Innovating for Better Buildings

An Opportunity Disguised as a Meltdown

PRIMARY AUTHORS:

Brian Walsh
N[th] Power, LLC

Bryan Urban
Fraunhofer Center for Sustainable Energy Systems

Sebastian Herkel
Fraunhofer Institute for Solar Energy Systems

OCTOBER 2009 | VERSION 1.0

"If innovation is the single most important ingredient for accelerating a vibrant sustainable economy—and it is—here is the analysis for unlocking what innovation means for the U.S. building industry. Nth Power and the Fraunhofer Institute provide a first-of-its-kind, venture capital perspective on how to capitalize on the sweep of 'better building' opportunities looming right here, right now."

— **CHRISTINE ERVIN**
First President & CEO, U.S. Green Building Council,
former U.S. Asst. Secretary of Energy

"'Innovating for Better Buildings' is an excellent report on the status of the U.S. Building Industry with a focus on the dramatic and exciting changes to come. The paper is an informative and comprehensive review of the building industry in the United States with a compelling argument for radical changes in the design, construction, and maintenance of American buildings. If you are part of that industry, this white paper is a 'must read'!"

— **GINO J. GEMIGNANI, JR.**
Sr. Vice President, Whiting-Turner Contracting Company

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Executive Summary

This report answers the question of how to innovate for better buildings. Nth Power and the Fraunhofer Institute believe that the new construction sector of the US building industry offers an attractive and timely opportunity to innovate from the venture capital perspective and that the market downturn is a favorable dynamic for the adoption of innovation. We define ***Better Buildings*** as the innovation opportunity within *Green Buildings* that meets venture capital investment criteria: compelling and defendable value propositions that can scale quickly. The industry is becoming more receptive to this type of innovation, resulting in a great opportunity for entrepreneurs, technologists, and investors.

The US building construction industry has evolved to rely on inefficient, compartmentalized construction processes that are unfavorable to the adoption of innovation. The result is an industry that has consistently produced buildings that are severe energy wasters and have far lower quality than can technically be achieved. The industry consumes 39% of the total US energy use, including 70% of the nation's power plant electricity. A staggering 34% of this consumed energy is lost through building envelopes. As a result, US buildings account for nearly half of all US greenhouse gas emissions – more than the transportation or industrial sectors. On a global scale, US buildings alone emit more carbon dioxide than Japan, France and the United Kingdom combined. Compared against other countries' total emissions, US buildings follow only China and the US as the world's largest source. The typical construction processes for buildings in this US are just as inefficient as the buildings they produce, in terms of time, materials and costs. According to the US Department of Energy, the construction of a typical US 2,000 square foot stick-framed home produces 8,000 pounds (4 short tons) of construction waste. Further, according to McGraw Hill Construction, 3.1% of all building project costs in the US, estimated to be $36 billion annually, are inefficiencies related to software non-interoperability issues.

The building construction industry inefficiencies have gone unaddressed for so long that the industry has essentially set itself up for disruption. Before the 1990s, pressures for change only included slight prescriptive code pressure and demand for larger (but not better) buildings in the residential sector, and more reliable buildings in the commercial sector. Several drivers are converging today, making the industry deliver cheaper, greener, and better performing buildings. This is transforming how the industry constructs new residential and commercial buildings to a more collaborative, efficient, and economical process that is better suited to adopt innovation. This transformation is described within as the *Perfect Storm* and is nothing short of a revolutionary change for the industry.

Counter to many perceptions, the current market downturn may be accelerating the industry's transition. The market downturn began in 2006, but the *Green Buildings* sector of the US building industry has grown 30% each year since. There is also a measured correlation between the downturn and the builder commitments to build green. From an entrepreneur's perspective, the market downturn offers benefits such as an easier time in getting key decision makers' time and attention. The stakeholders involved within the building construction process (developers, architects, general contractors, engineers, etc.) that entrepreneurs want to sell to tend to be less inundated with business in a downturn and therefore have more time to look for and assess new technologies and approaches. Building valuations are also dropping, further highlighting the rising cost of construction and the massive process inefficiencies, which are making it harder to build for a profit. This in turn, is driving a general attention to quality, as stakeholders and end consumers become more sensitive to valuations and long term building product and building system performance.

While the industry is set up for fundamental change to facilitate the needed innovation, challenges remain for entrepreneurs. Nth Power and the Fraunhofer Institute, drawing from 40+ years of combined experience overcoming these challenges, offer frameworks, guides, and insights to help entrepreneurs commercialize innovations more successfully. Particularly troublesome areas include: understanding who the decision makers are when selling an innovation, how these decision makers interact to collectively allow or deter the adoption of innovation, and how best an entrepreneur can successfully sell to this complex decision chain. The report offers advice on how entrepreneurs in this space can obtain funding from venture capitalists as well as how to manage some of the most important go-to-market issues. In short, multiple benefits need to be sold to many different stakeholders in order to succeed, and each benefit should have a compelling quantifiable value proposition. This will likely get an entrepreneur interest from investors, but closing a deal will also require a capital-efficient manufacturing and distribution strategy, which tends to require very specific knowledge and established relationships in the buildings industry.

The future innovation landscape for the US residential and commercial new construction industry is ripe. The need for innovation is clear, and the industry is shifting towards a model that facilitates the adoption of innovation. There is an obvious need for incremental innovations such as adding intelligence to building operations management or increasing the tightness and thermal efficiency of building envelopes. But there are also revolutionary innovations on the horizon, and these innovations will make building structures easier, cheaper, and better with a much less damaging impact on natural resources. The creative entrepreneur will succeed in bringing these solutions to market by understanding the industry framework outlined within this report. The resulting picture is one of great opportunities for entrepreneurs and investors.

