is 23". However, the 2 x 4 stud wall is only 5" thick. This characteristic can be viewed as both an advantage and a disadvantage. Some may enjoy the aesthetics offered by thicker walls, while others may view the consequent decrease in interior square footage as a drawback.

- R-value: The R-value of alternative building materials is generally one of its greatest advantages, as the product comparison demonstrates. Due to innovative materials and strategic design, these unconventional building products possess an average R-value of approximately 24. This achievement over conventional wood-frame housing (R 11-18) will result in long-term energy savings that will likely compensate for any up-front price premiums demanded by the alternative materials.

- Product availability: Alternative materials are generally much more difficult to obtain than conventional materials. Due to limited manufacturing facilities and high transportation costs, the products are at a disadvantage. Other than wood studs, Durisol and CMUs are the only products that are readily available nationwide.

- Durability: The baseline for durability was set at 60 to 80 years, the life span of a conventional wood frame home. The alternative wall systems were given higher ratings mostly due to the fact that concrete was incorporated into their structure. The CP Block is expected to have a life span as long as concrete if treated in the proper environment. If the durability of straw bale homes is any prediction, this will likely be the case. SIPs and Agriboard were given moderate ratings due to the fact that their strength varies based on wall thickness.

- Breathability: Conventional wall systems are designed with an air-tight building envelope that acts as both a moisture barrier and a method of increasing insulation by decreasing air flow. Many of the alternative wall systems have avoided using moisture barriers in their design. Instead, they are often made of breathable materials that allow for the natural diffusion of water vapor without diminishing thermal performance. The CMU wall system has no moisture barrier, the complete concrete wall is effectively air impermeable, creating its own building envelope and decreasing its breathability.

PRODUCT COMPARISON

PRODUCT COMPARISON SUMMARY

- Energy Efficiency: The efficiency rates of conventional wall systems were set as the baseline for assessment in this category. Alternative materials typically perform better, and the rating trends generally follow those associated with R-values. Most of the alternative products scored higher than conventional due to either their higher R-value or the strategic placement of insulation within the wall system material.

- Environmental Performance: Alternative wall systems typically perform better in environmental terms. This is due to several factors, including: the promotion of lumber conservation, the diversion of products from the waste stream by incorporating recycled components into the final product (e.g., using recycled polystyrene in TechBlocks or fly ash in CMUs), and the reduction of waste at the job site with the use of pre-fabricated walls. Large amounts of scrap wood are generally a by-product of conventional wall system construction, and very rarely are steps taken to reuse or recycle the scrap.

- Ease of Construction: Due to the novelty of alternative wall systems, they are generally viewed as being more difficult to construct. Often times the building industry is apprehensive of alternative building technologies due to the learning curve associated with new construction methods and the uncertainty of time demands and labor costs.

Overall, it appears that the biggest barriers faced by the alternative building materials fall into one of three categories: US Code acceptance, availability, and upfront costs. Without recognition by building codes, it is practically impossible to successfully compete in the building market. Likewise, without supply, demand is useless. The limitations posed by complicated product supply and delivery can be dire to market achievement. Finally, although savings will likely result from decreased maintenance costs and increased energy savings, the upfront premium that is demanded by alternative building materials is often a deterrent to both consumers and industry professionals.

The alternative materials market does, however, hold several product advantages over the conventional market. These include increased R-values and subsequent energy savings, breathability, and environmental performance. As consumers become increasingly aware of both the public and private benefits offered by alternative building materials and as industry professionals become familiar with the new construction methods, the alternative building materials market will likely be accepted as a viable alternative to what is offered in the conventional building market.

2. C. Estimating Demand for the CP Block

A significant aspect of the research was to estimate the potential market for the CP Block. This raised two primary questions:

- Would homebuyers purchase a straw block home? How would the block be perceived by potential homebuyers? Would they value it for its insulating properties and its environmental benefits? Would they be deterred by the notion of living in a straw house?
- Would builders adopt the block? While consumer demand would be an important factor in the potential market, homebuyers are not typically the individual consumers of the building materials; they purchase a home as a package, already built. It is builders who make most of the decisions about which materials to build with. Would builders view the block as a realistic option for housing construction? Would they perceive a potential market? Would they be likely to adopt the block?

Consumer demand: Theoretical approach

Theoretical model

In order to understand the potential homebuyers market we needed a model that could predict consumer demand. An equation estimating a homebuyer's likeliness to purchase a straw block house as a function of price and other explanatory variables would allow construction of a demand curve. We chose to conceptually represent a homebuyer's decision as a discrete, binary option: they could buy either a conventional wood frame house or a straw block house. While this simplification ignores other options that homebuyers might have, it is not far from reality: about 85% of new home starts are wood frame (Department of Commerce 2000).

We used the logistic regression model (logit) to represent homebuyers' likeliness to purchase the straw block house. Logit models are often used for dichotomous choice data because they accept binary data for the dependent variable. The logit model calculates the likelihood that one option is chosen instead of the other, restricting this likelihood to values between 0 and 1. This makes logit models conceptually attractive for binary data since the predicted probability for one outcome or the other can never be greater than 1. Our logit model represents the likelihood that a homebuyer would purchase a straw block home rather than a conventional home. The form of the logit model is:

$$Probability(Straw\ block\ house) = \frac{1}{1 + e^{-Z}}$$

$$\text{where } Z = \sum_{i=1}^{N} \beta_i X_i$$

Probability(Straw block house) is the predicted probability that a homebuyer will purchase a straw block house rather than the conventional house
X_i is a vector of explanatory variables, including price, product characteristics, and demographic variables for the individual
β_i is a vector of the coefficients for the explanatory variables

The logit model assumes that the probability of choosing the straw block house is independent for each respondent. Further, it assumes that Z is a linear function and that changes in the explanatory variables change the probability of choosing the straw block house but that the functional form of Z does not change (Lindsey 1997).

The explanatory variables fall into three categories: product attributes (including price), demographic characteristics of the respondent, and other explanatory variables. Common demographic characteristics that are used in many consumer choice logit models include income, gender, age, education, and political affiliation. Other explanatory variables may also impact consumers' choices and need to be included.

The two most commonly used methods for analyzing logistic regression data are weighted least squares and maximum likelihood. We used the maximum likelihood method to determine the coefficients (β_i) based on survey data. This was done in Matlab using an econometrics toolbox add-on (LeSage 1999). Once the coefficients are determined the logit model can be used to estimate the probability of purchasing the straw block house as a function of the variables.

To construct a demand curve for the United States, we applied the logit model to US 2000 Census data (United States Census Bureau 2000). We wrote a program in Matlab to take county-level averages of explanatory variables such as income, age, and education and then calculate the probability that this "average" person from each county would purchase a straw block house at a specific price. We multiplied the probability by the number of new housing starts in that county to obtain the number of new straw block homes per county. [5] County totals were summed across the US

[5] Housing starts were obtained from the 2000 US Census, covering the period Jan. 1999 – Mar. 2000. This was considered sufficient to calculate a nationwide proportion of new homes.

and divided by the nationwide total for new housing starts to give the proportion of new homes nationwide which would be straw block. This calculation was repeated over a range of prices to generate a demand curve.

The marginal effect that each of the explanatory variables had on the probability of choosing the straw block house was calculated by taking the first derivative of the logit equation with respect to the explanatory variable and then calculating the value of the derivative at survey sample averages.

Consumer Survey

With a conceptual model in place, data was needed to calculate the specific coefficients. *Revealed preference* data is ideal, since the actual consumer behavior is measured. However, obtaining revealed preference data relies on the good already being part of the market. When a good is not part of a market, researchers can use *stated preference* techniques to measure WTP. Economic valuation using stated preference techniques relies on asking research subjects what they *would* do in a hypothetical situation. Most commonly these techniques ask “What would you be willing to pay?” or “Would you be willing to pay $X?” for one alternative relative to another. Their accuracy depends on the willingness of subjects to respond to the hypothetical situation in realistic manner.

There are two primary stated preference techniques. Conjoint analysis (also called choice modeling) uses questionnaires which systematically vary specific product attributes in order to obtain the marginal WTP for each of those attributes. Contingent valuation (CV) uses surveys to estimate the total WTP for a good. Contingent valuation was chosen for this project because: (1) it is the preferred technique when total WTP is desired (Bateman 2002), and (2) it requires fewer responses than conjoint analysis to attain the same statistical power.

The basic approach of CV uses a survey, or questionnaire, to present respondents with a scenario in which they must consider the change in a good or service and then assign a monetary value to that change. There are several options for how to present the option to respondents and have them assign a monetary value: (1) an open-ended format can be used in which the respondent is asked to state their maximum willingness to pay for the change; (2) a bidding process can be used in which the respondent is shown a series of ascending (or descending) prices and they choose the one that most closely represents their willingness to pay; or, (3) have each respondent answer yes or no to whether they would pay a specific price for the change, with the specific price varying across the sample (Mitchell and Carson 1989; Cameron and Huppert 1991). This last technique is called the referendum process, and is the preferred CV technique (Arrow et al. 1993) because it offers a choice to respondents in the most familiar manner.

Despite the fact that the good or service is not traded in markets (hence the use of CV), the change that is being offered should be perceived by respondents to be realistic and feasible (Bateman 2002). For our survey this meant that respondents had to be presented with an alternative building material, the CP Block, in a way that was understandable and realistic. Since most homebuyers do not go to the hardware store to purchase the raw building materials for their home, the idea of offering the block itself was discarded. And while almost all respondents would already own or rent properties, the idea of changing the walls in an existing residence is not a realistic scenario. Thus it was decided that the choice should be between two new homes: the baseline would be a new home built with standard wood frame construction; the alternative would be an identical home whose walls were built with the CP Block. The choice to buy a new home would be a scenario that would be familiar, or at least feasible and realistic, to almost all survey respondents.

In summary, we measured the demand for straw block housing by administering a survey which offered respondents either a new wood frame house or a straw block house. The characteristics of each house were described, and respondents were asked which house they would choose if the price differed by a specific amount. The survey data was analyzed in the logit model. Logit model results were then used to predict the probability that any individual person or group of people would purchase straw block housing.

Building industry study: Theoretical approach

Estimating consumer demand alone did not seem a sufficient analysis of the potential role for a straw block in the residential housing market. Homebuyers rely on developers, builders, and contractors to construct the houses and then purchase the finished product. While homebuyers exert influence as consumers on what developers build, the building industry is a mature and generally conservative industry which can be slow to change or adopt new practices (Allen 2005). The perceptions of building industry professionals would significantly influence the prospects of a compressed straw building block.

These perceptions could be explored through a survey targeted at residential building industry professionals. The survey would have two primary goals: to obtain the builders' estimate of consumer demand for CP Block housing, and to investigate what would motivate builders to adopt the straw block. To accomplish these goals, a portion of the survey would be very similar to the consumer survey. Builders would be presented with a hypothetical scenario: "Given the choice between a conventional 2x4 house and a straw block house, what percentage of buyers would choose the straw block house if it cost $X more?" The second major question we wanted to explore was whether and why builders would use the compressed straw block in building projects. This portion of the survey would ask builders whether they were likely to adopt the straw block, and to rank the block against 2x4 construction for a range of factors.

Builders' estimate of consumer demand

Since builders are familiar with the choices that homebuyers actually make, their estimate of consumer demand serves as a useful comparison to consumers' own responses. Presumably, builders would not have any incentive to yea-say or overstate the preferences of a third party. Further, we are not aware of any previous studies which have used a similar third-party cross-check for stated preference survey data, so this was an opportunity to push the boundaries of stated preference analysis.

To conduct this aspect of the study we asked building industry professionals to estimate the percentage of new home buyers who would purchase a straw block home rather than a conventional home based on an offered price. The responses were treated as unbiased estimates of the proportion of buyers who would choose straw block housing at an offered price. The industry-estimated demand curve was assumed to be linear over the range of offered prices and to have the following functional form:

$$\%\ Buy\ straw\ block\ house = \beta_0 + \beta_1 \times Price + \beta_2 \times Surveytype$$

% Buy straw block house is the predicted percentage of new homebuyers that will purchase a straw block house

Price is the price premium for a straw block house relative to the conventional house (in $1,000s)

Surveytype is a dummy variable for the version of the survey

β_i are the coefficients for the variables

This model requires data on only the price difference between the two houses and the type of survey the respondent answers. Unlike the consumer choice data, in which we would have to use demographic variables to control for the effects of income, education, age, and other factors on a homebuyers' decision, by asking builders to estimate an overall percentage for their area we were implicitly having them control for all these variables in their estimate. The industry-reported estimates could therefore be directly analyzed in the equation above, and the resulting demand curve compared to the demand curve derived from our consumer survey data.

Builders' willingness to adopt straw blocks

We also analyzed how builders evaluate new materials. What factors do they consider important in deciding to adopt a material for projects they work on? How would they view the compressed straw block compared to conventional wood frame construction? Would they adopt the straw block? Why or why not? We developed a logit model to explain which factors were significant to builders in choosing to adopt the straw block. The primary variables in the logit would be the builders' own estimates of how the straw block compared to conventional 2x4 construction across a range factors such as ease of construction, regulatory acceptance, and construction cost. Rather than using this logit model to predict how many builders would adopt the straw block, we wanted to evaluate which factors were significant in influencing whether a builder stated they were likely to adopt the block—in other words, which criteria they weighed most heavily when considering the straw block

2. D. Consumer Demand Survey

Purpose

The purpose of the consumer survey was to perform a contingent valuation (CV) to estimate the WTP for a straw block in residential housing. The WTP would be a function of price, the demographic characteristics of the respondent, and the product attributes. The characteristics of the CP Block raised two significant questions that we used the survey to explore:

- What portion of consumers' WTP would come from the private benefits they get from the block, and what portion would come from the public benefits? Would respondents choose the CP Block because of its private goods characteristics (e.g., increased insulation and energy savings), or because they perceive the block to provide a public good (e.g., the block is environmentally friendly because it reduces air pollution and timber harvest)?
- How would consumers' reaction to a straw building material influence their WTP? Would that fact that the CP Block was made from straw, not usually viewed as a building material, deter some respondents? Would there be a "straw effect" because they doubted it was a durable and appropriate building material?

Designing the research question

Both of these questions could be answered with an appropriately designed survey. All of the surveys would offer respondents the choice between two houses: a conventional wood frame house, and the alternative, a nearly identical house built with CP Block walls. To measure the portions of WTP that came from the private benefits versus the public environmental benefits, all of the surveys would have to clearly delineate the private characteristics of the two houses; properties such as insulation, energy savings, or durability would be vital to the decision which respondents would make between the houses. A subset of the surveys would then also elaborate on the environmental benefits from using straw, and these responses could be used to measure the portion of WTP that came from the environmental benefits.

A similar solution could be employed to measure the “straw effect”. Some surveys would reveal that the alternative house was made with “building blocks made from compressed rice straw,” while other surveys would offer an alternative house with all the same characteristics but would not reveal the building material. The wall construction material would simply be referred to as a “new building material.” The difference between respondents who were offered the unnamed alternative and those who were offered the straw alternative would reveal the reaction people had to straw.

These two survey alternatives—discussing the public goods and naming the block “straw”—would be varied across the surveys. In theory this made for 4 possible versions of the survey. However, one of these options was not realistic; it was not feasible to accurately describe public environmental benefits without revealing that the CP Block was made from rice straw. Therefore, three versions of the survey were produced: the “new material” block with private benefits only (hence PrivNew); the “straw” block with private benefits only (PrivStraw); and the “straw” block with private and public benefits (PrivPubStraw). Each version of the survey was administered in equal numbers.

The price premium for a straw block house was also systematically varied. We chose to have 5 price differences. Based on results from survey pre-tests and on estimates of the potential price of CP Blocks, the 5 price differences for a straw home were set at: $5,000 cheaper, $2,000 more, $6,000 more, $12,000 more, and $25,000 more. Rather than distributing these prices equally across the sample space, prices in the middle appeared on more surveys, while the extreme prices appeared on less. This provided us with a greater number of responses in the more sensitive portion of the demand curve, thereby improving the statistical power of the resulting data.

Thus any individual respondent would see one of three versions of the survey and be offered one of five price differences when choosing between the two houses. The figure below summarizes the conceptual layout for the survey technique.

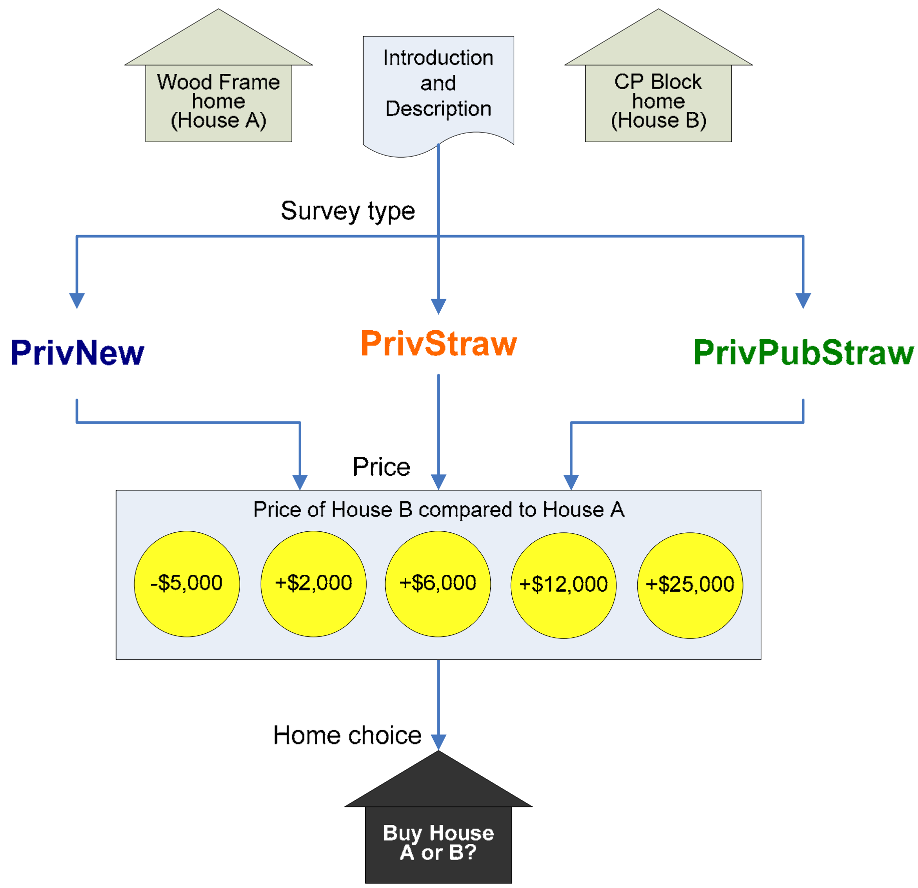


Figure 2.1: Survey distribution schematic

Within our logit model the three different versions of the survey were modeled as dummy variables. They joined price as the product characteristic variables in our logit model. Demographic explanatory variables in the model included income, age, education, gender, and political ideology. Other variables which were considered potentially significant included local temperature variability and rainfall. Table 2.1 explains the variables used for the survey and analysis. These data from the consumer survey were placed into the logit regression to calculate the model parameters and determine the effect of each of these variables on the likeliness of buying the straw block house.

Table 2.1: Variables used for consumer survey data in the logistic regression model

Variable	*Description*
Product Characteristics	
BIDPRICE	Price difference for straw house vs. conventional: -$5, +$2, +$6, +$12, or +$25 (in $1,000s)
PRIVATE_NEW	Survey version: 1 if private benefits, “new material” (PrivNew); 0 if otherwise
PRIVATE_PUB_STRAW	Survey version: 1 if private & public benefits, “straw” (PrivPubStraw); 0 if otherwise
Demographic Characteristics	
INCOME	Household income ($1,000s)
EDUCATION	Number of years of education (yrs.)
AGE	Age (yrs.)
IDEOLOGY	Self-described political ideology on a 1-7 scale, from “extremely liberal” to “extremely conservative”
GENDER	Male or female: 1 if male; 0 if female
OWN	Whether respondent owns residence: 1 if owns; 0 otherwise
Other Characteristics	
TEMPDIFF	Difference between average July daily high temp and average January daily low temp for ZIP code of respondent, (°C)
PRECIPITATION	Average annual rainfall in ZIP code of respondent, (in.)
HOMEPRICE	Median home value for the ZIP code of respondent, ($1,000s)

Development of survey

With the theoretical framework for the survey in place, we needed to obtain the technical data for each of the houses so that respondents could make an informed choice. Due to the novelty of the CP Block, there were certain values that could not be quantified for the straw block home. Instead, our assumptions are qualitatively based on similar materials already on the market.

To compare the two houses, we developed a set of factors by which to measure their performance. These factors were classified as either private or public benefits. The two following sections discuss the differences between the two homes in terms of their private and public benefits.

Private Benefits

The following list describes the major differences between a conventional home and a straw block home. We assumed that items such as durability and longevity of the house, pest and fire resistance, and maintenance and home improvement costs would be the same for both houses. The following information was presented on all versions of the survey.

- *Price:* The cost of the straw block home was varied between $5,000 less than and $25,000 more than the cost of the conventional home on individual surveys.
- *Insulation*: The conventional wall materials have a 'standard' value for insulation (R-11 to R-13). Due to the highly insulting properties of rice straw, the straw block home is expected to have an R-value of 24, or 'twice standard'.
- *Heating/Cooling Costs*: To translate the difference of insulation into energy savings, we utilized an online modeling tool that evaluated the energy efficiency of a home. It was estimated that the straw block house would save a homeowner $65 to $210 annually on their energy bill. More detail on this methodology is discussed below under *Energy Efficiency.*
- *Soundproofing*: Because the CP Block wall system is approximately 7 inches thicker than the conventional wall system and is similar to a straw bale wall system, we assumed the soundproofing characteristics of the CP Block home to be better than that of the average wood-framed home.
- *Moisture Resistance*: The moisture resistance of a typical wood-framed house was considered to be the baseline. In dry and moderate climates, the CP Block home is expected to have a similar resistance to moisture. Due to insufficient data of the CP Block's performance in wetter climates, it is assumed that the straw block home will perform, at minimum in a manner similar to a straw bale home.
- *Wall Thickness*: The wall thickness of a conventional wood-framed house is 5" compared to the 13" thick wall system of the CP Block home.
- *Interior Area*: We wanted to illustrate the loss of interior floor space due to the thickness of the rice straw material. The change in wall thickness causes an estimated 200 square feet loss in the interior of the CP Block home.

Energy Efficiency

Energy savings from increased insulation will depend on climatic conditions. To estimate energy savings from the straw block home we divided the US into three broad climate zones: warm, cold, and mixed. For each climate zone, the baseline conventional home was given the minimum recommended R-value[6] insulation as suggested by the Department of Energy, Oak Ridge National Laboratory; the straw block home was assumed to have R-24 insulation.

Seven cities were then selected within each climate zone in order to represent the wide variation that exists within one climate type (e.g., Flagstaff, AZ, Fairbanks, AK, and Washington, D.C. were all included in the mixed climate zone). The climate data for each city was then entered into the Home Energy Efficient Design (HEED) model developed by UCLA. HEED is an online tool that evaluates the energy performance of a home or building. We used the model to analyze the efficiency of:

- a modern home constructed with energy saving technologies (such as energy efficient appliances, lights, and climate control systems).
- a straw block house which was identical to the modern home, with the exception of a decrease in square footage and an increase in insulation

Insulation in the straw block home was estimated to be twice the insulation in the homes in warm and mixed climates, and 1.3 times the insulation of homes in cold climates. The efficiency rates of the two homes were calculated for each of the 21 cities, and the differences in rates were used to calculate the efficiency improvements of the straw block home.

To convert the efficiency improvements into actual annual monetary savings, average monthly consumption levels and energy costs for the 21 cities were used to calculate the annual energy costs of the conventional and straw block homes (US EIA 2005b). For each climate zone the potential energy savings were estimated as the range from the upper to lower quantiles of the city dataset. A more detailed description of the HEED results can be found in Appendix C.

Public Benefits

The next component of the survey explored features of the wall systems that provide public benefits in the terms of the environment. This information appeared only on the surveys describing the public environmental benefits of owning a CP Block home (the PrivPubStraw surveys). Table 2.3 identifies the public benefits associated with a CP Block home.

[6]R-value is a measure of resistance to the flow of heat through a given thickness of a material (as insulation) with higher numbers indicating better insulating properties. The minimum recommended R-values for the three climate zones were: Warm, R-11; Cold, R-18; and Mixed, R-13.

Table 2.2: Description of public benefits in consumer survey

Lumber conservation	Use of the straw building material saves approximately 15 pine trees (80 ft. tall) from being cut down for the lumber required for House A.
Rapidly renewing product	Unlike lumber, straw is a rapidly renewing resource. It takes less time for straw to mature for harvest than for trees to mature to harvest.
Waste reduction	Use of the straw building material promotes the use of an agricultural byproduct which, if unused, is treated as waste.
Air quality	Use of the straw building material will increase air quality in regions where straw waste is incinerated (BCAQMD 2006).

Lumber conservation

The number of trees saved was calculated by estimating the amount of wood displaced in the walls in a model wood frame home and converting that figure into a whole number of trees. Using a recent report commissioned by the Wood Products Council (WPC) (Adair 2005) and conducted by the NAHB Resource Center, we estimated that approximately 11,000 board feet[7] of lumber are used in the wall construction of an average 2,000 square foot home[8] in the US (Appendix D, Table D.1).

The amount of wood estimated to be used in wall construction of a CP Block home of similar size was subtracted. The resulting figure was approximately 9,000 board feet. By converting the volume of board feet used, it was estimated that the total amount of wood used is equivalent to 12 eighty-foot Southern Pine trees (Appendix D, Tables D.2 and D.3). It is important to note that the discrepancy between this

[7] The number of square feet of wood paneling for sheathing were converted to board feet in order to add that amount to the amount of framing lumber used, a figure typically measured in board feet. A board foot is equal to 144 cubic inches of wood.
[8] Though the average-sized home has hovered around the 2,300 square foot figure in recent years, our model homes were slightly smaller: approximately 2,000 sq feet for the wood frame home (based on the WPC data) and 1930 sq feet for the CP Block home.

figure and the survey (which states that 15 trees are saved) is due to an error in calculation which was not discovered until after the survey was administered. However, it is doubtful that this error has a significant impact on the accuracy of the consumer demand model.

Revision process and pre-test

The first version of the survey was written by project members, with input from internal and external advisors. Revisions to the survey were made through a two-tiered pre-test and modification process. For the first component, a focus group of fellow graduate students at the Bren School was gathered. The students were asked to read through the survey and identify sections that lacked clarity. Their suggestions resulted in major improvements to the graphics and a more straightforward narrative introducing the main question. Those changes were incorporated into the survey before the second tier of the pre-test was administered. At that point, the updated version was nationally distributed to colleagues, family, and friends of the project members. Over 100 completed surveys were received. One critical question included in the second-tier pre-test asked respondents to specify the dollar amount that they would be willing to pay for the CP Block home. This was an open-ended question, and the answers that were provided assisted in establishing the price bids ultimately used in the final survey. The other responses were reviewed and integrated into the survey content, leaving us with our third and final version. The pre-test process was essential in singling out gaps in information and clarifying which attributes were identical between the two houses.

Survey response mode

Knowledge Networks (KN), a marketing research firm, was selected to conduct the survey. Knowledge Networks provided the following advantages:

- *Sufficient sample size*: Because there are fifteen distinct versions of the survey (the three benefit categories crossed with the five price categories), it was necessary for us to obtain a sample size sufficiently large to allow for statistical analysis of each variation. Knowledge Networks guarantees a minimum of 1000 responses**.**
- *Random representative sample*: Knowledge Networks' survey panel is a random, U.S. Census representative sample within a very low margin of error.
- *Cost-effectiveness*: Recruiting potential respondents through conventional methods, e.g. direct mailing techniques, presented a significant cost barrier. Knowledge Networks is able to recruit and survey a sample population for

less than it would have cost for us to purchase a nationwide mailing list for direct mailing.

- *Ease of data collection*: A completely web-based methodology made it possible for us to easily collect, tabulate and analyze the data. In addition, human errors associated with paper surveys were eliminated.

Knowledge Networks recruits the nationwide panel of respondents it surveys using a method known as random digitized dialing (RDD). RDD is a widely used technique in which listed and unlisted phone numbers are randomly dialed in order to contact potential panel members in an unbiased manner. RDD eliminates one of the major problems associated with typical internet surveys, self-selection bias. Self-selection refers to when a researcher either purposefully or inadvertently selects a panel of participants in a subjective or otherwise prejudiced manner. If the researcher somehow plays a hand in who will be participating in the survey, it is impossible to ascertain whether those respondents are systematically different from persons who did not respond.

RDD also helps diminish the effect of coverage bias, which occurs when the sample population of the area being surveyed does not accurately represent the area population. Coverage bias is an inherent problem for most internet surveys: only 57% of US households are equipped with internet access (Couper 2000), and a method of systematically contacting those households is not available. On the other hand, 96% of US households are equipped with telephones and comprehensive lists exist for these households (Pineau 2003). This means that households with telephones may be contacted in a systematized manner. Results yielded from RDD sample pools are significantly less affected by coverage bias.

Knowledge Networks' panel of respondents includes households with and without internet access. Households without internet access are able to take the survey using an interactive television set. This solution to the coverage problem has allowed KN to conduct online surveys as if it were reaching a sample of almost all of the households in the US. The major benefit is results yielded from surveys taken by KN's sample population can be projected onto the US population (once adjusted for US Census figures).

Human subjects consent agreement

In compliance with federal law, it is the policy of the University of California, Santa Barbara, to inform survey participants that they are participating in a research survey and that they are entitled to rights and protections under federal law. Before participating in our survey, participants were made aware of their entitlements and required to electronically sign an agreement that they understood these entitlements and consented to participating in the survey. Participants were given the contact information of the researchers and the Office of Research at UCSB for further inquiry into the nature of the survey, their rights as research subjects, and information regarding research-related injuries.

2. E. Industry Demand Survey

Purpose

The purpose of the industry survey was two-fold:

- To compare consumers' own stated WTP with perceptions in the building industry of consumers' WTP. Building industry professionals would be familiar with the choices that homebuyers actually make. Further, if asked about the preferences of homebuyers, it seemed that they would be less likely to yea-say: they would not be responding about their own preferences, and should not have an inherent interest or bias in misrepresenting consumers' preferences. Because of these factors the industry survey could serve as a useful reality check for the consumer survey data.
- To evaluate whether builders would be likely to adopt the straw block. The survey could also be used to determine which aspects of the CP block made it appealing (or unappealing) to builders, and whether they would be likely to adopt it for their own projects. This question would go beyond consumer demand and try to gauge builders' perceptions about other factors such as material cost, ease of construction, or regulatory acceptance.

Design

Industry perception of consumer willingness to pay

The second survey, intended for experts and decision-makers in the building industry, was developed parallel to the consumer demand survey. The main question in the consumer survey was modified for the industry audience in order to analyze the potential gap between consumers' stated demand and the industry perception of consumer demand. While the consumer survey asked respondents if they would purchase a CP Block home over a standard home, the industry survey asked the respondent to estimate the percentage of consumers that would purchase a CP Block home, based on an offered price. Rather than giving the respondent one price to base their consumer purchase estimate on, we asked the industry representatives to estimate the consumer demand for the straw block home for the entire range of price points (from $5,000 less than to $25,000 more than the cost of a conventional home).

This portion of the survey would have two variations matching two of the versions of our consumer survey. One version for builders would present only the private benefits (analogous to the consumer PrivStraw survey), while the other would also present the environmental benefits (as the PrivPubStraw survey had). However, all versions would acknowledge the block was straw (and thus there would be no PrivNew version of the survey). This was necessary because the second major question we wanted to explore was whether and why builders would use the compressed straw block in building projects, and we felt builders would want to know what the block was made of before answering such questions.

Two versions of the industry survey were developed. One described only the private benefits of CP Block house (analogous to the consumer PrivStraw survey), while the other also presented the public environmental benefits of owning a CP Block home (as the PrivPubStraw survey had). A third version of the survey, modeled after the PrivNew survey and describing the block as a “new building material”, was deemed inappropriate because we were also going to be asking builders if they would be likely to use the block in their own building projects. Builders would need to know what the block was made of before making that decision. After asking each respondent to estimate the consumer demand for the CP Block, we asked them to rate the factors that would influence a homebuyer making a decision about whether to buy a CP Block house.

Likelihood of straw block inclusion in the mainstream residential building market

In order to determine the particular factors that might limit the straw block’s inclusion as a viable building material option, we asked the respondents their overall opinion on the performance of the CP Block wall compared to a standard wall system. Further, in order to analyze whether the building industry is likely to build CP Block homes, we asked the industry respondents if they or their company would consider adopting the CP Block as part of their building portfolio, based on the assumption that the CP Block is International Code Council (ICC) approved. Demographic questions were also incorporated to help profile the respondents, their specific industry or employer, and their types of residential projects.

Distribution

The industry survey was developed through an online survey tool, Survey Monkey (www.surveymonkey.com). For a nominal fee, Survey Monkey offers a professional subscription that allows the creation of unlimited surveys, unlimited number of survey questions, and storage of 1,000 responses. The Survey Monkey user interface was non-technical and easy to use. In addition, it offered added features like survey logic functions, data filtering options, and the ability to import raw data into Microsoft Excel.

Because the survey was distributed online, the potential audience was limited by internet access. The research team investigated industry and professional associations that could broadly and electronically distribute the invitation to their members. After making multiple contacts with industry representatives, the survey was distributed across the nation by placing an announcement in various industry newsletters with the intention of reaching industry association members and employees. An invitation to take the survey and a short introductory paragraph (Appendix E), along with active links to the survey, was published in:

- Nation's Building News, the weekly newsletter for members of the National Association of Homebuilders (www.nahb.org/nbn) from December 12th, 2005 – January 31st, 2006.
- American Institute of Architects Housing Committee newsletter in January 2006.
- United States Green Building Council monthly newsletter in January 2006.
- BDMag, the monthly regional professional homebuilder's magazine serving California, Arizona, Nevada, and the West (www.bdmag.com) in the January 2006 issue.

The respondents were directed to a web site which randomly assigned the user to one of the two survey versions (private benefits only or private and public environmental benefits). The survey offered respondents the chance to participate in a prize drawing for a $50 Visa gift card, sponsored by the research group. Due to a low initial response rate, additional industry respondents were contacted directly.