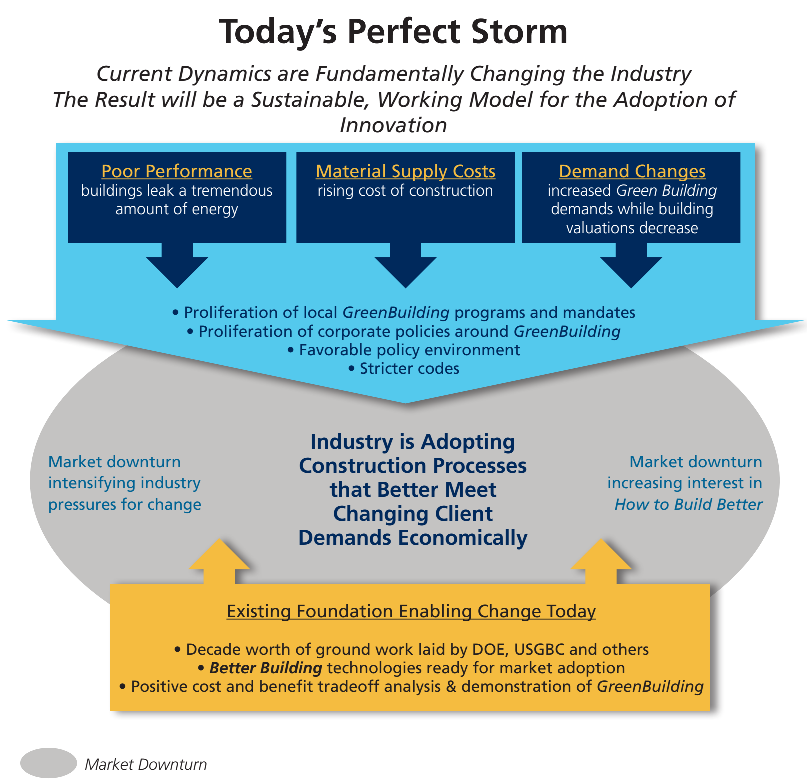
I. Introduction

This report answers the question of how to innovate for better buildings. Historically, the new building construction industry has been slow to adopt innovation. Today, however, several industry pressures are changing how the industry functions and is reversing its historic aversion towards innovation adoption. This is making the industry attractive for high growth, high margin venture capital investment opportunities, which is the focus of this report and is referred to as ***Better Buildings***. Contrarian in view, the report outlines why now is a great time for entrepreneurs, technologists, and investors to get busy working on creative ideas. The authors hope that the unique view on the innovation opportunity, the how-to guides and the technology landscape within this report encourages more activity within this currently underserved space.

Nth Power, a venture capital firm, and the Fraunhofer Institute, a nonprofit research organization, have put their frameworks together to explain the many massive and timely innovation opportunities within the US building industry's residential and commercial new construction sectors. Both groups have decades of experience commercializing and developing innovative building technologies. Nth Power is the oldest US-based Cleantech venture capital firm, with over seven building-related investments, and the Fraunhofer Institute has been advancing and demonstrating building innovations for more than 25 years.

Attracting venture capital typically requires innovations that can yield large-scale results in a short timeframe, typically within eight years. Technical and business model innovations must be practical, scalable, and economical; they must have compelling and defendable value propositions; and they must serve large markets. In simple terms, venture capitalists seek to invest in young businesses that have unfair and defendable advantages that have the potential to capture markets quickly. Since these criteria are more specific than what the industry calls *Green Buildings*, we call this investment space ***Better Buildings***.

Historically, the US building industry has been slow to adopt innovation. The industry's fragmented structure, complex and compartmentalized decision chain, and a lax environment for improvement have produced a broken innovation model. The authors propose, however, that a perfect storm is forming within the US building industry that is mending the broken innovation model for new building construction projects, signaling the start of an unprecedented industry-wide shift towards the adoption of innovation. As illustrated to the right, the storm is fueled primarily by three 'Industry Pressures': poor performance, material supply costs, and demand changes. These drivers are unlikely to reverse and are discussed in detail within this report. Guiding the industry's response is the foundation of studies, frameworks, and training developed by the US Department of Energy, the US Green Building Council and many other groups over the past decade. Their efforts are enabling a predictable, industry-wide reaction to the growing pressures. One significant result is industry's transition toward a more collaborative construction process that better allows stakeholders to meet the changing client demands economically. This is facilitating a working model for innovation adoption for the first time in the industry's history. Counter-intuitively, the current economic downturn is accelerating this progression. The industry changes taking place right now are truly exceptional.

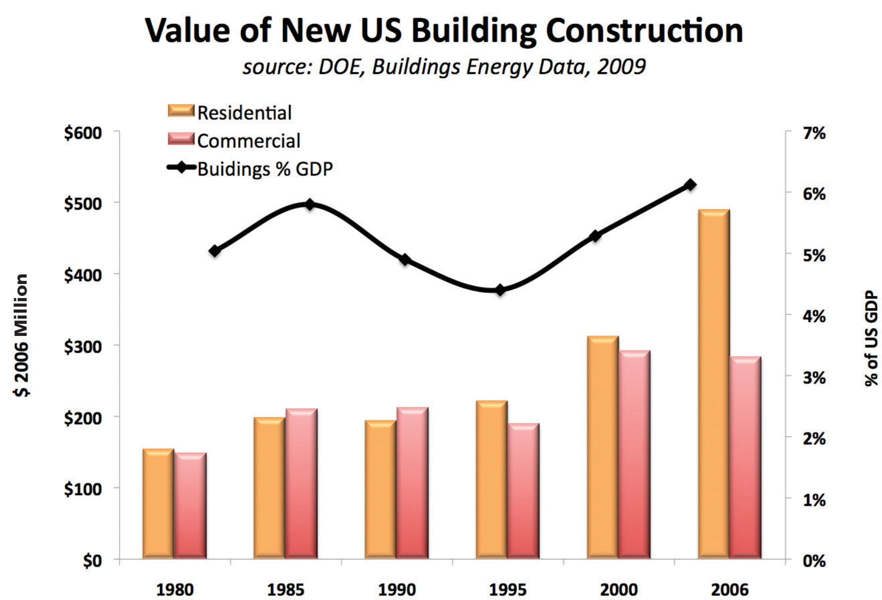


The *Perfect Storm* creates an enticing environment for early stage entrepreneurs and investors to supply the industry with new tools and capital to encourage, enable, and capture value from the industry transition. Despite the industry's unprecedented need for innovation, producing successful venture capital returns (8-10x on capital invested) is challenging. The chain of decision makers to whom entrepreneurs must sell remains complicated, and the industry will remain highly fragmented. This report offers a guide for entrepreneurs to help them understand and sell to the decision makers, and it addresses important factors to consider when a business reaches the stage of going to market. Finally, the report provides a landscape analysis of promising major technology innovations, filling out answers to the questions of what, where, when, and how to innovate for ***Better Buildings***.