CHAPTER 3: RESULTS

3. A. Consumer Survey

Overview

A total of 1720 panel members received an invitation to the survey, 1238 of those read the consent form, and 1026 consented to take the survey. The rate of response can be measured in two ways: a percentage (60%) which is simply the number of persons invited to the survey who responded and a percentage (70%) which excludes those persons who did not consent to take the survey. Five respondents were not included in the analysis because they did not answer the main purchase question.

The survey sample obtained from KN is representative of the US population according to Census demographics with respect to average age, gender, and household income, as shown in Table 3.1. The KN group appears to be one education level above the Census group.

Table 3.1: KN sample demographics compared with US population data

Demographic	*KN (2006)*	*US Census (2000)*
Median age (years)	47	47
Percent male	47%	47%
Median household income	$40,000 - $49,999	$40,000 - $44,999
Median education (yrs)	14	12

Respondents were randomly assigned to surveys which varied only by the description of the building material of the wall, the type of benefits associated with each house, and the bid price of the straw home. Tables 3.2 and 3.3 illustrate that the surveys were distributed in the intended manner, and that the margins of error were very low across all categories.

Table 3.2: Actual and expected numbers of respondents by survey type

Survey Type	*Expected*	*Actual*	*% Diff*
Private, “New Material” (PrivNew)	341.3	345	+1%
Private, "Straw" (PrivStraw)	341.3	342	0%
Private and Public, "Straw"	341.3	337	-1%
Total	**1,024**	**1,024**	

Table 3.3: Actual and expected numbers of respondents by bid price

Bid Price	*Proportion*	*Expected*	*Actual*	*% Diff*
$ (5,000)	0.10	102	101	1%
$ 2,000	0.15	154	163	-6%
$ 6,000	0.25	256	259	-1%
$ 12,000	0.35	358	348	3%
$ 25,000	0.15	154	153	0%
Total	**1.00**	**1,024**	**1,024**	

Model results

The logit regression was run using all of the modeled parameters. A few of the respondents were dropped from the analysis because of missing data: home price was not available for 53 respondents, and ideology was not available for another 70. The logit regression was therefore run on 901 responses. Table 3.4 reports coefficient estimates, t-stats, and marginal effects for the modeled parameters.

Table 3.4: Summary of consumer survey results using all modeled parameters ("full form" model)

Coefficient	*Estimate*	*t-stat*	*ME*
INTERCEPT	0.6954	0.95	—
Product Characteristics			
BIDPRICE	-0.0474	-5.60 ***	-0.0118
PRIVATE_NEW	0.6466	3.82 ***	0.1614
PRIVATE_PUB_STRAW	0.2804	1.65 *	0.0700
Demographic Characteristics			
INCOME	-0.00144	-0.67	-0.00036
EDUCATION	-0.0263	-0.93	-0.00656
AGE	0.00662	1.47	0.00165
HOMEPRICE	-0.00054	-0.60	-0.00013
IDEOLOGY	-0.0697	-1.41	-0.0174
TEMPDIFF	0.00675	0.56	0.00169
PRECIPITATION	0.00028	0.05	0.000069
MALE	-0.0869	-0.63	-0.0217
OWN	-0.316	-1.85 *	-0.0788

Significance code * $p<0.1$ ** $p<0.05$ *** $p<0.01$

ME	marginal effect
BIDPRICE	price premium for CP Block house ($1,000s)
PRIVATE_NEW	respondent received the PrivNew survey
PRIVATE_PUB_STRAW	respondent received the PrivPubStraw survey
INCOME	respondent's income ($1,000s)

EDUCATION	respondent's education (years)
AGE	respondent's age (years)
HOMEPRICE	median home price in respondent's ZIP code ($1,000s)
IDEOLOGY	respondent's self-described ideology: 1-7 scale
TEMPDIFF	annual temperature variation in respondent ZIP code (°C)
PRECIPITATION	average annual precipitation in respondent ZIP code (in.)
MALE	respondent is male
OWN	respondent owns their place of residence

The coefficient for price (BIDPRICE) is statistically significant and negative. This accords with standard economic theory: as the price premium for a straw block house rises, a respondent is less likely to choose to buy it. The marginal effect shows that a $1,000 increase in the price premium will reduce the likelihood that a respondent will choose the straw block house by 1.2% holding all other variables equal.[9]

The parameter estimates for the different versions of the survey (PRIVATE_NEW and PRIVATE_PUB_STRAW) reveal the WTP for environmental benefits and the effect of naming the block as "straw." As can be seen from the marginal effects, those who received the version of the survey which detailed public environmental benefits were 7% more likely to choose the CP Block house than those who saw only the private benefits. (Note that the PrivStraw version of the survey is the baseline case due to the way the dummy variables are constructed.) Meanwhile, those who did not know the block was compressed straw (the PrivNew version of the survey) were much more likely to choose the CP Block house, by 16%. Both these coefficients are statistically significant in the model.

A couple of the variables went in unexpected directions. The marginal elasticity of the income term is negative; economic theory says that, *ceteris paribus*, the probability of buying a good should rise with income, assuming it is a normal good. However, the marginal effect of income is small, and further, we cannot reject the null hypothesis that the coefficient is zero. A similar situation exists for the education term. It is negative, but has a small marginal elasticity and is not significant.

[9] Recall that respondents are constrained to purchase a house, so the likelihood of choosing the wood frame house must rise by the same percentage. To illustrate, suppose the logit model predicts that, when the straw block house costs $10,000 more, a specific potential buyer has a 43% chance of buying the straw block house, and therefore a 57% chance of buying the wood frame house. If the price premium rises to $11,000 the same buyer will have a 41.8% chance of buying the straw block house, and a 58.2% chance of buying the wood frame house.

Finally, the other significant term in the model is home ownership: those who own their homes (~70% of the survey sample) were approximately 8% less likely to choose the straw block house. We surmise that a likely explanation is that homeowners can relate to the hypothetical scenario more realistically because they have purchased a home in the past, and therefore have a lower tendency to overstate their WTP. Another possible explanation is that renters, who tend to be younger and less established, may be more open to alternative construction materials. It is also possible that a portion of this effect is endogenous, as most current homeowners will own a wood frame house, suggesting a previous preference for wood frame housing. Without further data, however, it is not possible to conclusively decide what explains this effect.

Extrapolation to US population

To derive a demand curve for the US, we needed a model which incorporated only those parameters for which data could be obtained for all counties in the US. The ideology variable was thus removed from the model. For simplicity the two weather variables (temperature difference and precipitation) were also removed from the model. (None of these removed variables were significant in the full form model.) The 70 respondents who were missing ideology data were added back into the sample group to give a total sample population of 971. The logit regression was run with these data to obtain the reduced form model presented in Table 3.5.

Table 3.5: Summary of consumer survey results using model parameters available from US Census ("reduced form" model)

Coefficient	*Estimate*	*t-stat*	*ME*
INTERCEPT	0.718	1.65 *	—
Product Characteristics			
PRICE	-0.0471	-5.77 ***	-0.0118
PRIVATE_NEW	0.684	4.19 ***	0.171
PRIVATE_PUB_STRAW	0.292	1.79 *	0.0729
Demographic Characteristics			
INCOME	-0.00217	-1.05	-0.000542
EDUCATION	-0.0240	-0.89	-0.00598
AGE	0.00617	1.43	0.00154
HOMEPRICE	-0.00064	-0.81	-0.00016
MALE	-0.0477	-0.36	-0.0119
OWN	-0.409	-2.51 **	-0.102

Significance code * p<0.1 ** p<0.05 *** p<0.01

In comparing the full and reduced form models, note that most of the marginal effects are nearly identical in both models, suggesting the model is robust to the key variables. Price remains significant and downward sloping. Both of the survey type dummy variables retain similar values. Home ownership remains a significant factor in probability of choosing straw block housing. Table 3.6 summarizes the marginal effect of the major variables in our model.

Table 3.6: Marginal effects: Change in percentage of buyers predicted to choose the straw block house from a change in variables

Variable	*Change*	*Change in % buyers*
Significant variables		
Price	▲ $1000	▼ 1.2%
Environment	Environmental benefits explained	▲ 7.3%
"Straw Effect"	Block called straw	▼ 17%
Home ownership	Respondent owns home	▼ 10%
Non-significant variables		
Income	▲ $10,000/year	▼ 0.5%
Age	▲ 10 years	▲ 1.5%
Education	▲ 1 year	▼ 0.6%

Three demand curves were produced from the reduced model, one for each survey version. As discussed previously, we feel that current homeowners could provide a more realistic evaluation of the hypothetical presented in the survey, so the ownership variable was used in constructing all demand curves. The curves are presented in Figure 3.1.

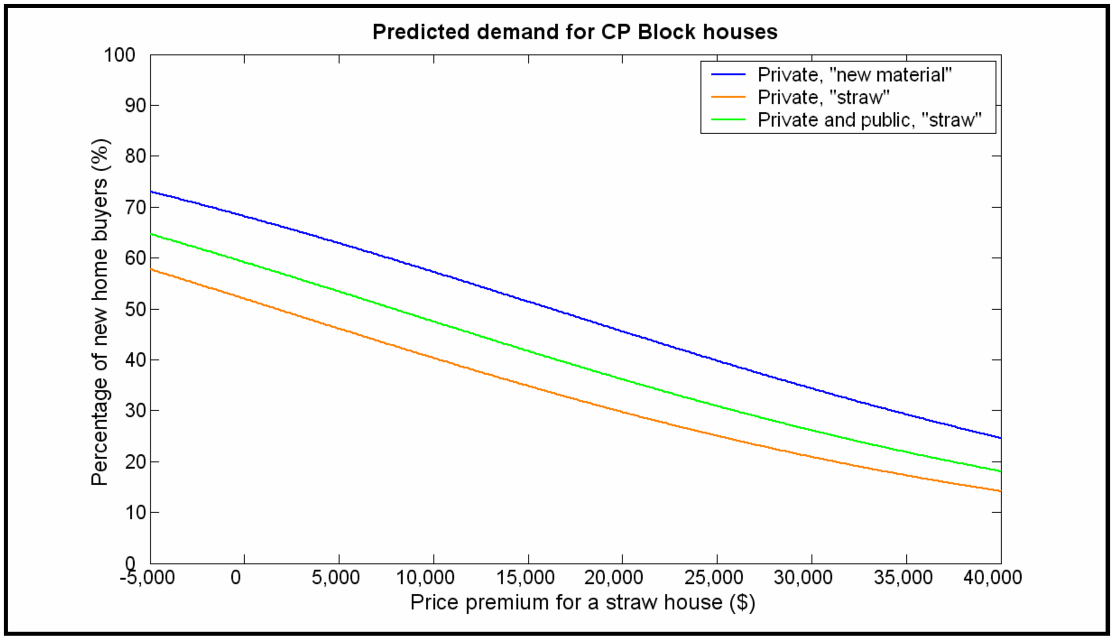


Figure 3.1: Predicted demand for CP Block houses, reduced form model

Extrapolation to housing demand in California

We used the reduced form model with county-level data for California to generate a map of counties in California with the greatest projected demand and determine the location of "hotspots". The logit probability for the PrivStraw curve and a price premium of $6000 was calculated for each county. Next, we downloaded the number of new homes per county built between 1999 and 2000 (the most current available complete dataset) and used this with our logit model to predict the percentage of CP Block homes that would be bought per county.

Next, we used ESRI GIS software (ArcCatalog and ArcMap) to construct the predicted demand per county in California using shapefiles from the US Census cartographic boundary files. A map was constructed to accurately reflect the predicted hotspots for the CP Block home market. The number of projected CP Block homes per county was divided by the total area of the county to obtain a forecasted density per county. In addition, data downloaded from the California Department of Water Resources were used to construct a layer indicating the location of rice fields in the state. The final map is shown in Figure 3.2.

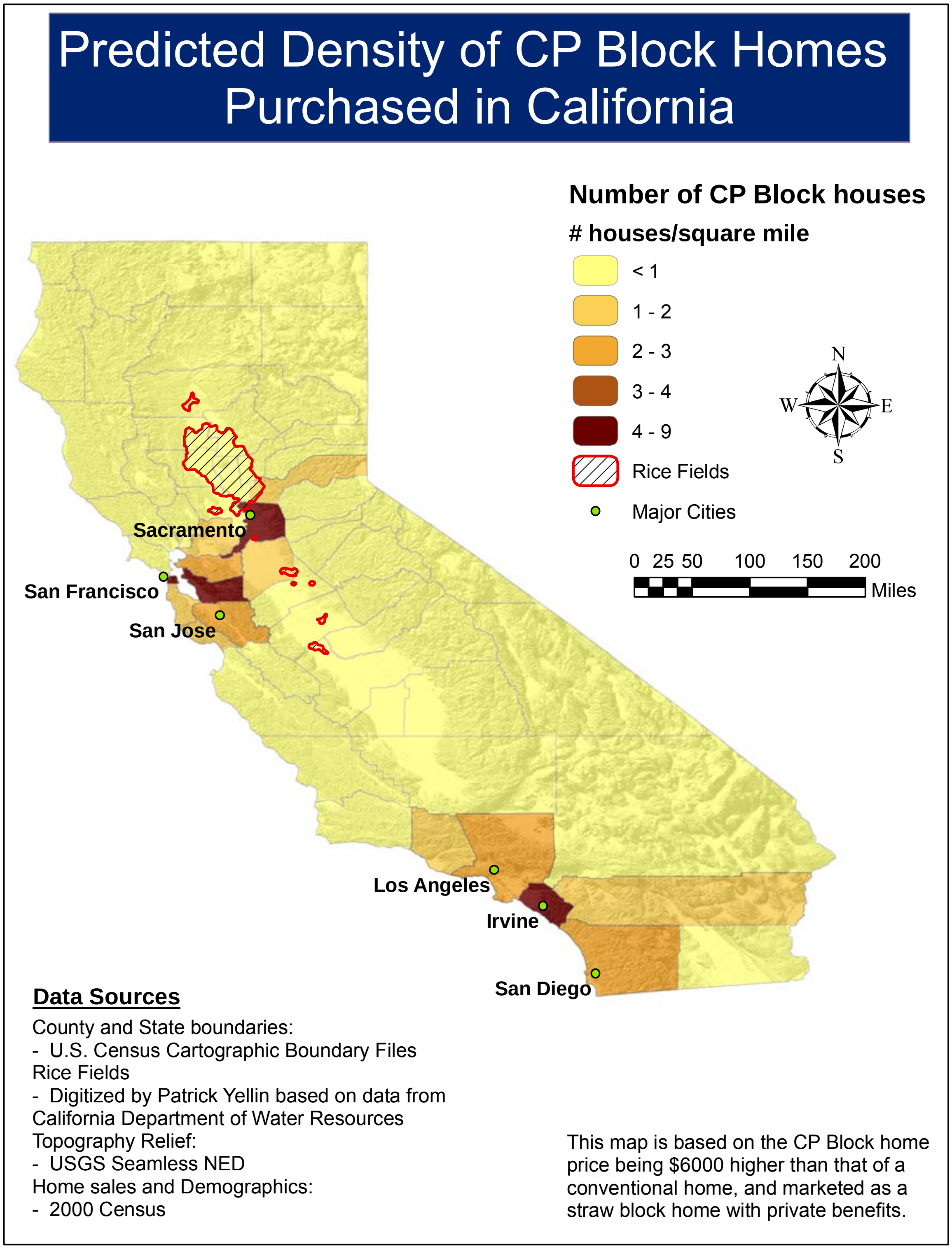


Figure 3.2: Predicted density of CP Block homes purchased in California

This map tells us two different things: the location of hotspots in California, and the proximity of the hotspots in northern California to the rice fields. This proximity is beneficial to Oryzatech, because the transportation costs will be lower as a large majority of potential building sites will be close by, in Sacramento and the East Bay.

To project the potential demand for CP Block houses in the Southwest (defined as California, Nevada, Arizona, New Mexico, Utah and Colorado), a GIS map was created in the same manner as the California projected demand map (Figure 3.3).

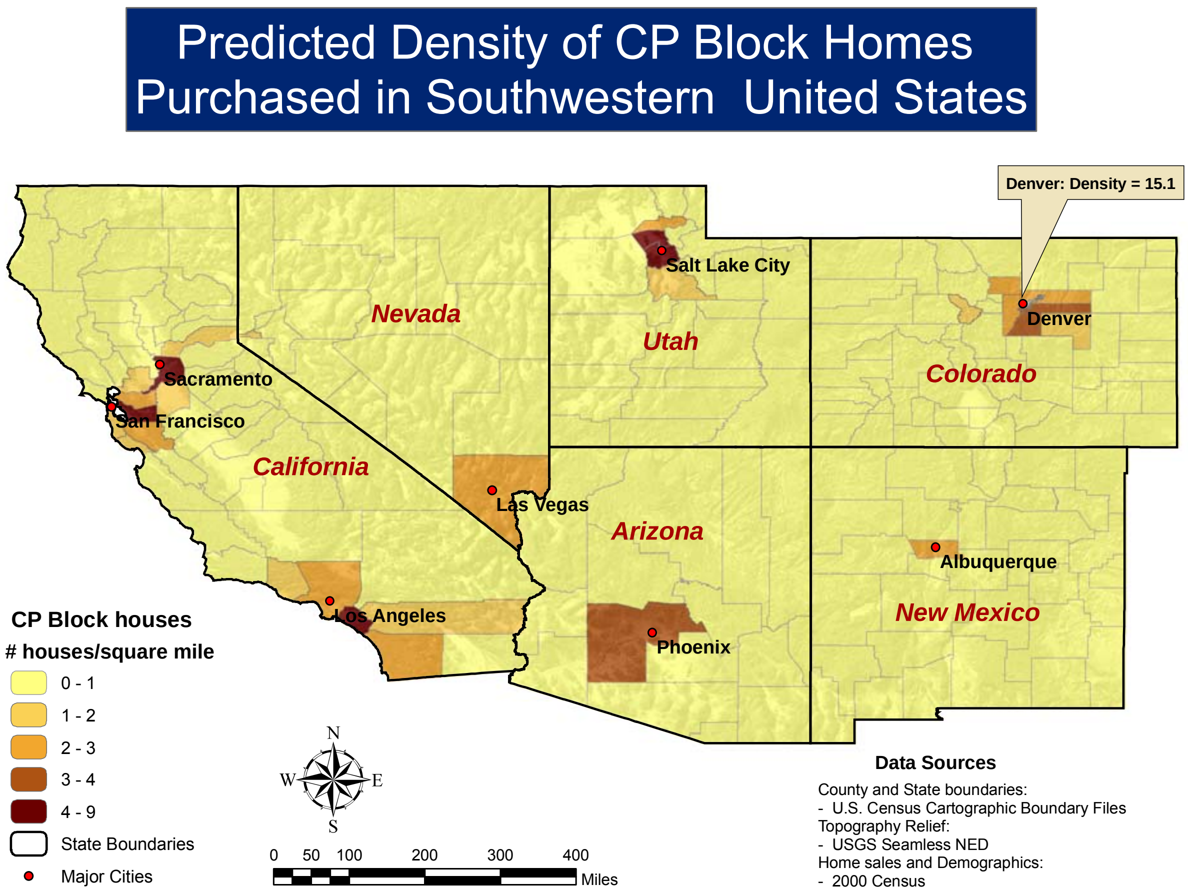


Figure 3.3: Predicted density of CP Block homes purchased in Southwestern US

It is clear that hotspots are related to the major cities of the Southwest, with Denver and Salt Lake City having the highest densities outside California. The highest predicted density is in Denver, where it was slightly more than 15 houses per square mile, by far the highest in the Southwest.

3. B. Industry Survey

Overview

There were 95 respondents to the industry survey. The two main questions regarding the estimation of consumer demand and the likelihood of the respondent to adopt the block as a conventional building material had 74 and 65 responses, respectively. Incomplete responses are attributed to the “skip question” feature added to less important questions.

The respondents represented all four major regions of the United States: Northeast, Midwest, South and West and all political ideologies. The majority of the surveyed industry professionals were:

- male
- between the ages 25 and 64 years
- college-educated
- employed at small or medium-sized firms
- earning over $40,000/year

Over 60% of the respondents were employed in the building industry as architects, engineers, developers, or members of a design or construction team. The remaining respondents were building material manufacturers or employed in the administrative, research, or policy sectors of the building industry. Almost 70% of the respondents were members of either the National Association of Homebuilders (NAHB) or the United States Green Building Council (USGBC).

Almost 90% of the respondents worked in residential construction, mainly on custom homes or multifamily projects, and some of the respondents were additionally involved in commercial and institutional construction. The majority of the respondents always or frequently worked with wood stud construction and occasionally or rarely worked with CMU, ICF, steel frame, or other alternative materials. Summary tables for the survey responses are presented in Appendix F.

Industry perception of consumer demand

Between both surveys, 74 respondents estimated the percentage of consumers they expected would choose to purchase the CP Block house. There was significant variance in the estimates, and the 95% confidence interval was very large at each price point for both the private benefits survey and the private and public benefits survey. There were individual estimations of 0% to 100% depending on the price point.

The 74 responses were analyzed in our linear model of industry-predicted consumer demand to generate the graph below. Parameter estimates for the variables are given in Table 3.7.

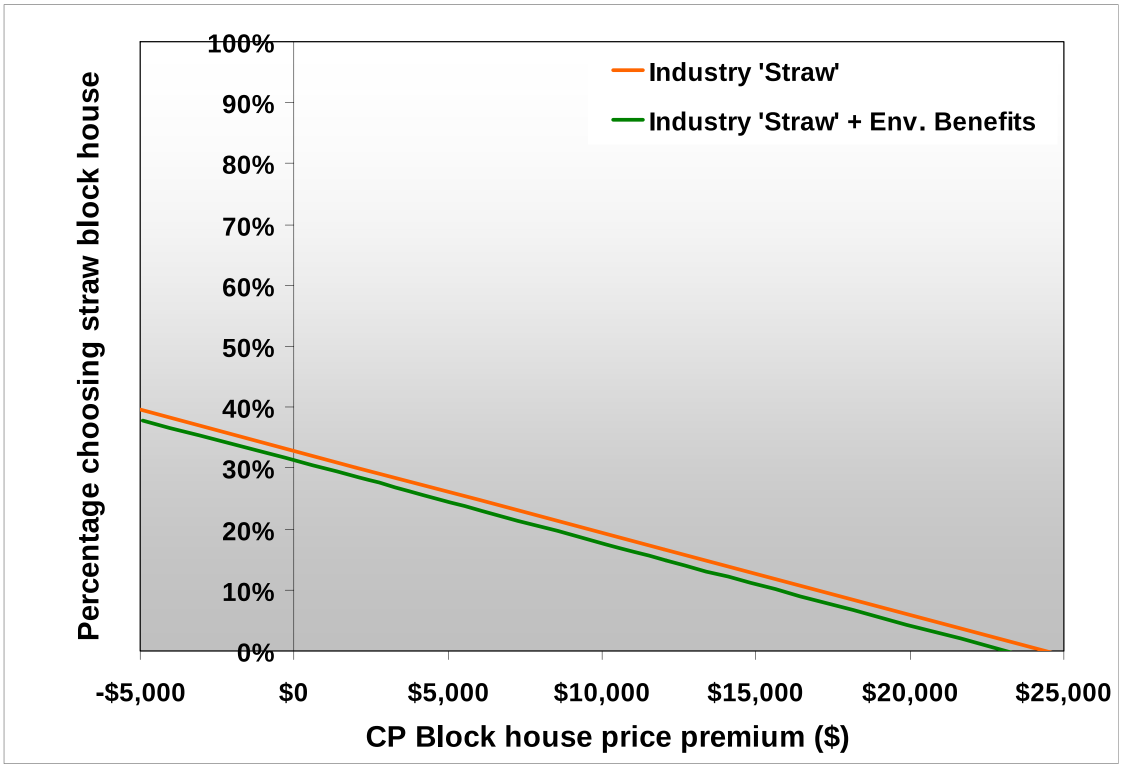


Figure 3.4: Industry-predicted consumer demand

Table 3.7: Parameter estimates for variables in industry survey

Coefficient	***Estimate***	***t-stat***
Intercept	31.06	19.08 ***
Price	-1.345	-10.71 ***
Survey w/ public env. benefits	-1.784	1.39

Significance code:* p<0.1 ** p<0.05 *** p<0.01

The data show that price is statistically significant. When the relative price of the CP Block house increases by $1,000, the amount of consumers estimated to choose the home decreases by 1.35%. Surprisingly, the industry-predicted consumer demand for the survey that described the public environmental benefits of the straw block house was lower than the industry-predicted demand for the survey listing only private benefits. However, according to the linear regression results, there is no statistical difference between the two sets of responses.

Comparison of consumer demand and industry-predicted consumer demand

The industry-predicted consumer demand curve was compared to the stated consumer demand curve. There is a large gap between the consumer demand curve and the industry's prediction. The industry-estimated percentage of consumers that would choose the straw block home was about 25 percentage points lower than the consumer survey estimation. Despite the gap, however, note that the slopes of the curves are nearly identical; this indicates that both survey instruments estimated the same marginal effect of price on willingness (or likelihood) to buy a straw block home.

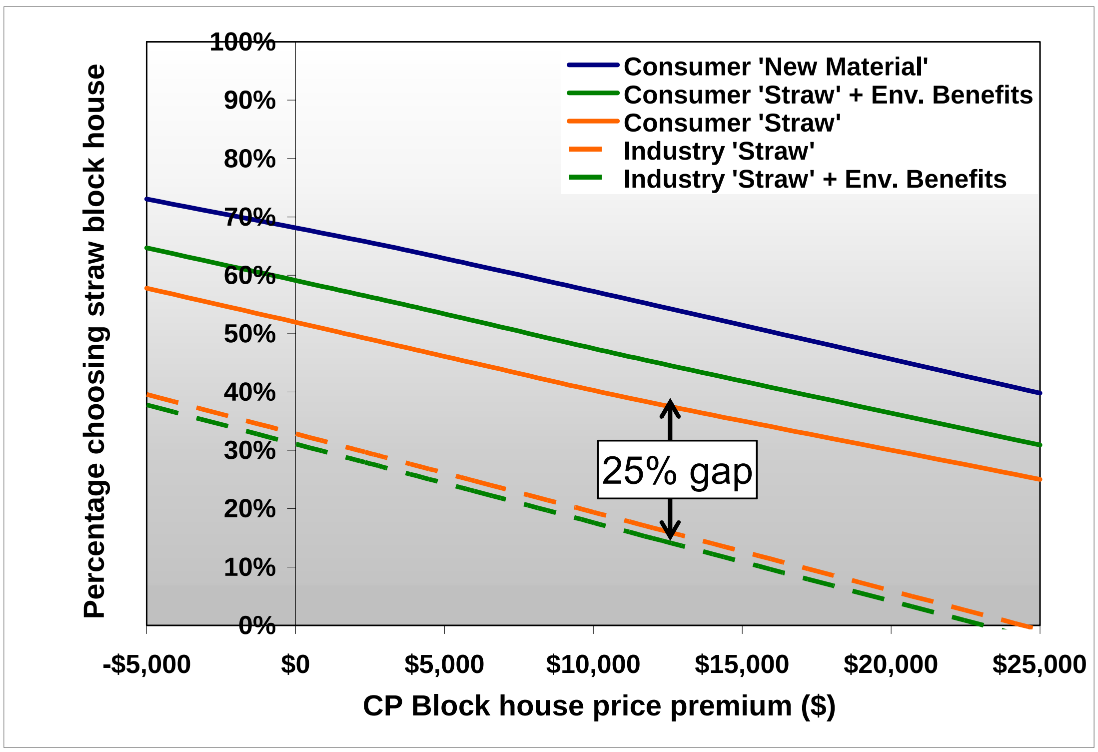


Figure 3.5: Consumer demand and industry-predicted consumer demand

Industry rating of home buying factors important to consumers

The industry was prompted to rate the factors that consumers would consider when deciding between the conventional house and the straw block house. Respondents were offered five levels of importance from extremely important to not important. The percentage of respondents that rated the following characteristics as extremely or very important are listed in Table 3.8.

Table 3.8: Industry rating of home buying factors important to consumers

Characteristics of CP Block home	*Percentage of "Extremely important" or "Very important" responses*
Heating/cooling costs	75%
Interior area	73%
Moisture resistance	59%
Insulation	55%
Environmental benefits	29%
Soundproofing	25%
Wall thickness	21%

Industry willingness to adopt the CP Block

In addition to comparing the demand curves, we asked the industry to rate the block's projected performance and if they would be likely to build CP Block homes.

Summary assessment of CP Block

Respondents were asked to rate a straw block wall, as it compares to conventional wall systems, across factors that impact market performance.

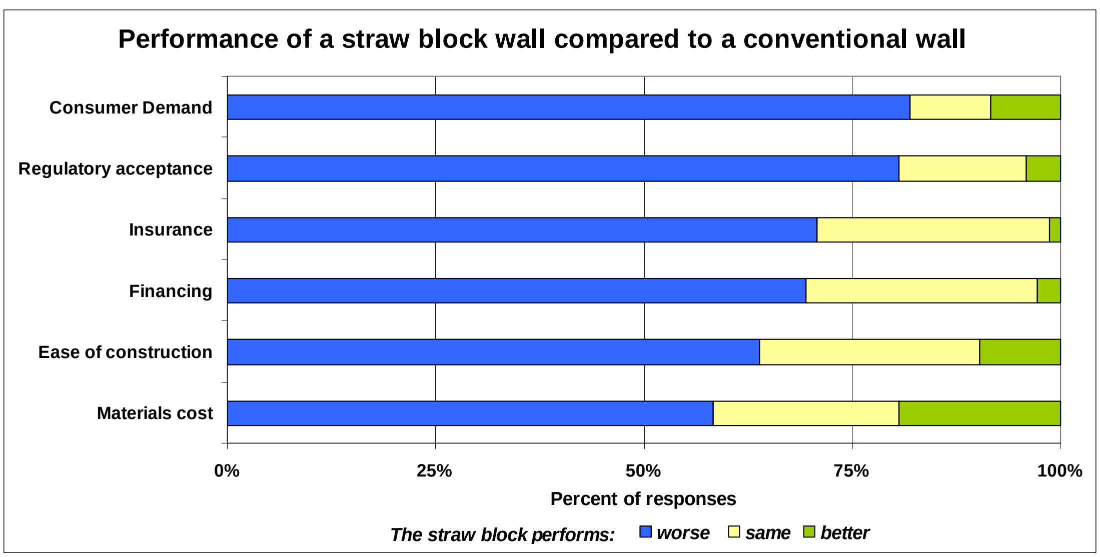


Figure 3.6: Performance of a straw block wall compared to a conventional wall

Over 60% of the industry felt that a straw block wall would perform worse than a conventional wall across all of the given factors. About 10%-30% of the industry believed a straw block wall would perform the same as a conventional wall and about 1%-10% thought a straw block wall would perform better.

Willingness to adopt the CP Block

Thirty industry professionals responded that they would be willing to adopt the block at their firm while thirty five industry professionals indicated that they would not. Six respondents either did not reply or stated that they were uncertain.

Logistic regression was used to establish which factors were significant in influencing the likelihood a builder said they would adopt the CP Block. The respondents' own estimate of consumer demand (expressed as the average percent of consumers predicted to purchase the straw block house) and their rating of ease of construction are the significant factors in a respondent's willingness to adopt.

Table 3.9: Factors that influence willingness to build (logistic regression)

Factor	***Estimate***	***Prob>ChiSq***
Intercept	-4.89	0.0036
Survey type	0.092	0.8221
Revenue of firm	-0.000163	0.4615
Average demand estimate (% of buyers)	**0.114**	**0.0058**
Consumer demand	0.227	0.4851
Materials cost	0.215	0.5373
Ease of construction	**0.736**	**0.0712**
Regulatory acceptance	-0.635	0.2381
Insurance	0.419	0.4588
Financing	0.0082	0.9873
NAHB membership	-0.193	0.6561
USGBC membership	-0.0727	0.8787

Summary of open-ended responses

Almost 40 respondents had comments about the CP Block and straw blocks in general. The most common concern was the need for more detailed information on the CP Block, especially on the issue of moisture resistance. Respondents were concerned how the CP Block would resist moisture, mold, or mildew and remain structurally sound. Other comments included the need for more information on ease of construction and the projected availability of the CP Block.

CHAPTER 4: DISCUSSION AND RECOMMENDATIONS

4. A. Consumer Survey

Demand for green building materials

The results of our contingent valuation consumer survey suggest there is substantial demand for straw block housing; indeed, so great a demand that the results are hard to believe at first. The data indicate that even at a substantial price premium of $10,000 that around half of new homebuyers would choose a straw block house. This does not pass a common sense litmus test, at least not in the near-term. Actual penetration rates of alternative materials into the US residential housing market suggest that currently it is very difficult for new materials to achieve even a few percent of the market. Part of the explanation for the results lies in the tendency of survey respondents to overstate their willingness to pay in CV studies, an effect called yea-saying which is widely recognized in the economics literature (Blumenschien et al. 1998). Results from the industry survey provide confirmation of this, as builders had much lower estimates of demand.

The consumer survey results become more reasonable, however, when characterized as the long-run demand for any green or alternative construction material with characteristics similar to the CP Block. Because the survey limited respondents to either a wood frame or a CP Block home, many respondents may be choosing the advantages of the CP Block rather than the Block itself. Given the choice among a full range of green or alternative wall materials which offered similar benefits, some homebuyers would undoubtedly choose other technologies. When survey results are viewed from this perspective they become far more believable. It is not unreasonable to think that, upon obtaining supplier and code acceptance and reaching full market penetration, that green and alternative materials could constitute half of the US residential housing market. Our survey results indicate that potential homebuyers want the benefits green buildings provide.

Willingness-to-pay effects

Our consumer survey research allows us to quantify the size of the “straw effect” and WTP for the public environmental goods the CP Block provides. For the “straw effect,” the difference between the survey naming it “compressed rice straw” and the one naming it “a new building material” indicates that WTP drops by $14,500 when the respondent knows the house is made from compressed straw. (This amount corresponds to the horizontal distance between the two demand curves for a given proportion of buyers.) This was a large and statistically significant effect in our analysis.

Why the large effect? Although our survey research did not directly address this question, interactions with pre-test respondents and conversations with friends and colleagues over the course of our research provide some clues. Doubtless a portion comes from cultural perceptions—the “Three Little Pigs Effect,” as it were. The children’s story, in which a wolf blows down the straw home of the first little pig, came up frequently when discussing our research with friends and colleagues. While it was (usually) brought up as a joke, more serious concerns were also frequently expressed: flammability, moisture and mold, susceptibility to rodents and pests, and structural stability. Although inquirers were usually more open-minded once these initial questions were answered, their initial concerns probably come from the lack of any experience with straw as a building material, making most people immediately skeptical of its structural properties. Further, with regard to pest susceptibility, many people confuse straw, the dried stalk of cereal grains, with hay, the mown grass that is meant for livestock feed. Our guess is that it may be common knowledge that hay is a food source, while fewer people know that straw is not a food source. Finally, a portion of the straw effect is doubtless based on a realistic perception of its suitability; for example, since moisture susceptibility is an issue, homebuyers in very wet climates would be appropriately put off by the prospect of a straw block house.