II. The Opportunity for Innovation and the Effect of the Market Meltdown

Frost & Sullivan reported that the market for buildings that incorporated resource-efficient (energy, materials, etc.) practices or technologies in 2007 was $12 billion. Similarly McGraw Hill Construction Company's Green Outlook 2009 report measured that the value of US green building construction starts had increased 5x from 2005 to 2008 and forecasts that green construction starts could triple over the next five years to reach $140 billion.

To appreciate the scope of this opportunity, it's necessary to become familiar with the size, structure, decision-making practices of the industry, and its historical trends. Construction of new residential and commercial buildings is the largest part of the US construction industry. In 2006, it contributed over 6% of the entire US GDP: more than $785 billion of a $12.8 trillion economy. The relative contributions of residential and commercial construction were about even during most of the last two decades. From 2000 to 2006, however, residential construction has nearly doubled its share of GDP.



Construction of new residential and commercial buildings in the US comprised over 6% of the US GDP, accounting for over $785 billion of a $12.8 trillion economy in 2006. Source: DOE, Buildings Energy Data, 2009.

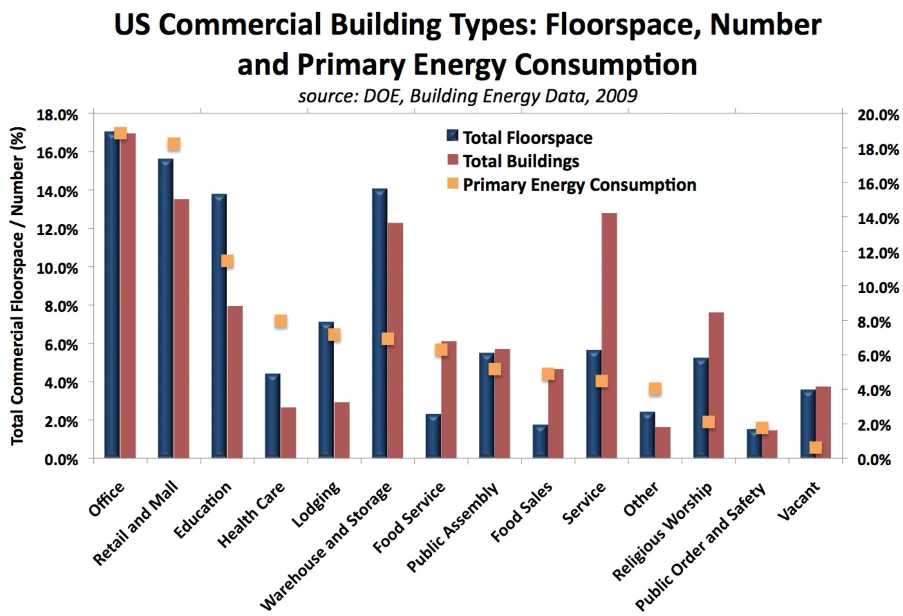
Segmenting this industry must be done carefully because it is highly fragmented vertically, horizontally, and geographically. Since the market encompasses a greatly diverse set of products and services, entrepreneurs must focus on needs particular to a section of a specific market, e.g. residential foundation walls for the northeast climate or servicing mechanical equipment in the hospitality sector. Such market segments can have sales figures in the billions. The unparalleled size and breadth of the US new building construction industry is one reason it should be attractive.

The US commercial building sector is considerably more diverse than the residential building sector. Commercial building types include hospitals, schools, offices, houses of worship, lodging, and the retail sector, which includes big box stores, enclosed malls, strip malls, grocery stores and fast food and sit down restaurants. Each of these subsectors contains unique market structures and decision makers.[1]

[1] US Department of Energy, EERE, Energy Efficiency Trends in Residential and Commercial Buildings; October, 2008.

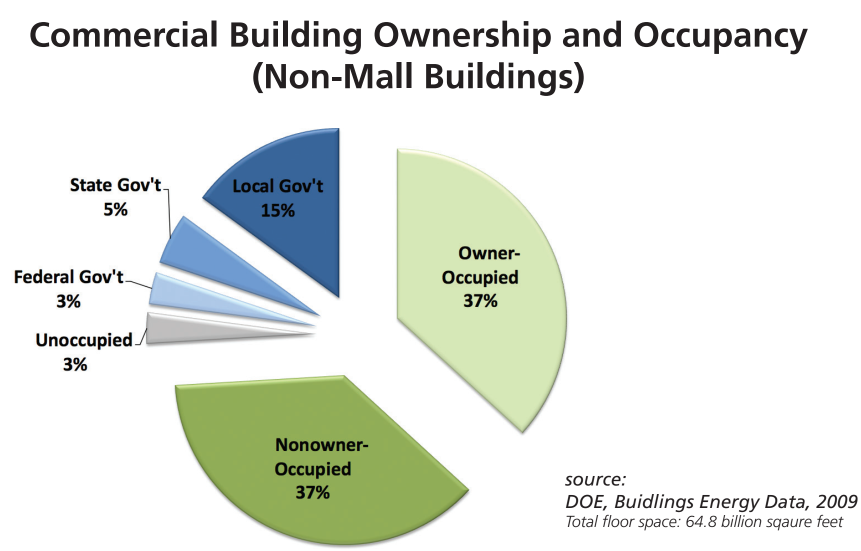
The Decoupling Effect – an Example of Non-Aligned Stakeholder Self Interest

Premium-priced energy efficient windows benefit the occupier or owner by reducing the utility bill. The general contractor, however, wants to maximize his profits by delivering on the design for the lowest cost. Since he sees no benefit from the improved energy efficiency, he is motivated to install the cheapest windows, which are often the least energy efficient.



While residential buildings serve an almost singular purpose (shelter), commercial buildings serve a wide range of purposes, each distinct from the next. The illustration above shows the spectrum for most US commercial buildings and how they compared in terms of total floor space, number in existence and how much of the US's primary energy each type consumes. As shown, Office, Retail / Mall, Education, Health Care and Lodging consume the most energy. Source: DOE, Buildings Energy Data, 2009.

The mindset of those occupying any building is another important market consideration for entrepreneurs. The commercial sector is much more heterogeneous than the residential sector, where most buildings are owner-occupied (single-family, non-rented). Within the commercial sector, 77% of the floor space is owned by the private sector, which is evenly split between owner- and non-owner occupied. Governments own the remaining 23%. Sales of innovations must target the concerns of decision-makers, who may or may not be the building's occupants. In many circumstances, the building occupier is 'decoupled' from the value proposition.[2]



source:
DOE, Buidlings Energy Data, 2009
Total floor space: 64.8 billion sqaure feet

[2] US Department of Energy, EERE, Energy Efficiency Trends in Residential and Commercial Buildings; October, 2008.

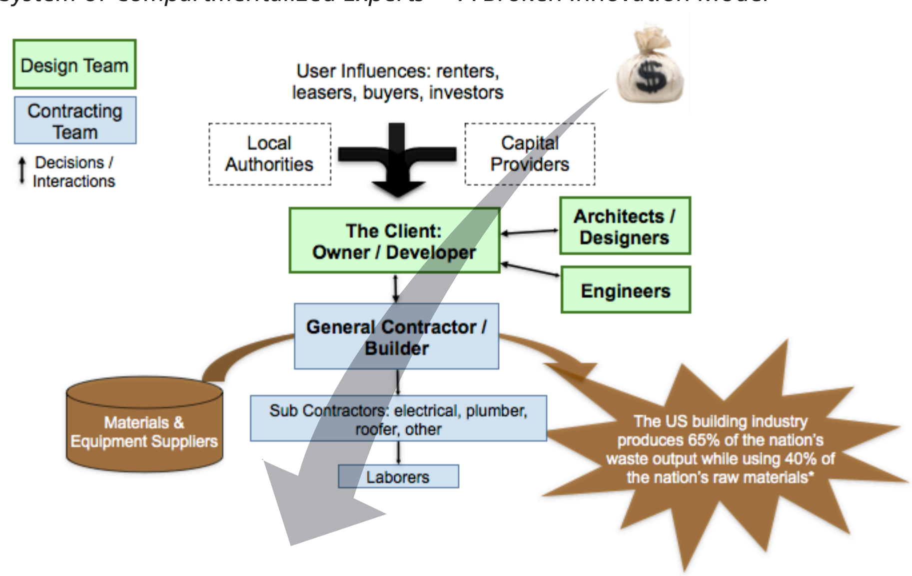
According to the US DOE 2008 Buildings Energy Data Book, the construction of a typical 2,000-sqft stick-framed home produces 8,000 pounds (4 short tons) of construction waste, 25% of which is drywall and 38% of which is wood.

When investigating any of these industry subsectors, it is important to study the value and decision chain within it, as each subsector will have a unique set of incumbents and dynamics. Buildings in general are manufactured products, designed and built in a production process that comprises a sequence of discrete steps. New building construction steps can include conception, planning, architectural and engineering design, contractor bidding, construction and commissioning. Today's general building process evolved during a time when the US enjoyed inexpensive construction materials and energy. Over most of the industry's history, there was little understanding of the consequences of carbon emissions, product lifecycle issues or the benefits from enhanced building design and functionality. Nor was there much perceived need for an understanding. With few checks and balances in place, the industry grew up to be fragmented and non-standardized regarding stakeholder interaction. For example, hundreds of design and modeling software tools are available for architects, engineers, contractors and consultants. Because these were developed independently and without standardization, there are major problems with electronic information sharing between incompatible software programs. Stakeholders must translate information manually or develop custom file sharing software. Both can be expensive, error-prone and time consuming.

Due in part to poor stakeholder communication, the industry has grown to be wasteful of materials, time, and costs. In the traditional building construction process, it is a "construct by committee" process in which the committee never actually meets to establish common goals. Each discipline involved in the process is managed by an expert, who typically seeks to satisfy the interest of his or her specific industry segment and is involved in only one or two steps. Experts often do not meet with other key stakeholders – even those whom their decisions affect. The developer or owner and architect create the design specifications, budget and schedule in isolation from the general contractor and engineer, who get involved afterwards to specify subsystems and manage the construction process. This compartmentalized process structure, illustrated below, creates multiple inefficiencies. It has been a significant barrier to innovation because it does not align the interests of those involved in the collective process. This process (i.e. how the industry works together), however, is changing.