Our research also measured WTP for public environmental goods. The version of the survey which listed the environmental benefits provided a basis to measure WTP for the public goods characteristics of straw block housing. The difference between the PrivStraw and the PrivPubStraw surveys suggests that respondents were willing to pay $6200 on average for the environmental goods listed in the latter version of the survey.

4. B. Industry Assessment of the CP Block

The invitation to take the industry survey was widely distributed and the response rate was low, suggesting there was self-selection among respondents. The responses can therefore not be considered a random and representative sample of building industry professionals. While a large, random, structured distribution would have been preferable and provided a more statistically accurate sample of the national building industry, the results obtained are still useful. Rather than viewing survey results as an accurate statistical predictor of industry response to the CP

Block, they should be considered a preliminary assessment which provides useful insight into how the building industry views:

- consumer demand for a new alternative building material
- the potential performance of the CP Block
- characteristics of the CP block that most influence consumer willingness to pay and the industry's willingness to adopt

Predicted consumer demand

As indicated by the industry prediction of consumer demand, there was no difference in the responses of those who saw the public environmental benefits and those who did not. This indicates the industry does not think environmental benefits are important to consumers, a fact that is supported by the industry's rating of which factors are important to consumers. Only 29% of the industry sample believed that environmental benefits were extremely or very important to consumers, compared to the 75% that thought heating and cooling cost were extremely or very important.

Comparison of consumer demand and industry-predicted consumer demand

The large gap between the consumer demand curve and the industry's prediction of the consumer demand curve can partly be explained by the theory of hypothetical bias, or yea-saying. Hypothetical biases occur when contingent demand questions do not elicit responses that are consistent with actual behavior (Champ 2001). The contingent valuation method used to determine consumer demand was based on a hypothetical choice between the conventional home and the straw block home. Previous research has indicated that similar dichotomous choice contingent valuation methods can result in hypothetical bias and overestimate the real WTP (Blumenschien et al. 1998). Because our consumer survey methods were constrained by cost and technology, it was impractical to include an additional question that would screen for yea-sayers. In terms of the industry response we are uncertain if the estimates are realistic, pessimistic, or a combination of both. We can assume that builders, due to their experience, are aware of consumer demand and their WTP, but we also know the building industry is very conservative and slow to adopt alternative methods. Additionally, the industry's evaluation of the CP Block's potential performance indicates why they estimated a low consumer demand.

At the same time, even the builders' lower estimate represents a large potential market for the CP Block. For example, at a $10,000 price premium, builders estimated that around 20% of new buyers would choose a straw block house, still an enormous market. Further, as discussed previously, the consumer survey may have measured the long-run demand for all alternative materials. Builders, on the other hand, may have been taking the short view, and further, would be more familiar with other materials with similar characteristics that homebuyers might choose.[10] This would explain a portion of the gap. While we cannot conclusively decide from the data where the demand curve lies, the results of the two surveys taken together indicate that there could be a large market for straw blocking housing.

Building industry attitudes and perceptions

Potential performance of the CP Block

The industry overwhelming rated the CP block as performing worse than conventional materials. The logistic regression on likeliness to adopt revealed that the estimated consumer demand and the rating of construction ease had a significant effect on the likelihood of the industry respondent to adopt the straw block as a viable building material. The greater the predicted percent of consumers who choose the straw block house (the greater the perceived demand), the more likely the industry respondent would be willing to adopt the block as a building material at their firm. In addition, the higher the block was rated for ease of construction (i.e. the easier the straw block was perceived to construct with), the more likely the industry would be willing to build with the block. This suggests that perceptions of these two factors will be instrumental in builders' choice to adopt the CP Block.

Open-ended responses received on the survey suggest additional perceptions that will influence adoption. Many builders simply wanted to know more about the block; some felt they could not answer because there was not enough information provided. Other comments received indicate that concerns about the CP Block's resistance to moisture may be an important factor in marketing the block down the road.

Concerns about moisture

To investigate the relationship between the predicted hotspots and precipitation, the Southwest demand map was modified to include the average annual precipitation. The result is shown in Figure 4.1. It is intriguing that the majority of the hotspots correspond with areas of low precipitation. Even though the precipitation data did not have significant effect on our consumer demand model, the fact that most of the hotspots are located in arid areas may alleviate the industry's concerns about moisture problems. This would help with marketing, because there may be less concern about moisture damage in these drier areas than in, for example, the Southeastern US.

[10] We received a few open-ended responses about ICF or SIPs as alternatives which indicated this was the case.

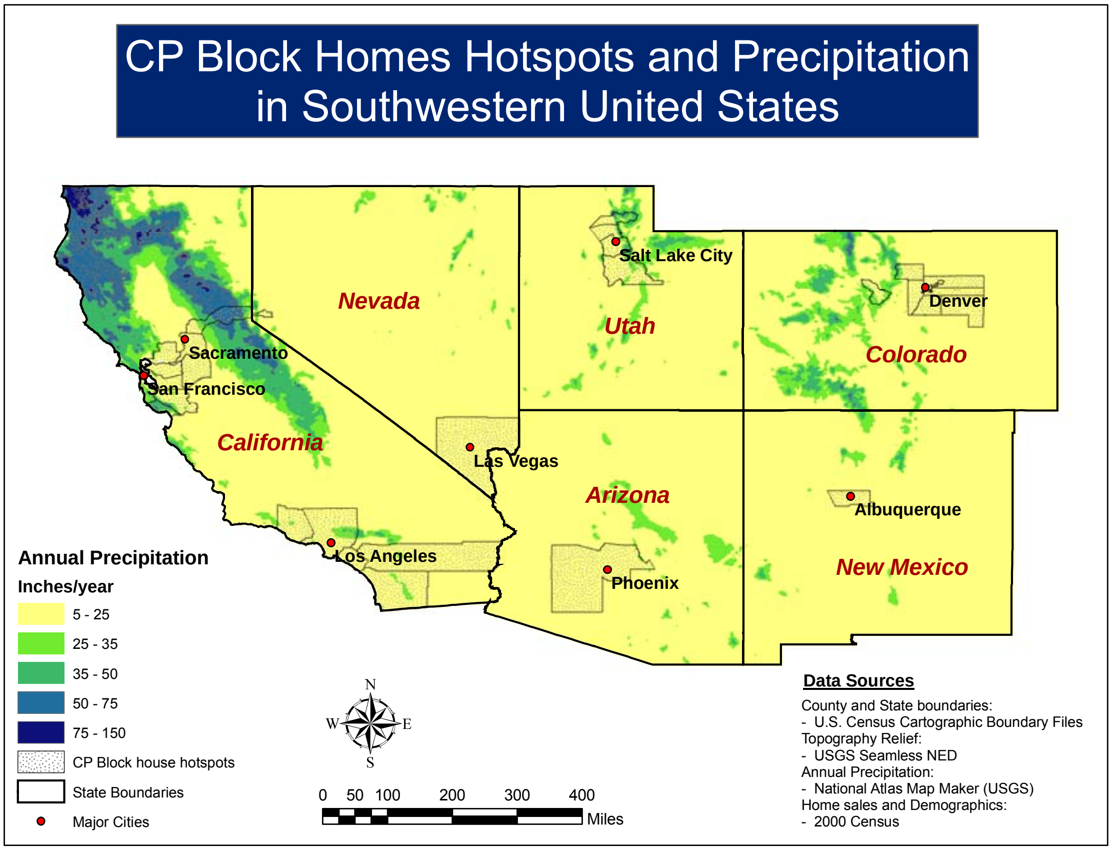


Figure 4.1: CP Block homes hotspots and precipitation in the Southwest

4. C. Straw Block Homes: Potential Market Size and Impact

What do our results suggest about the potential market size for CP Block homes? What impact would this have on rice straw in California? And how should Oryzatech price the CP Block to get there?

To answer these questions we will take the industry-estimated demand curve to represent actual demand. We assume that the entire price difference between a CP Block home and a nearly identical wood frame home comes from the cost of the wall system itself, both materials and labor. We then have to make a few reasonable guesses as to the cost of materials and labor. We assume that:

- a wood frame wall for an average size home (~2000 sq. ft.) costs $13,500 (Melchiori Construction Company 2005)
- the production cost of a CP Block is $4
- 1300 CP Blocks are required to construct a 2000 sq. ft. home
- the cost of other materials in a CP Block wall is $1300

The revenue-maximizing price for Oryzatech under these assumptions will be when the CP Block home costs $15,000 more than a conventional home. The optimal price for the CP Block itself depends on the assumptions made about labor costs for CP Block walls. If labor costs represent two-thirds of the cost of a wall system (a standard building industry estimate (Melchiori Construction Company 2005)), then the CP Block should be priced at $6.28/block. If, on the other hand, labor costs are constant at $13,000[11], then the CP Block should be priced at $10.85/block. Although this is a wide range, if the assumptions about wood frame wall costs, CP Block production costs, and other costs of materials in a CP Block wall are relatively close, then the profit-maximizing price will be one which results in a $15,000 price premium for the CP Block home, regardless of how the Block itself is priced.

The demand curve predicts that a price premium of $15,000 will lead to 12% of the new home market having CP Block walls. In California this would mean ~18,000 CP Block houses.[12] This would require approximately 370,000 tons of rice straw, providing an economically viable use for about one-third of the rice straw produced in California each year.

4. D. Suggestions for Further Research

While our analyses yielded significant results, there are aspects of the research that could be examined further. We recommend that future research could aim to:

- measure the effect each benefit had on a homebuyer's purchase decision
- uncover the reasons behind the "straw effect"
- survey a larger number of building industry professionals
- create a more rigorous product comparison

Measuring the effect each benefit had on a homebuyer's purchase decision

Our survey presented respondents with a choice between two homes, with the walls made out of different materials. The characteristics of each home, along with its private and public benefits were all made known to the respondent. The benefits were presented as a package, yet we would have liked to know the relative effect of

[11] This price comes from assuming CP Block wall labor costs at 2/3 of the total wall cost when the Block is priced at $4. This was an assumption results in a price difference of $6,000, and was used in deciding where to center the price differences on the surveys. This labor cost also passes a common sense test when compared to wood frame wall labor cost estimates of $9,000, as labor for a new technology would likely be more expensive initially than for an established product.

[12] Based on 151,417 new housing units in 2004 (CIRB 2005).

each benefit on the homebuyer. We had originally planned to ask respondents to rate each benefit in terms of how important that benefit was in their final purchase decision. Quantifying those self-evaluations would have allowed us to include the individual effects of the benefits in our consumer demand model. Further comparisons could have been made between consumer responses and the parallel estimates given by building industry professionals. Unfortunately, we were unable to conduct this research due to budget constraints; the survey service we used charged a fee per survey question asked. We suggest that future research include this line of questioning.

Uncovering the reasons behind the “straw effect”

Our intuition told us that there was a “straw effect” based on common misconceptions regarding the flammability and durability of straw. We believed that consumers would be less likely to buy a straw home than an equivalent conventional home. While we established the existence of a “straw effect,” we did not use the survey to explore its causes. In order to determine why a person’s knowledge that the CP Block is made out of straw reduces consumer demand, future research should require that consumers state (or reveal) why they would not choose straw as a building material.

Survey a larger number of building industry professionals

Surveying large samples is often compulsory in order to obtain reliable results. While we had a sufficiently large sample for statistical analysis of the consumer survey, the sample size of the industry was too small to construct a reliable model of the industry professional’s likelihood-to-adopt. This problem could be overcome in the future by soliciting more builder newsletters and administering surveys at places where builders congregate (such as builder conferences).

Create a more rigorous product comparison

At the time of this writing, the CP Block’s performance testing has not been fully tested. Product characteristics such as load capacity, shear strength, and fire retardance are unknown. Assumptions for the product comparison were made either on the basis of tests done on straw bales or by estimations by the manufacturer, Oryzatech. Including empirical evidence of the block’s performance will increase the value of the product comparison. In addition, presenting this information to builders and homebuyers as part of future surveys similar to our own should increase the accuracy and reliability of responses.

4. E. Recommendations for Oryzatech

In order to become a significant part of the residential housing market, Oryzatech, Inc. must convince consumers that a compressed straw block is a viable building material. Oryzatech must also gain acceptance in the building industry in order to instigate the actual construction of CP Block homes. Based on our research results, we derived a series of recommendations for Oryzatech in order to enhance their marketing strategy. In this section, we describe how our recommendations will enable Oryzatech to reach out to homebuyers as well as the builder industry.

Marketing the block to homebuyers

Traditionally green goods have initial difficulty in penetrating their market; it takes time to gain a significant portion of any market. This study looked at a new alternative wall material for residential housing—the CP Block—to understand the potential future market. The survey of consumers provided Oryzatech with data to understand:

- consumer response to environmental benefits
- consumer perceptions of a “straw” building material
- potential market segments
- potential areas of demand

Our research survey showed that consumers preferred the CP Block when informed about its environmental benefits. Further, we would expect this effect to be particularly strong with early adopters and committed green consumers. As these customers will likely form a significant part of the early CP Block market, <u>Oryzatech should highlight the environmental benefits of building with a recycled material.</u>

Specifically, this study focused on environmental attributes that are exclusively public goods. But many of the most successful green goods to this point are adopted by many consumers because they are perceived to be healthier or of a higher quality than their conventional competitors. This suggests that characteristics beyond the scope of this research project—breathability, the lack of VOCs, and interior air quality, among others—may play a significant role in determining the market acceptance of the CP Block. <u>Oryzatech should seek to quantify and tout the potential health benefits of building with compressed straw blocks.</u>

Describing the environmental and health benefits of the CP Block requires knowing the block is made of straw. However, our research survey also revealed that consumers had a negative perception of straw. This “straw effect” significantly lowered the likelihood that the respondent would choose the CP Block house. This question may go to the heart of most consumers' concerns about the CP Block: can straw really be a viable and durable building material? The answer cannot be to brush aside or hide the fact that the CP Block is straw, because simply marketing the block as compressed agrifiber would not properly explain the environmental benefits and potential health benefits. Thus, Oryzatech should not overemphasize the fact that the CP Block is straw, using instead an alternative term in its mass marketing; but it should also strive to explicitly demonstrate to consumers that compressed rice straw is a viable and durable building material.

In the consumer survey, current homeowners showed a significantly lower probability of selecting the CP Block house than non-homeowners. Our primary interpretation of this effect is that homeowners have a more realistic approach to evaluating a home purchase scenario. However, some portion of this effect may have an alternate explanation: those who are not yet homeowners are generally younger and may be more open to alternative materials. Oryzatech should market the CP Block to first-time home buyers who may be more receptive to alternative technologies.

Because the CP Blocks offers above average soundproofing, and people who are renting are more likely to choose straw homes, we recommend that Oryzatech market the block to multi-unit rental housing developers.

Finally, by applying the derived demand model to California, the study showed a significant potential market in the fast-growing regions of California's Central Valley where most of the state's rice is grown. Oryzatech should look in its own backyard to promote and market the CP Block.

Convincing the building industry

The building industry has been reluctant to adopt alternative or green building methods and materials in the past. In order to gain acceptance from the typically conservative industry, Oryzatech, Inc. should carefully consider:

- factors that influence builders when deciding whether they will build homes with a new material
- the industry prediction of CP Block performance
- commentary the CP block received from industry professionals

The industry's willingness to use the block as a building material was most affected by their estimate of consumer demand. Additionally, when comparing the CP block with a conventional wall system, the industry rated consumer demand as the worst in terms of overall performance. Because the industry thinks consumer demand is low, they will be less willing to take on a novel product. Therefore, Oryzatech should demonstrate the potential demand for CP block homes. In the near term, the consumer survey results show the potential demand. However, the demand curve derived from the consumer survey is most likely an overestimate, but it provides an initial, if somewhat inaccurate, confirmation of demand. In the long term, Oryzatech needs to provide further evidence of consumer demand through actual CP Block homes. To achieve wider acceptance, Oryzatech needs to convince builders that demand exists.

In addition, the industry's decision to adopt the block as a building material was affected by whether or not the CP block was user-friendly. The harder the industry thinks the block is to build with, the less likely they will include it in their construction portfolio. Thus, when approaching the industry with their new product, Oryzatech should explicitly describe the construction techniques related to CP block wall systems and any additional training, equipment, or labor requirements in order to clarify the ease of construction. Oryzatech can further involve the building industry by hosting construction workshops or erecting test homes to demonstrate construction techniques and design.

In addition to providing information on construction techniques, Oryzatech needs to seek approval from the International Code Council (ICC). This certification will have two benefits. First, it will facilitate incorporation of the CP Block into local building codes. In addition, results from the ICC testing process will likely fill in other gaps regarding CP Block performance, such as load bearing capacity and seismic, wind and fire resistance levels.

Oryzatech can use the additional commentary provided by the industry professionals as a preliminary assessment of the block's perceived performance. The most frequent comments focused on the lack of information on the block and its performance in a wall system, especially in terms of moisture resistance. Most building professionals require detailed information about the performance of a new product before they will consider building with it. Oryzatech should build model homes or test walls in order to evaluate and provide accurate figures for the performance of the block.

Additional industry commentary questioned whether or not the CP Block was associated with USGBC LEED points or if it qualified as an Energy Star product. Oryzatech should investigate methods of green certification or branding, specifically by determining if constructing a home with CP Blocks equates to LEED-Home points or will increase the likelihood of accreditation as an Energy Star Qualified New Home.

REFERENCES

Adair, C. (2005). American Plywood Association. Personal communication, 21 November 2005. From an unpublished report by the NAHB Resource Center: "Wood used in new residential construction", 2003, commissioned by the Wood Products Council.

Allen, D. (2005). Allen Associates. Personal communication, 1 December 2005.

Anderson, R. C., and Hansen, E. N. (2004). "The impact of environmental certification on preferences for wood furniture: A conjoint analysis approach". *Forest Products Journal* 54(3):42-50.

Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R., Schuman, H. (1993). "Report of the NOAA Panel on Contingent Valuation*".* Blue Ribbon Panel Report to the National Oceanic and Atmospheric Administration. Rockville, MD.

Bateman, I. J. (2002). Economic Valuation with Stated Preference Techniques: A Manual. Cheltenham, UK. Edward Elgar.

Business Week. "Sales Continue to Speed Up". 28 December 2005. Available at http://www.businessweek.com. Accessed 11 February, 2006.

Butte County Air Quality Management District (2006). "Agricultural Burning". Available at http://www.bcaqmd.org/agburn.asp Accessed 16 March 2006.

Blumenschein, K., et al. (1998). "Experimental Results on Expressed Certainty and Hypothetical Bias in Contingent Valuation". *Southern Economic Journal* 65(1): 169-177

Botelho, A. and Pinto, L.C. (2002). "Hypothetical, real, and predicted real willingness to pay in open-ended surveys: experimental results"*. Applied Economics Letters* 9: 993-996

Brandon, D., et al. (1999). "Rice Straw Management Today and Tomorrow". Available at http://www.agronomy.ucdavis.edu/uccerice/index.htm Accessed 17 Sept 2005.

Brown, S. K. (1997). "Indoor air quality". *Australia: State of the Environment Technical Paper Series (Atmosphere)*. Department of the Environment, Sport and Territories, Canberra.

Cameron, T. C. and Huppert, D. D. (1987). "Non-market resource valuation: assessment of value elicitation by payment card versus referendum methods". Discussion Paper #448, Department of Economics, University of California, Los Angeles, CA.

Cameron, T. C. and Huppert, D.D. (1991). "Referendum contingent valuation estimates: sensitivity to the assignment of offered values". *Journal of the American Statistical Association* 86: 910-918

CARB (2003). "Rice Straw Tax Credit". California Air Resources Board Web Site. Available at http://www.arb.ca.gov/smp/rice/ricefund/ricefund.htm Accessed 17 January 2006.

Cassidy, R. (2003). "White Paper on Sustainability: A Report on the Green Building Movement". Supplement to *Building Design and Construction.*

CDFA (2000). "Rice Straw Utilization Grant". Available at http://www.cdfa.ca.gov/exec/aep/aes/rs_grant_program/ Accessed 19 January 2006.

Champ, P. A. and Bishop. R.C. (2001). "Donation Payment Mechanisms and Contingent Valuation: An Empirical Study of Hypothetical Bias". *Environmental and Resource Economics* 19: 383-402.

Chung, E. (2004). "Green buildings back in fashion". *The Toronto Star*. Toronto, Canada.

CIRB (2005). "New housing units and building permit valuations by County, 2004". Construction Industry Research Board.

Couper, M. P. (2000). "Web Surveys: A Review of Issues and Approaches". The Public Opinion Quarterly 64(4): 464-94

Clay, J. (2004). World Agriculture and the Environment. Island Press.

CRC (2005). California Rice: A Circle of Life in Every Grain. Available at http://www.calrice.org/ Accessed 17 October 2005.

David and Lucille Packard Foundation (2002). "Building for sustainability: six scenarios for the David and Lucille Packard Foundation Los Altos Project". A Report. October 2002.

Department of Energy (2005). "Short-term Energy Outlook". Available at http://www.eia.doe.gov/emeu/steo/pub/10ctab.html. Accessed 15 November 2005.

Dimitri, C. and C. Green (2002). "Recent Growth Patterns in the U.S. Organic Foods Market". *Agriculture Information Bulletin*. Economic Research Service, USDA, AIB 277, 42: 1-8

Drake, D., Nader, G., and Forero, L. (2002). "Feeding Rice Straw to Cattle". Publication 8079. University of California Division of Agriculture and Natural Resources.

Energy Information Administration (EIA). (2005a). Annual Electric Power Industry Report". Electric Power Annual 2004

EIA. (2005b) "US Regional Electricity Prices, November 2005". Available at http://www.eia.doe.gov/emeu/steo/pub/10ctab.html. Accessed 29 November 2006.

Fisk, W. J. (2000). "Health and productivity gains from better indoor environments and their relationship with building energy efficiency". *Annual Review of Energy and the Environment* 25: 537-566

Glaser, L. and G. D. Thompson (2000). "Demand for Organic and Conventional Beverage Milk". Annual Meeting of the Western Agricultural Economics Association, Vancouver, British Columbia. 29 June - 1 July.

Grist, D.H. (1986). Rice. Sixth edition, Longman Group Limited.

Heschong Mahone, G., Inc. (1999). Daylighting in Schools: An Investigation into the Relationship Between Daylight and Human Performance. Condensed Report. Submitted to the Pacific Gas and Electric Company.

Hill, J.E., Roberts, S.R., Brandon, D.M., Scardaci, S.C., Williams, J.F., and Mutters, R.G. (1998). "Rice Production in California". Available at http://www.agronomy.ucdavis.edu/uccerice/PRODUCT/rpic13.htm Accessed 17 Sept 2005.

Hrynchuk, L. (1998). Rice Straw Diversion Plan. McGuire, T., editor. California Air Resources Board. Sacramento, CA.

Janssen, M. and Jager, W. (2002). "Stimulating diffusion of green products". *Journal of Evolutionary Economics* 12: 283-306

Johnson, S. (2000). "The Economic Case for High Performance Buildings." *Corporate Environmental Strategy* 7:4:350-361

Kats, G. (2003). The Costs and Financial Benefits of Green Buildings. A Report to California's Sustainable Building Task Force.

King, B. (1996). Buildings of Earth and Straw: Structural Design for Rammed Earth and Straw-Bale Architecture. Ecological Design Press.

Lacayo, R. (2002). "Buildings That Breathe". *Time*. 26 August 2002.

LeSage, J. P. (1999). Econometrics Toolbox. Public domain. Available at http://www.spatial-econometrics.com/. Accessed 15 February 2006.

Lindsey, J. K. (1997). Applying Generalized Linear Models. New York, Springer.

Lipper, D. (2005) "Green legislation getting the greenlight". *State Net Capital Journal* 13(7).

Lipman, T. E. and Delucchi ,M. A. (2003). Hybrid-Electric Vehicle Design Retail and Lifecycle Cost Analysis. Davis, University of California, Davis: 70.

Mas, C.J and Everbach, E.C. (1995). "Acoustical Characterization of Straw Bales as Structural Elements". Acoustical Society of America, 130th Meeting. St. Louis, Missouri, Acoustical Society of America.

Manley, S.W., Kaminski, R.M., Reinecke, K.J., and Gerard, P.D. (2004). "Waterbird foods in winter-managed ricefields in Mississippi". *Journal of Wildlife Management* 68: 74-83.

Melchiori Construction Company (2005). Personal communication from company representative, 16 January 2005.

Mitchell, R. C. and Carson, R. T. (1989). Using Surveys to Value Public Goods: The Contingent Valuation Method. Baltimore, MD, Johns Hopkins University Press, for Resources for the Future.

Murphy, C. (2003). "The Next Big Thing". *Fortune Small Business*. Volume 13.

NAHB (1994). Alternative Framing Materials in Residential Construction: Three Case Studies. Office of Policy Development and Research. Prepared for the U.S. Department of Housing and Urban Development. NAHB Research Center in Upper Marlboro, MD, National Association of Home Builders.

NAHB (2004). "Survey Reveals Nationwide Shortages of Cement, Other Key Building Materials". Available at http://www.nahb.org/news_details.aspx?newsID=974. Accessed 5 April 2005.

NAHB (2005). "Smart Growth: Building Better Places to Live, Work, and Play". NAHB's Smart Growth Policy Statement. National Association of Home Builders.

NAHB. (2006). "Annual Housing Starts (1978-2005)". Available at http://www.nahb.org/generic.aspx?genericContentID=554. Accessed April 5, 2006.

Natural Foods Merchandiser, various issues.

Novelli, T. (2004). “Green building resource update”. *Building Safety Journal: The Professional Journal of Construction and Fire Safety*. May/June.

Office of the Federal Environmental Executive (2003). The Federal Commitment to Green Building: Experiences and Expectations. 18 September.

Ozanne, L. K. and Vlosky, R. P. (1997). “Willingness to pay for environmentally certified wood products: a consumer perspective”. *Forest Products Journal* 47(6):39-48

Pineay, V. and Slotwiner, D. (2003). Probability Samples vs. Volunteer Respondents in Internet Research: Defining Potential Effects on Data and Decision-Making in Marketing Applications. Available at http://www.knowledgenetworks.com/info/press/papers. Accessed 13 October 2005.

Porter, M. (2003). Environmental Product Differentiation by the Hayward Lumber Company. Stanford Graduate School of Business.

Rametsteiner, E. and Simula, M. (2002). “Forest Certification – an instrument to promote sustainable forest management?” *Journal of Environmental* Management 67(1): 87-98

Schuler, A. (2003). “Environment Lumber Market Dynamics”. *Structural Building Components Magazine*. December.

Silverman, M. and Lamphar, T. (2003). Benzinger Family Winery. San Francisco State University.

Social Funds (2005). “New Study Shows Benefits of Sustainable Forestry Certification”. 27 July 2005. Available at http://www.socialfunds.com/news/article.cgi/article1765.html Accessed 8 February 2006.

Soil Erosion and Hydroseeding (2003). Available at http://www.soilerosiononline.com/html/0104/0104wattles.html. Accessed on 11 November, 2005.

Swearingen, J. (1998). "Moisture Barriers in Straw-bale Construction”. *The Last Straw* (22).

Thomson (2000). Agricultural Biomass Utilization Account. AB 2514. California State Assembly. 31 August 2000.

Toolbase Services. (2006). "Residential Construction Waste: From Disposal to Management". Toolbase Services. Available at http://www.toolbase.org/tertiaryT.asp?TrackID=&CategoryID=34&DocumentID=2301 Accessed 7 March 2006.

United States Census Bureau (2000). “American Fact Finder: Decennial Census”. Available at http://factfinder.census.gov/ Accessed 15 February 2006.

United States Department of Commerce and Department of Housing and Urban Development. (2000). “Characteristics of New Housing, 1999”. Current Construction Reports.

van Kessel, C. and Horwath, W. (2000). “Research on Alternative Rice Straw Management Practices in California”. Available at http://www.agronomy.ucdavis.edu/uccerice/STRAW/nflyer.htm Accessed 17 Sept 2005.

van Kooten, G., et al. (2005). Certification of Sustainable Forest Management Practices: A Global Perspective on Why Countries Certify. *Forest Policy & Economics* 7(6): 857-867

Wanek, C. (2003). The New Strawbale Home. Gibbs Smith.

Williams, J. (2001). "Estimated Costs of Different Rice Straw Incorporation Method".. Available at http://www.calrice.org/downloads/Straw_Inc_Costs.pdf Accessed 20 June 2005.

Xenergy Inc. and S. Architects (2000). Green City Buildings: Applying the LEED Rating System. Prepared for the Portland Energy Office. Available at http://www.sustainableportland.org/CityLEED.pdf. Accessed 18 June 2005.

APPENDICES

APPENDIX A: Consumer survey

Introduction

The following survey invites you to be a part of a home-buying simulation. You will play the role of a home buyer who is going to make a final purchase decision between two homes in your area. Since you are the homebuyer, it is very important that you base your purchase decision on your preferences and what you are able to afford.

The homes are identical in almost every respect except for the walls, which are made out of different materials. The characteristics of these two wall systems differ, and thus your purchase decision will be based on:

1) your preferences about these characteristics, and

2) the difference in price.

The homes and walls will be fully described to you in a short series of text, illustrations, and tables. Please pay careful attention to the differences in the two wall systems and consider how these differences may affect your decision about which home to purchase. After reading the descriptions, you will be asked to choose one of the two homes to purchase.

This survey is being conducted as a part of a graduate-level research project. Please note that your answers are completely anonymous and that there are no right or wrong answers.

Please note that the survey consists of only one question: the purchase decision. Please make sure your have read all of the information before answering this question.

The survey will take about 5-10 minutes to complete.

Assume that you have decided to buy a new house in your area. After searching with your real estate agent you find a 3 bedroom/2 bath house that satisfies your needs such as price, location, size, quality, etc. You decide you would like to purchase this house.

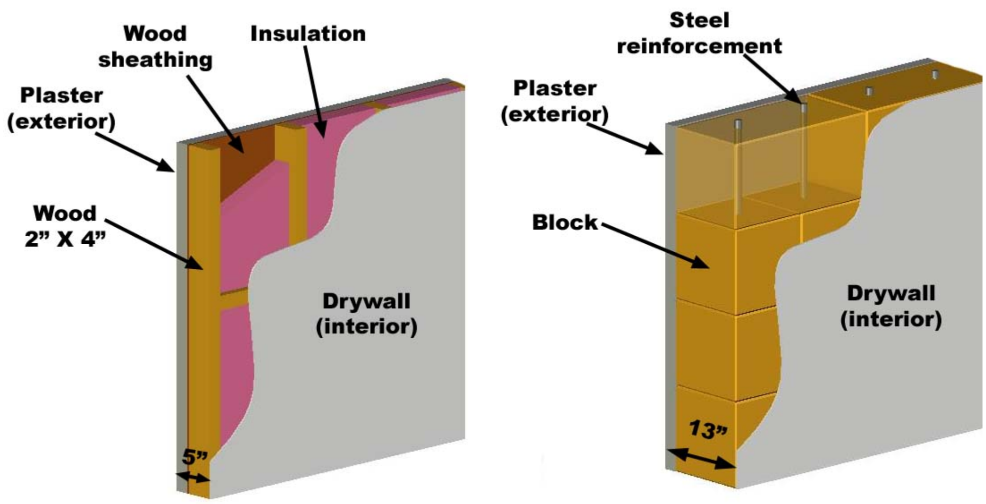
We'll call this "House A." The walls in House A are standard, and are constructed with the following materials:

1. Drywall
2. Wood stud framing
3. Standard insulation
4. Structural wood sheathing
5. Plaster finish

Before you purchase House A, however, your real estate agent informs you of another new 3 bedroom/2 bath house on the market. This house, "House B," is in the same neighborhood as House A. In fact, when you visit House B it turns out to be nearly identical to House A. Assume the two houses are also identical with respect to things like view, lot, general quality, etc. The only difference is that the walls in House B are constructed with the following different materials:

1. Drywall (same as House A)
2. Building blocks made from {**a new building material** / **highly compressed rice straw** / ***highly compressed rice straw***}
3. Internal steel bar reinforcement
4. Plaster finish (same as House A)

The diagram below shows a simple sketch of each wall system:



Wall of House A **Wall of House B**

The new wall system gives House B a few different properties:

HOUSE COMPARISON

	House A	House B
Price	House B is **{bid price difference}** than House A.	
Insulation	Standard	Twice standard
Heating/cooling costs	Average for your area	Annual savings of $65-$210, depending on your climate zone* (see table below)
Soundproofing	Average	Above average
Moisture resistance	Standard	Standard in dry and moderate climates; below average in wet climates
Wall thickness	5”	13”
Interior area	2,000 square feet	1,800 square feet due to thicker walls

***Expected Annual Energy Savings according to Climate Zone (House B relative to House A)**

Climate Zone	Description (based on the U.S. Department of Energy)	Annual savings on your utility bill (based on current energy costs)
Warm	Cooling is required with minimal heating, e.g. FL, coastal CA, coastal TX, southern states, etc.	$65-$100 (~8%)
Cold	Heating is required with minimal cooling, e.g. the Northeast, Midwest, Great Lakes, etc.	$150-$175 (~20%)
Mixed	Moderate cooling and heating, e.g. the Mid-Atlantic, Great Plains, etc.	$180-$210 (~20%)

{***In addition, House B has the following environmental benefits when compared to House A:***

Lumber conservation	Use of the straw building material saves approximately 15 pine trees (80 ft. tall) from being cut down for the lumber required for House A.
Rapidly renewing product	Unlike lumber, straw is a rapidly renewing resource. It takes less time for straw to mature for harvest than for trees to mature to harvest.
Waste reduction	Use of the straw building material promotes the use of an agricultural byproduct which, if unused, is treated as waste.
Air quality	Use of the straw building material will increase air quality in regions where straw waste is incinerated.

}

Finally, despite the different wall systems, all of the following characteristics are expected to be the same for both houses:

- Durability/longevity of house
- Structural stability
- Fire resistance
- Pest resistance
- Meets building codes
- Insurance costs
- Maintenance/home improvement costs

Given the different properties of the wall systems and the fact that House B costs **{bid price difference: $5,000 less / $2,000 more / $6,000 more / $12,000 more / $25,000 more / $50,000 more}** than House A,

Which house would you buy?