Traditional US Building Value Chain & Decision Chain

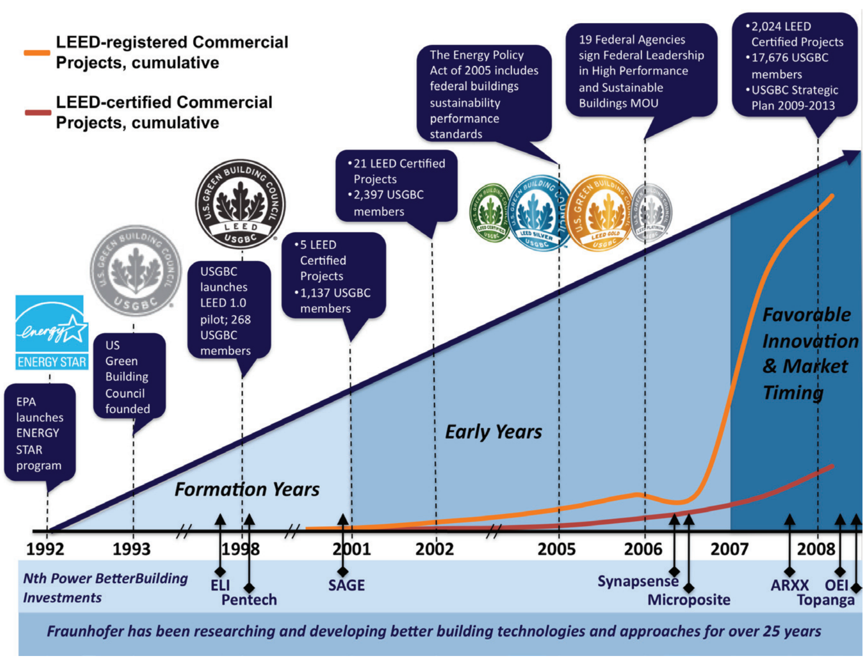
System of Compartmentalized Experts = A Broken Innovation Model



To the right is a schematic of the traditional construction process for residential and commercial buildings in the US. Each stakeholder operates with very apparent boundaries, lending to a compartmentalized, non-standardized and inefficient process for achieving a set of design goals. Statistic from: Lenssen and Roodman, 1995, "Worldwatch Paper 124: A Building Revolution: How Ecology and Health Concerns are Transforming Construction," Worldwatch Institute.

The strong division between function groups has brought about the industry's broken innovation model. Compartmentalization prevents industry stakeholders from sharing or retaining the knowledge gained from newly demonstrated innovations and even from natural ingenuity. This industry has, instead, maintained a preference for re-using what has worked reliably in the past. While this reduces liability, it eliminates any meaningful industry 'technology improvement learning curve' or performance improvement trajectory common to other industries. The ability of an industry to adopt innovation is an important attribute that venture capitalists study to determine the timeliness of investments.

Since the 1990's, however, key industry organizations have made concerted efforts to address these innovation barriers, establishing direction and confidence that supports the industry-wide change seen unfolding today. Groups such as the US Department of Energy (DOE) and the US Green Building Council (USGBC) continue to be instrumental in laying this groundwork. Without the unifying efforts of programs like the USGBC's Leadership in Energy and Environmental Design (LEED) rating system, the industry's response to the growing pressures would likely be chaotic, unpredictable and much more litigation-heavy. Further, policies would have limited 'tools' to use in implementing needed market changing mandates and incentives.



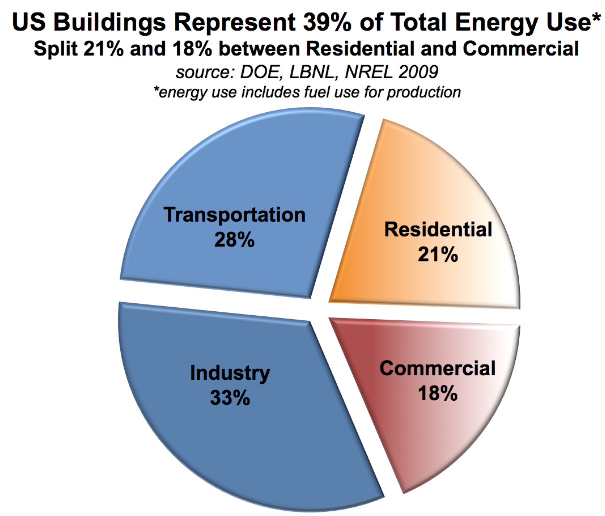
The US Green Building Council, along with some other organizations, laid the foundational groundwork over the past decade that is enabling the industry to react in concert to the growing demand pressures. The very early numbers in the USGBC's LEED growth seen above are for New Commercial Construction. Registered projects (orange line) grew quicker because, by definition, a project remains in the construction pipeline for 2-6 years before certification is possible. Thus, the early registration growth reflects strong momentum early on, despite the certification numbers starting slowly.

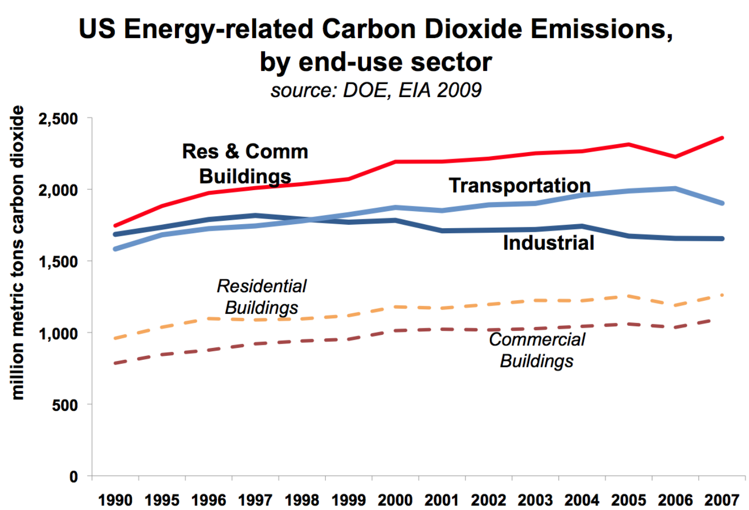
Growing Industry Problems

For social, political, economical and environmental reasons, the industry is under unprecedented pressure. Poor operational performance, rising costs of construction materials and a widespread demand for better, cheaper buildings are some of the more apparent pressures for change. These driving forces for change show little likelihood of reversing or declining in the long term, which should give confidence around the market opportunity to savvy entrepreneurs.