- I would purchase House A (conventional walls)
- I would purchase House B ({**walls of new material**/**straw block walls**/***straw block walls***})

APPENDIX B: Industry survey

Survey of Building Industry Professionals

Introduction
The following survey is being conducted as part of a graduate-level research project at the University of California Santa Barbara. Your responses are anonymous and will be used only for research purposes.

The survey takes 10-15 minutes to complete. Several of the questions ask about your experience in the building industry. A few of the questions will place you in a hypothetical scenario. Please try to answer these questions to the best of your ability, based on the information given and your own knowledge or experience. Please note that there are no right or wrong answers. In order to best view the survey you may want to maximize this window on your computer screen.

Once you complete the survey you will be given the opportunity to enter a drawing for a $50 Visa gift card. You will need to provide your email address if you wish to enter the drawing. Your email address will be kept confidential and will only be used for the drawing.

Click on the link below to start the survey.

Employment and company information

1. What category best describes your primary occupation?
    - Architect
    - Engineer
    - Other design team
    - Construction team
    - Building owner/developer
    - Government agency staff
    - Manufacturers/vendor
    - Education/research
    - Other

2. What category best describes your current employment status?
    - I work as a paid employee
    - I am self-employed
    - I am an owner/partner in small business or professional practice
    - I am president/executive officer of a firm
    - I am retired
    - Other

3. What category best describes the company or organization where you are employed?
    - Architectural firm
    - Design-build firm
    - Engineering firm
    - Building company
    - Developer
    - Contractor
    - Consulting firm
    - Industry association
    - Academic institution
    - Government agency
    - Other

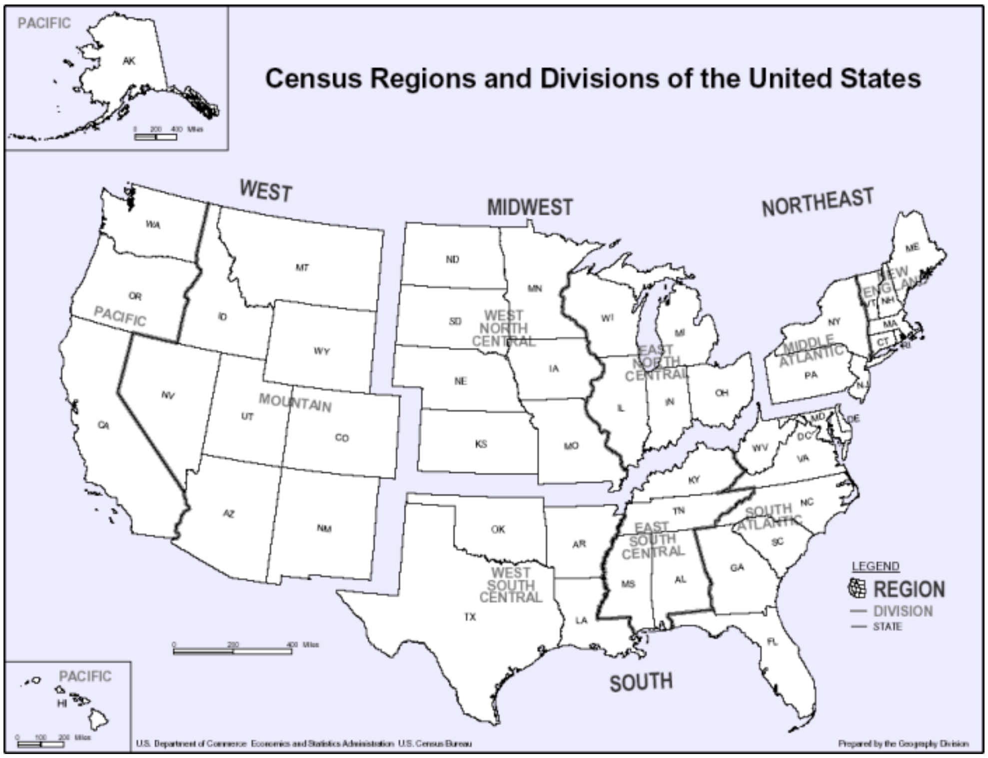
4. What was the approximate revenue your company generated last year (FY 2004)?
    - Less than $1 million
    - $1 million to $10 million
    - $10 million to $50 million
    - $50 million to $500 million
    - Over $500 million

Region

5. Which of the following best describes the primary scale of your operations? (Please select the area over which you personally design or build projects.)
    - City
    - County
    - State
    - Region
    - Nationwide
    - Not applicable

   Follow-up:
    - City
        - ➢ What is a ZIP code in the city where you have most of your business?
    - County
        - ➢ What is a ZIP code in the county where you have most of your business?
    - State
        - ➢ In which state do you have most of your business?
    - Region
        - ➢ In which region of the country do you have most of your business? Please use the map below to first select the broader region (or regions) of the country in which you work, and then, if possible, identify the sub-regions where you work.

- o Nationwide
  - ➢ In which regions of the country do you have most of your business? Please use the map below to first select the broader regions of the country in which you work, and then, if possible, identify the sub-regions where you work.
- o Not applicable
  - ➢ What is your ZIP code?



Residential construction projects

6. With what types of residential construction projects is your company involved? (Please check all that apply)
   - o *My company is not involved in residential construction*
   - o Custom homes
   - o Planned communities
   - o Multifamily projects (condos, townhouses, etc.)
   - o Rental housing
   - o Affordable housing
   - o Senior housing
   - o Remodeling
   - o Other

Residential wall systems

7. How frequently are the following types of wall systems used in the residential projects your company designs/constructs?
    - ➢ Always
    - ➢ Frequently
    - ➢ Occasionally
    - ➢ Rarely
    - ➢ Never
    - ➢ N/A
  - o Wood stud
  - o Concrete masonry units (CMU)
  - o Concrete Insulated concrete forms (ICF)
  - o Steel/metal frame
  - o Alternative materials (e.g. adobe, straw, SIPs)

Other types of construction

8. With what other types of construction projects is your company involved? (Please check all that apply)
  - o My company is not involved in non-residential construction.
  - o Commercial (including industrial)
  - o Institutional (e.g. schools, government, military)
  - o Other (please specify) [Open-ended response.]

Sound wall construction

9. Does your company work on highway or other sound wall projects?
  - o Yes
  - o No
  - o I don't know

  Follow-up (if Yes):
  - o What types of sound wall projects does your company work on? (Please check all that apply.)
    - ➢ Private (i.e., residential communities, private builders, etc.)
    - ➢ Public (i.e., highways, airports, etc.)
  - o Which of the following materials does your company use in sound wall construction? (Please check all that apply)
    - ➢ Concrete
    - ➢ Masonry block
    - ➢ Wood
    - ➢ Metal
    - ➢ Brick
    - ➢ Absorptive
    - ➢ Other

A hypothetical scenario

10. Please think about a typical buyer of a new home in your area. Assume this homebuyer is planning on purchasing a new 3BD/2BA home in the area, and has narrowed their decision down to two houses. The two homes are identical in almost every respect except for the walls, which are made out of different materials.

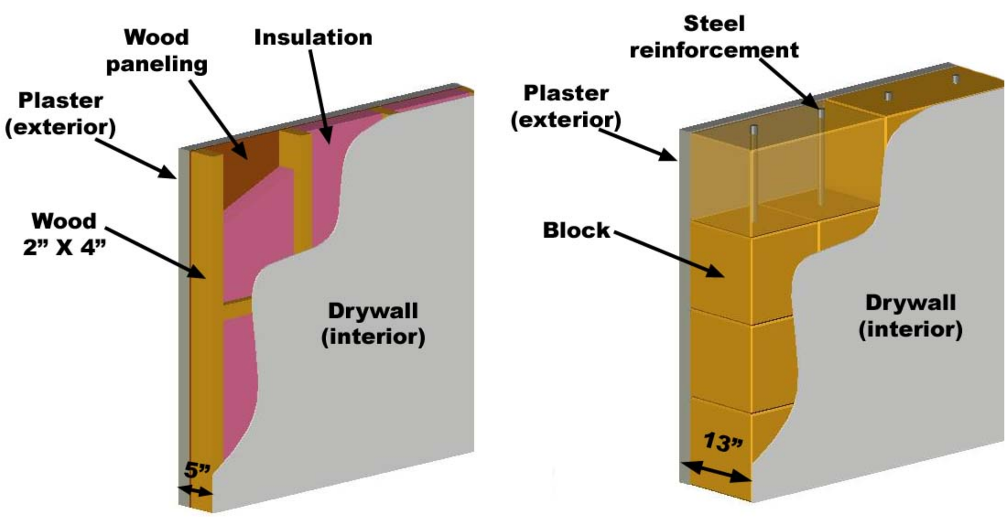
The first house we will call “House A.” House A is constructed with a standard wood frame stud and drywall system, consisting of the following primary materials:

1. Drywall
2. Wood stud framing
3. Standard insulation
4. Structural wood sheathing
5. Plaster finish

The second house we will call “House B.” Assume that House B is identical to House A with respect to things like location, land value, lot, quality of build, floor plan, etc. The only difference between the houses is that the walls in House B are constructed from the following different materials:

1. Drywall (same as House A)
2. Building blocks made from {**highly compressed rice straw** / ***highly compressed rice straw***}
3. Internal steel bar reinforcement
4. Plaster finish (same as House A)

The diagram below shows a simple sketch of each wall system:



Wall of House A **Wall of House B**

The different wall system gives House B a few different properties:

HOUSE COMPARISON

	House A	House B
Insulation	Standard (R-11 to R-18)	Above standard (R-24)
Heating/cooling costs	Average for your area	Annual savings of $65-$210, depending on your climate zone* (see table below)
Soundproofing	Average	Above average
Moisture resistance	Standard	Standard in dry and moderate climates; below average in wet climates
Wall thickness	5"	13"
Interior area	2,000 square feet	1,800 square feet due to thicker walls

***Expected Annual Energy Savings according to Climate Zone (House B relative to House A)**

Climate Zone	Description (based on the U.S. Department of Energy)	Annual savings on your utility bill (based on current energy costs)
Warm	Cooling is required with minimal heating, e.g. FL, coastal CA, coastal TX, southern states, etc.	$65-$100 (~8%)
Cold	Heating is required with minimal cooling, e.g. the Northeast, Midwest, Great Lakes, etc.	$150-$175 (~20%)
Mixed	Moderate cooling and heating, e.g. the Mid-Atlantic, Great Plains, etc.	$180-$210 (~20%)

In addition, House B has the following environmental benefits when compared to House A:

Lumber conservation	Use of the straw building material saves 16 pine trees (80 ft. tall) from being cut down for the lumber required for House A.
Waste reduction	Using the straw building material promotes the use of an agricultural byproduct which, if unused, is treated as waste.
Rapidly renewing product	Unlike lumber, straw is a rapidly renewing resource. It takes less time for straw to mature for harvest than for trees to mature to harvest.
Air quality	Using the straw byproduct as a building material will increase air quality in regions where straw waste is incinerated.

Finally, despite the different wall systems, all of the following characteristics are expected to be the same for both houses:

- Durability/longevity of house
- Structural stability
- Fire resistance
- Pest resistance
- Meets building codes
- Insurance costs
- Maintenance/home improvement costs

Assume that buyers of new homes in your area are restricted to buying one of these two homes. Given their different properties, what percentage of homebuyers in your area would purchase House B (straw block walls) instead of House A (standard wood frame)?

Please estimate the percentage of buyers (0-100%) that would purchase House B for each of the price scenarios below:
If House B cost $5,000 less than House A: _______________%
If House B cost $2,000 more than House A: _______________%
If House B cost $6,000 more than House A: _______________%
If House B cost $12,000 more than House A: _______________%

If House B cost $25,000 more than House A: _______________%
If House B cost $50,000 more than House A: _______________%

11. How important do you think the following factors would be for a homebuyer when deciding between House A and House B?
    - Extremely important
    - Very important
    - Somewhat important
    - Slightly important
    - Not important at all
    - N/A
  - Insulation
  - Savings on heating/cooling costs
  - Soundproofing
  - Moisture resistance
  - Wall thickness
  - Interior area
  - Environmental benefits

Building with the straw block

12. Suppose your company was considering adopting the straw block as part of its building portfolio. Based on the information in the last page, please rate how you think straw block construction would compare to conventional wood frame construction in your region for each of the factors below.

    "For this factor, I think straw construction would be:"

    - Scale of 1-7
    - 1 (Much worse than conventional construction)
    - 4 (About the same as conventional construction)
    - 7 (Much better than conventional construction)
  - Consumer demand
  - Material cost
  - Ease of construction (i.e. cost, time, labor)
  - Regulatory acceptance (i.e. inclusion in building code or building permit approval)
  - Obtaining insurance
  - Obtaining financing

13. Based on your current knowledge about the straw block, would you be likely to adopt it at your firm for projects you design/build? (Assume the straw block has been approved as a building material by the International Code Council (ICC).)
  - Yes
  - No
  - Comments [Open-ended response]

14. Are there any other factors which would be important in your decision to design/build with the straw block? [Open-ended response]

Demographic information

15. Which of the following building associations are you a member of? (Please check all that apply.)
    - National Association of Home Builders (NAHB)
    - United States Green Building Council (USGBC)

16. What is your gender?
    - Male
    - Female

17. What is your age?
    - 18 to 24 years
    - 25 to 34 years
    - 35 to 44 years
    - 45 to 54 years
    - 55 to 64 years
    - 65 years or older

18. What is the highest level of education you have completed?
    - Less than high school
    - Some high school, no diploma
    - Completed high school, diploma or equivalent (GED)
    - Some college
    - Bachelor's degree
    - Postgraduate degree

19. What category best describes your income for the year 2004, before taxes?
    - Less than $10,000
    - $10,000 to $39,999
    - $40,000 to $69,999
    - $70,000 to $99,999
    - $100,000 or more

20. Which best describes your political ideology?
    - Extremely liberal
    - Liberal
    - Slightly liberal
    - Moderate
    - Slightly conservative
    - Conservative
    - Extremely conservative

Conclusion

You have completed the survey! Thank you for your time and your assistance with our research!

If you are interested in being entered in the drawing for the $50 Visa gift card, please enter your email address below. Your email address will be kept confidential.

Email address:

Look for a summary of the survey results this spring in NAHB's Nation's Building News Online! In addition, if you would like, we can notify you at the email address above when the complete final research report is published. The report will be available online in PDF format in late spring 2006.

Would you like to be contacted by email when the final report is published?

- Yes, please notify me by email when the research report is published.
- No, I do not want to be contacted

Click on the link below to exit the survey. You will be redirected to the home page for our research project.

Thanks!

APPENDIX C: HEED results

Climate Zone Cool:	Efficiency when insulation meets code (modern home):	Efficiency with modifications (CP Block Home):	Change in efficiency:	Average Monthly Consumption (kwh) (for entire state):	Average Consumption (kwh), more efficient:	Average Energy Cost (cents/kwh) (for entire state):	Average Annual Cost ($):	Average Annual *efficient* Cost ($):
Boulder, CO	13%	32%	19%	684	544	8.14	668.09	531.13
Boston, MA	10%	30%	20%	642	510	11.68	899.99	715.49
Portland, ME	10%	32%	22%	534	425	12.37	793.20	630.60
Pierre, SD	12%	32%	20%	925	736	7.47	829.61	659.54
Des Moines, IA	12%	32%	20%	836	664	8.57	859.39	683.21
Sheridan, WY	10%	32%	22%	820	652	7.04	693.15	551.05
			avg: **21%**					
Mixed:								
Atlanta	36%	49%	13%	1,097	885	7.7	1013.25	817.84
Sterling, VA	12%	31%	19%	1,165	940	7.76	1084.81	875.60
Newark	12%	33%	21%	699	564	10.69	896.44	723.56
Ft Worth, TX	9%	23%	14%	1,191	961	9.16	1308.81	1056.39
Seattle, WA	19%	34%	15%	1,040	840	6.31	787.70	635.78
Flagstaff, AZ	11%	34%	23%	1,067	862	8.35	1069.49	863.23
Fairbanks, AK	10%	40%	30%	671	541	11.98	964.05	778.12
			avg: **19%**					
Warm:								
LA, CA	42%	49%	7%	554	509	12	797.46	733.66
New Orleans, LA	42%	49%	3%	1,277	1175	7.84	1201.71	1105.57
Miami, FL	37%	40%	3%	1,222	1124	8.55	1253.38	1153.11
Roswell, NM	25%	39%	14%	590	542	8.69	614.88	565.69
Houston, TX	41%	50%	9%	1,191	1095	9.16	1308.81	1204.10
Bakersfield, CA	38%	50%	12%	554	509	12	797.46	733.66
			avg: **8%**					

Modifications:
1- sq footage decreases to 1904
2- R-value increases by:
    1.5 times for cool cities
    2 times for warm & hot cities

APPENDIX D: Further notes on lumber conservation

Note: The amount of lumber used in roofing, floors, and structural beams is not included in the calculation because these amounts do not differ between our two model homes. However, the walls of the CP Block home do contain some wood; this amount was subtracted from the wall estimate of the wood frame home in order to calculate a final CP Block home estimate. It should be noted that sawmill and construction waste were both included as a factor in all calculations. Ultimately, waste accounted for nearly half of the wood used (Adair 2005).