BUILDING PERFORMANCE PRESSURES

The operational performance of the built environment – a function of building envelope construction, occupant behavior and subsystem interactions – is a growing social and political concern. Today, a staggering 34% of the energy consumed by buildings (roughly 14 quadrillion Btus [quads] out of the 40 quads used in residential and commercial buildings in 2005) is lost directly through building envelopes.[3] Energy usage by the built environment has been steadily increasing over time. Today, the 114 million households and more than 4.7 million commercial buildings in the US consume more energy than the transportation or industry sectors. This accounts for nearly 39% of the total US energy use, including 70% of the nation's power plant electricity consumption.[4] The burning of coal (primarily) and natural gas to supply buildings with electricity, coupled with direct burning of natural gas, makes buildings responsible for the largest share of US carbon dioxide emissions – approximately 40% today, up from 33% in 1980, and as with energy use, accounts for more than the transportation or industry sectors.[5] The new building construction industry has created a built environment in the US that is hemorrhaging energy and carbon.





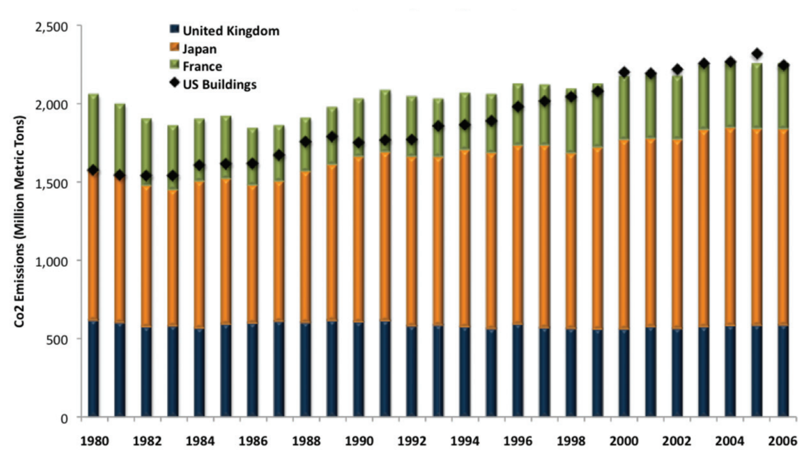
[3] According to Marc LaFrance, Building Technology Program, US DOE, EERE, Building Envelope R&D, SPRI Annual Conference, 2006.

[4] DOE, Buildings Energy Data, 2009; 70% is primary use, so includes transportation and distribution.

[5] EIA Annual Energy Review 2005. U.S. Energy Information Administration, U.S. Department of Energy.

CO2 Emissions of US Residential and Commercial Buildings Relative to Japan, France, and the UK

source: DOE, Buildings Energy Data, 2009

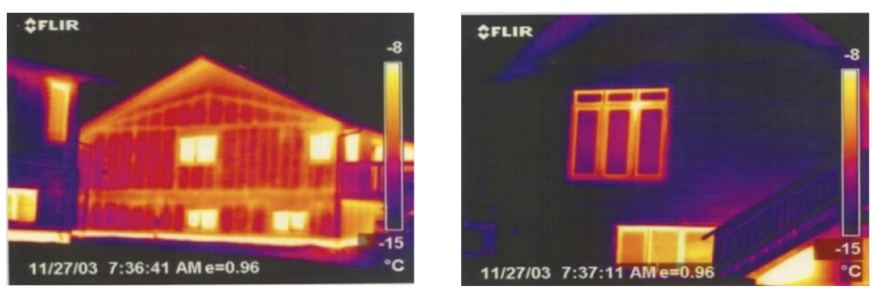


The illustration to the right shows CO2 emissions in million metric tons each year starting in 1980 and through 2006. The bars are cumulative with the UK in blue on the bottom; Japan in orange in the middle; and France in green on top. The black dots are CO2 emissions from US residential and commercial buildings. Starting in 1999, US buildings surpassed the cumulative CO2 emissions of UK, Japan and France on an annual basis. Source: Energy Information Administration, US Department of Energy.

Since carbon is a global issue, it's important to put the US buildings' contribution into perspective. US residential and commercial buildings accounted for roughly 8% of worldwide carbon dioxide emissions in 2006 (2,241 million metric tons of carbon dioxide).[6] Compared to total carbon dioxide emissions of entire economies, the US building sector would rank third, following only China (6,018) and the US itself (5,902). Carbon dioxide emissions from US buildings exceed the combined emissions of Japan, France and the United Kingdom.[7]

Conventional Woodframed ICF Thermal Mass Home

Yellow = Heat Loss



LEFT is a common wood-framed home with conventional fiberglass insulation. **RIGHT** is a similar home next door constructed with insulated concrete form (ICF) walls (poured concrete walls and foundation that use Styrofoam-like framing which are left as part of the energy efficient wall system). The inside temperatures of the two houses are around 22 degrees C (room temperature) and the outside air temperature is approximately -15 degrees C. Heat (yellow) can be seen as abundantly escaping from the wood-framed home, primarily through the wood beams where nails act as thermal bridges around the insulation. The ICF home on the right does not use nails and so the only thermal bridges are seen around the windows. Inefficient envelopes are a significant issue in both hot and cold climates.

The root of this problem is poor thermal integrity of the building envelope, or exterior shell. The building envelope consists of walls, windows, doors, roofing, and other exterior components, and thermal leaks through and around these components are common. Envelope inefficiencies, such as thermal bridges and air gaps, represent pathways for heat to escape. This renders insulation less effective and forces the mechanical systems to work harder to compensate. Most of today's mainstream building techniques do create thermal bridges, perhaps most notably in residential wood framing, where each wood stud is a potential thermal bridge. Computer simulations show that with tighter construction, heating and cooling costs can be reduced between 3 and 36%[8], so the benefits of improved building envelopes are clear.

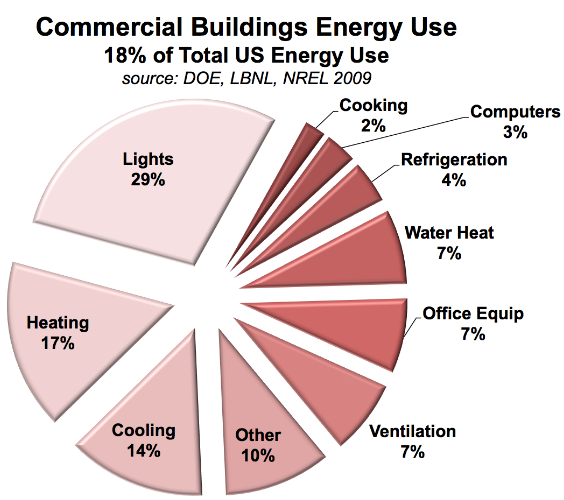
[6] US building sector includes existing residential and commercial buildings. The measured carbon dioxide emissions are from energy used operating existing buildings; energy used in making building materials are included with the industrial sector.

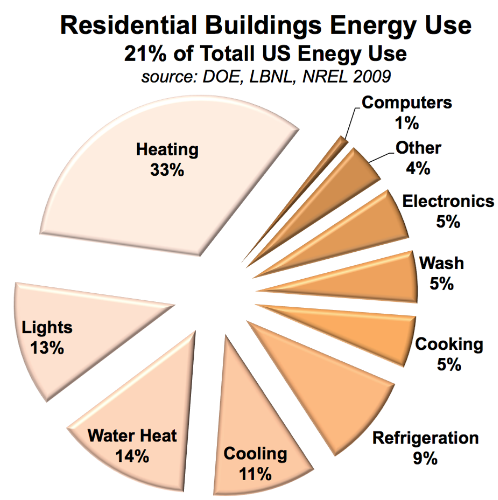
[7] US Energy Information Administration, US Department of Energy, 2009.

[8] Emmerich, SJ, et. al,, NISTIR 7238, Investigation of the Impact of Commercial Building Envelope Air Tightness on HVAC Energy Use, 2005.

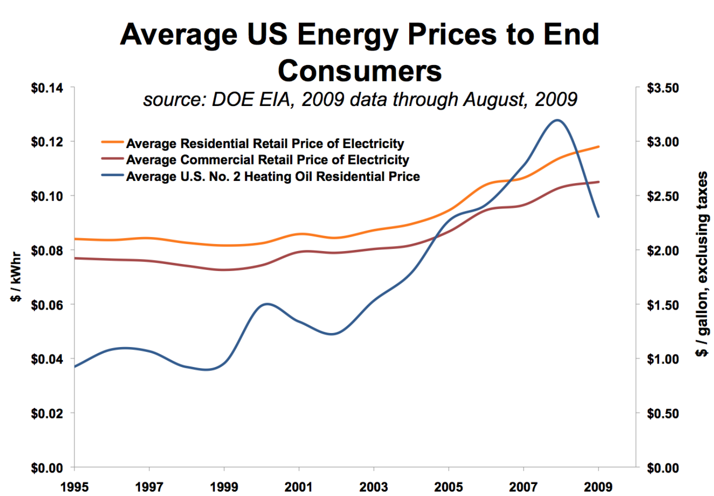
Many highly energy efficient building products, like windows for example, are amazing from a stand alone perspective, but then in practice, the energy efficiency benefits can be completely negated by thermal bridging or air gaps.

Building subsystem performance is also a key contributor to the problem. Heating, ventilation, and air conditioning (HVAC) systems and lighting systems use energy to create and maintain suitable environments for the owner or occupier. These sub-systems consume a tremendous amount of energy and therefore contribute large amounts of carbon to the atmosphere. The DOE estimates that HVAC systems in commercial buildings create around 1.1 quads of waste heat per year from inefficient lighting, equipment, and solar gains from windows.[9] This alone represents about 3% of the annual energy consumed by US buildings.

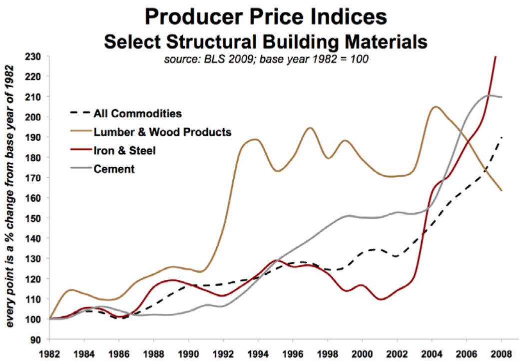




Bringing this energy-hemorrhaging problem to the forefront is the rising cost of energy sources used by the built environment, as well as the social and political pressures around the associated carbon emissions. Prices for electricity and No. 2 heating oil, for example, have both been rising steadily. Energy prices are often volatile in the short term, but the underlying trend, as seen in the chart below, is one of increasing costs, which is adding economic pressure in many geographic regions to several building sectors through more expensive operations.

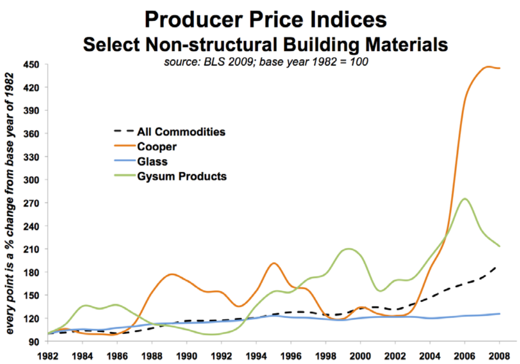


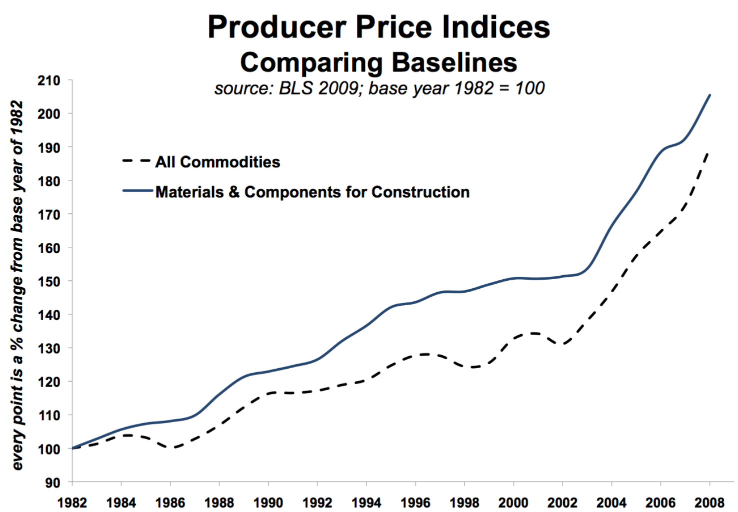
[9] Department of Energy, BTS Core Databook, LBNL, 2004.