The CP Block home was based on a model home 1,930 square feet in size (Appendix E) which approximates the 2,000 square foot "average home" in the WPC study. The top and bottom plates of the walls, designed to be constructed out of 2x6s, total up to a volume of approximately 2400 board feet (Table D.1).

Table D.1. The amount of wood in a conventional home which a CP Block home displaces (in board feet)

	Excluding Waste	Including Waste
Panels	1086	2068
Framing lumber	5021	9128
Walls	6106	11197
Walls	6106	11197
Walls of a CP block home	1296	2356
Total wood displaced (bd. ft.)	**4810**	**8840**

Converting board feet into number of trees

Determining the actual number of trees used in the walls of an average-sized home poses several problems. First, a generalization we have already made is further compounded: as the phrase "average-sized home" is misleading, statements about an "average-sized tree" are likewise subject to scrutiny. Second, while it is true that using square feet as measure of a home's total footprint is fairly standard and that dividing the total number of homes in the US by the total number of square feet of those homes returns a useful figure, it is less apparent that 80-foot tall pine trees is a useful unit in terms of estimating the number of trees saved.

The type of lumber used in residential wall construction depends on many factors: region, cost, type of home, etc. Market factors are especially important. The two major candidates for a representative tree, Douglas fir and Southern yellow pine (or simply, Southern pine), were based on dominance of those trees in the residential housing industry. The final selection of Southern pine is not arbitrary: we chose the tree which we believed had the broadest use in terms of geographical range.

A few more difficulties presented themselves during our attempt to convert board feet into whole trees. A board foot is a unit of volume used exclusively to measure lumber, and it is not used in practice when estimating the volume of a single tree. The closest equivalent for a single tree would be the number of saw logs, i.e. logs which are stripped and ready to be milled, that can be produced from a felled tree. We chose 16 feet, a standard value, as our saw log measurement. This number is not significant in that it used only as a divisor to find out how many logs of a given volume are contained in a tree of a known height; saw logs of other lengths could have been used as well. We chose 24 inches as the width and 80 feet as the height of the tree because those are reasonable dimensions for a mature tree (older than 20 years) to be harvested in a stand of southern pines. These dimensions also served to simplify calculations: both the saw log and the tree are 24 inches, and an 80 foot tree divided by a 16 foot saw log unit is equal to 5 saw logs.

Once we knew the number of saw logs per tree, we applied both Doyle’s Scale and Scribner’s Scale to determine the number of board feet that could be produced. We used the average of the two applications as our final estimate of board feet (Table D.2).

Table D.2. Estimating the number of board feet per tree

Tree diameter (inches)	24
Tree height (feet)	80
Board feet used per single tree (Doyle's scale)	668
Board feet used per single tree (Scribner's scale)	770
Average of Doyle's and Scribner's Scales	719

Finally, the number of total board feet in the wood frame home was divided by the number of board-foot equivalent trees for both waste and non-waste estimates:

Table D.3. Number of trees saved per 2,000 sq. foot wood frame home

	Excluding Waste	Including Waste
Total wood displaced (bd. ft.)	4810	8840
Average number of board feet per tree	719	719
Total number of trees saved	**7**	**12**

Errata

The above calculations indicate that 12 trees (including waste) are saved when CP Block walls are substituted for wood framed walls in an equivalent 2,000 sq. foot home. However, the figure used in the survey was 15 trees. This discrepancy is due to an oversight in calculations which was not discovered until after the survey was administered. Though this represents a 20% decrease in the absolute number of trees, we do not expect that there would be a significant difference in the predictive power of the consumer demand model based on this error.

APPENDIX E: Blurb for industry survey

Online Survey to Assess Use of Green Building Material

The research team from the University of California, Santa Barbara Donald Bren School of Environmental Science and Management

Want to help out young academic researchers? Want to have a chance at winning $50 for your charitable efforts?

A research team at the University of California, Santa Barbara, is investigating the perceptions of building professionals. The survey introduces an innovative building technology (a highly compressed block made of rice straw) to gather the following information:

- How well do architects, builders, developers and others in the industry assess consumer concerns with regard to new building materials?
- What are the professionals' opinions regarding acceptance and use of new building materials?

All building professionals, regardless of whether they have experience with alternative or green materials, or whether they are home builders, are invited to participate. All participants will be entered in a drawing to win a $50 Visa gift card.

The survey takes approximately 10-15 minutes to complete. Survey responses are completely anonymous.

Go to the survey! To start the survey, please **click here: Survey**.

For more information, e-mail the research team at the Donald Bren School of Environmental Science and Management

APPENDIX F: Industry survey demographic results

Number of respondents	Occupation
6	Architect
4	Engineer
4	Design team
34	Construction team
11	Building owner/developer
3	Government
16	Manufacturer/vendor
7	Education
9	Other

Number of respondents	Employment status
53	Paid employee
11	Self-employed
18	Owner/partner of small business
10	President/executive
0	Retired
0	Other

Number of respondents	Revenue of firm
28	Less than $1million
30	$1 to $10 million
15	$10 to $50 million
10	$50 to $500 million
9	Over $500 million

Number of respondents	Scale of operations
9	City
26	County
16	State
26	Regional
12	Nationwide
5	Not applicable

Number of respondents	Construction type
29	Only residential
55	Residential plus commercial or institutional or other
11	No residential

Number of respondents	Type of residential construction
54	Custom homes
33	Planned communities
40	Multifamily projects
12	Rental
31	Affordable
23	Senior
28	Remodeling
11	Other

	Types of wall systems				
	Wood stud	CMU	ICF	Steel frame	Alternative materials
Always	33	3	5	1	4
Frequently	17	12	6	13	5
Occasionally	4	8	12	10	7
Rarely	2	6	12	11	9
Never	4	20	18	16	24

Number of respondents	Industry association membership
41	NAHB
23	USGBC

Number of respondents	Gender
65	Male
5	Female

Number of respondents	Age
4	18- 24 years
19	25-34
20	35-44
15	45-54
10	55-64
2	65 +

Number of respondents	Education
1	Less than High School
0	Some High School
7	High School or equivalent
13	Some college

33	Bachelor's degree
16	Post graduate

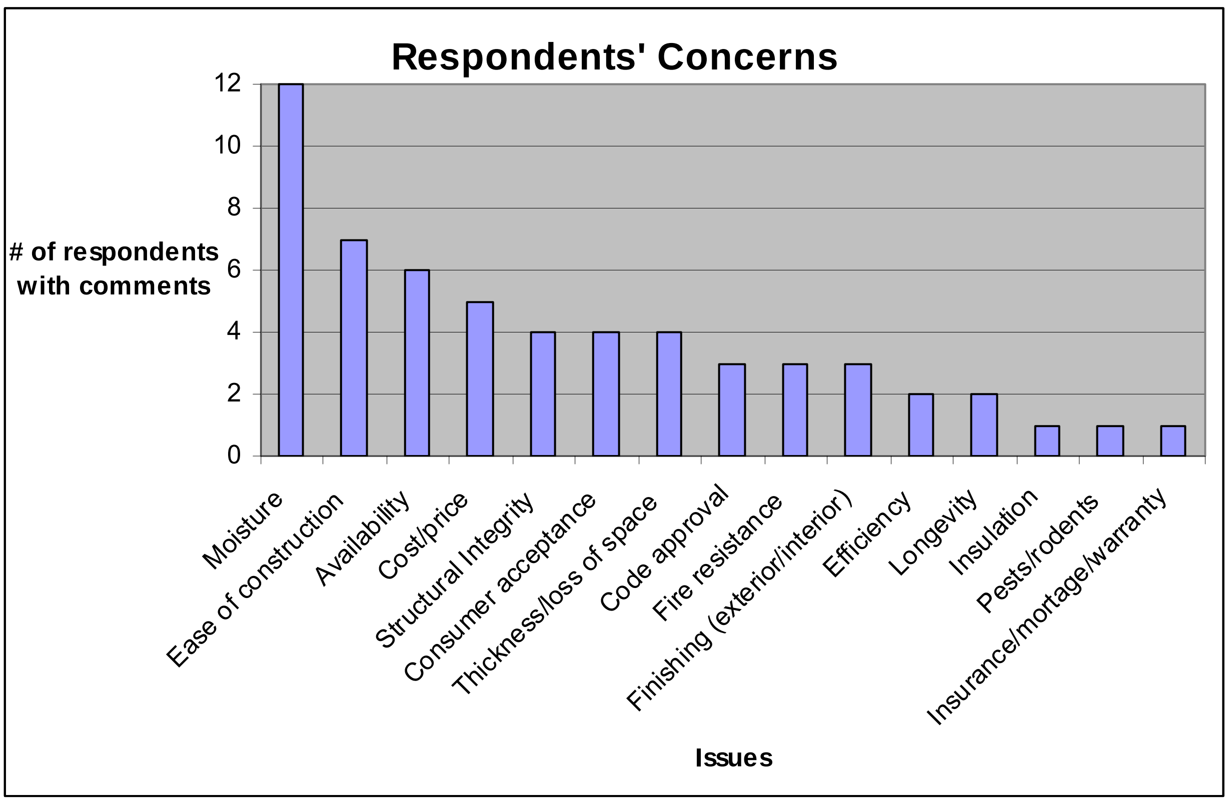
Number of respondents	**Yearly income**
3	Less than 10K
8	10 to 39K
20	40 to 69K
13	70 to 99K
24	100K +

Number of respondents	**Political ideology**
6	Extremely liberal
15	Liberal
11	Slightly liberal
13	Moderate
7	Slightly conservative
17	Conservative
1	Extremely conservative

Number of respondents	**Location**
13	Northeast
22	Midwest
16	South
25	West

APPENDIX G: Industry survey open-ended comments

	Count		
Concerns	**Private**	**Public & Private**	**Total**
Need to know more (generic response)	5	0	5
need more info on performance and comparasion with other materials	2	1	3
Moisture (mold and/or strength)	5	7	12
Ease of construction	4	3	7
Availability (seasonally, locally)	4	2	6
Cost/price	4	1	5
Strength/seismic characteristics	3	1	4
Consumer acceptance	3	1	4
Thickness/loss of space	2	2	4
Code approval	1	2	3
Fire resistance	0	3	3
Finishing (exterior/interior)	0	3	3
Efficiency (proven effectiveness)	2	0	2
Longevity	1	1	2
Insulation	0	1	1
Pests/rodents	0	1	1
Insurance/mortage/warranty acceptance	0	1	1



COMPILATION OF RESPONSES

Other types of construction projects:

Private: light commercial, housing, health care (one response each)

Private&Public: commercial and residential codes development, specialty coating, government regulator, Anything we find interesting and profitable, panelized projects (one response each)

Based on your current knowledge about the straw block, would you be likely to adopt it at your firm for projects you design/build? (Assume the straw block has been approved as a building material by the International Code Council (ICC).)

****Note – these comments are taken verbatim from the survey results.**

PRIVATE

need more info to make that decision
As a vendor of 'green' building materials I would gladly sell such a product, and currently work with builders and architects using somewhat similar products.
I am a SIP's builder and could get a lot higher r-value with the same thickness and not have customer resistance
I would have to know more about the environmental provenance of the straw block and compare it to other alternative building systems that also exist.
Need to know more about the product
We live in a very wet and humid climate.
My current knowledge is very limited.
As you probably noticed in our earlier responses we are an ICF builder. To peg us more, we are 'spec' (build first and then sell) builders. Even though we have heard good things about strawbale, we think: 1. It is still 'very unusual' as far as most buyers are concerned. We feel most buyers would not even consider buying a straw bale home. 2. We still have MAJOR reservations re: building exterior walls out of organic material which, in our minds can have major moisture issues in the rainy Pacific Northwest where we are based, and also in our minds can be food for any number of 'carbon based units'.
cost size and needs to be proven
wall thickness would impact buildings on small lots
Training of crews in the use of the material would be important. This should be provided by the manufacturer or supplier.
My expierience has been 'if it's different it's not good'.
Don't know enough about the material at this time to make a judgement. It would take research to determine if it is a right fit for this region
maybe

PRIVATE & PUBLIC

On a trial study
I'd definately need more info in regards to moisture protection. Mold is becoming a larger issue as of late.
We currently focus mostly on renovation rather than new construction
we are a light gauge steel home builder/manufacturer, We see our product as envromentally friendly(mold resistance, fire and insect resistant. Your product while renewable has draw backs as I see it in the errection phase. Rain will cause mold and I would believe strength reduction issues.

there is a considerable interest in straw bale homes in our area, but this type of construction does not fit with out typical customer, does not lend itself to our multi-family projects, and we have as much work as we can possibly take on without trying to enter into new markets such as this.
I would not take the liability for a design that has a potential for mold.
moisture would be a huge factor
There are traditional 'mainstream' building practices that can achieve the same results without the lost of valuable interior space. IE. 10% reduction.
With a different exterior wall than plaster, for security reasons.
In our jurisdiction seismic/structural requirements might make the use o straw blocks somewhat prohibitive. From a building department standpoint, the plan review process would be longer due to a learning curve for plan review staff as well as closer scrutiny of the seismic design of the structure. Currently California Building Code does not include alot of information regarding this type of construction. The State would need to provide additional information in its adopted codes to address issues that would arise out of the use of this product. An alternative might be to use it in a non-structural application to infill the walls of a structural frame building.
I would still have to see how the straw block compares to the straw bail houses I have plastered over the last 37 years and used my invention of green stucco trim instead of lumber or foam. Some of the straw bail houses I have plastered were made from rice straw bails because rice straw does not rot. This is first time I heard of straw blocks.
The moisture issue is huge. There are a ton of problems with moisture infiltration which can lead to mold issues and a big headache. This might work for a dryer climate, but I am not sure if the midwest is the right application.
Insulation is good, but there are other methods that are more convertional. Like 6' or 8' stud walls.
I don't understand why the straw block needs to be so much thicker then the wood blocking w/ insulation. I think it is very important for consumers to get as much space out of their building as possible, and looking at the comparisions between insulation, sound barrier, etc. The straw block excels past wood block and insulation, why would they reduce the thickness of the straw block, and create more surface area for the living spaces?

Are there any other factors which would be important in your decision to design/build with the straw block?

PRIVATE

Availability of matierials, unkown risks of longevity, interaction with moist climates, unkown siesmic characteristics, costs of educating code officials
Availability, cost, freight, ease of handling, proven effectiveness
Lead time for products. Are they stocked locally? Are they produced locally? How do they hold up to moisture heat and humidity on site before installation?
Moisture control concerns
How well the product performs in the cold climate and the humid warm summers
Ease of construction, limited retooling
cost efficiency mold
ease of construction
Availablity would be #1 concern.
Price.
Yes. ICF as we use know make nearly a fortress. Strawbale would not make nearly as secure a home. Especially if we were in tornado or huricane prone areas.

Strength of the blocks.
Cost and getting through the 'experimental stage' are the two most important factors to widespread acceptance.
Consumer acceptance is THE important thing when deciding what to build.

PRIVATE & PUBLIC

warranty moisture drying capability code aapproval availability complete system components cost long term viability of the manufacturer
Overall construction costs and how they would override/benefit my energy compliance code on the Title 24. If construction costs we slightly higher and my energy compliance benefit allowed me to lower a few things like HVAC cost, insulation(straw bale would already factor this replacement), types of windows(SHGC & U-Factor) etc, it could balance the cost to our consumer. A process like this may also allow me to receive incentives(if I qualified for) Energy Star provides to offset original expenditures. Consumers on the other hand do not know the difference from an Energy Star qualified home compared to the same type of home that justs meets the energy code requirements in California. More needs to be done to inform new homebuyers of the overall benefits of this type of construction so the market is more educated and understands the benefits. Too many consumers are more interested in if they can upgrade to granite counter tops and stainless steel kitchen appliances then how the energy performance measures built into the home will benefit them. They might be able to afford the home, but will they be able to LIVE in the home as utility prices increase. In Climate Zone 15 this construction technique would benefit all involved.
Ease of install in walls for mechanical and electrical
How does it hold up to the different weather related events during errection
Finishing - exterior and interior
Fire resistace
Government and Union acceptance/objections. Fire resistance. Labor expense and training. Reception of product for on-site use, how will it conform for immediate use?
Long term durability of the product. How long will this stuff last in a normal application under normal climatic and other conditions? Fire safety aspects of the product. Is it safe? Will mortgage companies and insurance companies accept this type of construction? How will it hold up in an earthquake?
Yes, I noticed on the drawings the exteriors were plastered. How thick is the plaster? and is there any metal lath to plaster over? Or is it just a skim coat. I am excited to hear about this new system. It seems like a no brainer if its sustainable? My new green stucco trim system is designed for straw bail houses, wood frame or metal stuc, but needs three coats at 7/8 or one coat at 1/2 inch thick to secure the Trim Tech to the wall. When I seen you were in Santa Barbara I wanted to fill out this form since its in my back yard, and directly related to my new green system. Where can I get a few of these blocks so I can test my system on them? I have a Leed credit of MR-4
This Product Would be a plus for LEED Buildings/Homes
I'd be leary about moisture and rodent problems. I live in a 100 year old house and have mice and bugs no matter how often I trap and remove them. The straw block is a great idea, and would last for 10's of years, but 30 years old, crack are going to form and a mouse would love to live in the straw not to mention bugs. Also, any moisture that got in the wall would quickly degrade the straw.
Availability, do they only make the straw block during 'season'. Or would be be stock piled to install during winter months?