BUILDING MATERIALS SUPPLY PRESSURES

Like energy prices, building material and component prices are volatile and rising over the long term. Data from the US Bureau of Labor Statistics (BLS) shows that materials and components for construction have increased almost 200% since 1983, with half of this increase realized just in the past four years. Compared to an index of all commodities for all industries, the construction index has risen about 30% higher since 1983. Both steel and concrete now cost twice as much as they did four years ago.[10] Copper, a common piping material, now costs five times what it did four years ago. Labor costs are also increasing, driven by supply restrictions. There will be some price relief in the near term as demand decreases because of the industry slowdown, but the long term trend is clearly one of rising prices, as shown in the chart below, which puts more strain on the industry.





A study by Carnegie Mellon University measured the relationship between increased lighting control and productivity, showing an average increase of 7.1% in productivity.

DEMAND PRESSURES

A third source of growing industry pressure is increased consumer demand for optimized building environments delivered at lower costs. While construction costs are rising, building valuations are decreasing (i.e. correcting), making it harder for industry stakeholders to meet client demands and still make a profit. At the same time, the market is becoming more confident about positive economic correlations between energy efficiency, tighter envelopes, better indoor air quality, etc., with lower operating expenses, higher asset valuations, higher rent or lease rates and what is simply needed to achieve a Class A rating in an ever increasingly competitive market.

Functional parameters that can be optimized for economic gains include worker productivity, health (i.e. air quality), comfort, retail sales and, of course, energy, water and carbon. Savvy entrepreneurs will realize that energy will typically underline most of these functional parameters but may not be the most compelling selling point. For example, operation expenses for many commercial buildings are mostly related to worker salaries while only a fraction is related to energy. In fact, a 1% increase in worker productivity (valued roughly at a 1% savings in salary expenses) can well exceed operation, maintenance, and energy costs for a commercial building occupier.[11] For homes, comfort-related benefits like temperature control and noise reduction often have

[10] CERA Index, derived from Bureau of Labor Statistics Data and Bureau of Economic Analysis data.

[11] "Sustainability: High Performance Buildings Deliver." City of Seattle. Seattle City Light. 26 February 2004.

Importance of Economic Impacts

*Energy efficiency, and carbon intensity reduction, though necessary and fundamentally needed, must be sold to the building's owner, user or builder, in terms of economic benefits, which are more often related to worker productivity, comfort, health or sales. Herein lies one of the tricks to implementing **Better Buildings**.*

more compelling value propositions than energy efficiency. Researchers are continuing to develop data suggesting correlations between natural light and better air quality and increased retail sales or worker productivity, which have economic benefits to building owners and occupiers and typically have underlining energy and carbon benefits.

Market Reaction and Indicators for the Rate of Change

In reaction to these growing industry pressures, there is a growing number of market reactions that provides positive indicators of change. Industry consortia, such as the American Institute of Architects, are aligning themselves in support of change and industry support services, such as insurance companies and commercial building underwriting services, are offering green mortgages to homeowners and developing commercial real estate green building underwriting standards. Three more measureable market indicators include: policy changes (social and political indicators); building code changes (industry indicators); and voluntary certification growth (market indicators).

SOCIAL AND POLITICAL INDICATORS

There have been several favorable policy indicators for change at the local, state and federal level in the past year. Many states, such as California, Arizona and Connecticut, and cities, such as Boston, Washington DC, and San Francisco, are setting progressive green building policies, serving as an example for others within the US as well as for governments abroad. As of late 2008, there were roughly 27 cities in California with passed mandatory green building ordinances, including San Francisco and Los Angeles.[12] The San Francisco law, which passed in 2008, requires all new large commercial buildings and their interiors to reach LEED Silver by January 2009 and LEED Gold by January 2012. It also requires all new high-rise residential buildings to reach LEED Silver after January 2010.

At the state level, tax credits to incentivize green building practices are proliferating – Maryland, Oregon and many others already have this in place. California took a much stronger policy action last year in 2008, by approving a state-wide green building standard as a vehicle for the state to help meet its ambitious greenhouse gas reduction goals. This standard requires that all new construction in the state—from commercial buildings to homes, schools, hospitals, etc—to reduce energy usage by 15% and water usage by 20%. The standard will be voluntary in 2009 but will become mandatory in 2010. Other states are now debating the adoption of similar laws, including Massachusetts, New York and New Jersey. Debate around national green building laws and national building energy and carbon labels is increasing at the federal level.

These indicators are creating a ***Better Buildings*** market quickly in the US. In fact, product and service companies out of Germany, Holland and other countries are taking note. Companies in these countries are generally ahead of the US in developing better building products because of an earlier awareness around the energy and carbon consequences from the built environment. Such companies are actively visiting the US in order to position themselves and establish the needed relationships to sell into this quickly growing market.[13]

INDUSTRY INDICATORS

Building codes play a major role in determining which products can be used in a building. Mandatory building codes set minimum performance thresholds for new construction and existing buildings in areas including energy, air quality, fire protection, and other

[12] State of California, Dept of Justice: http://ag.ca.gov/globalwarming/pdf/green_building.pdf
[13] Dan Geiger, Executive Director, USGBC-Northern California Chapter at The GreenBuilding Summit in June 2009.

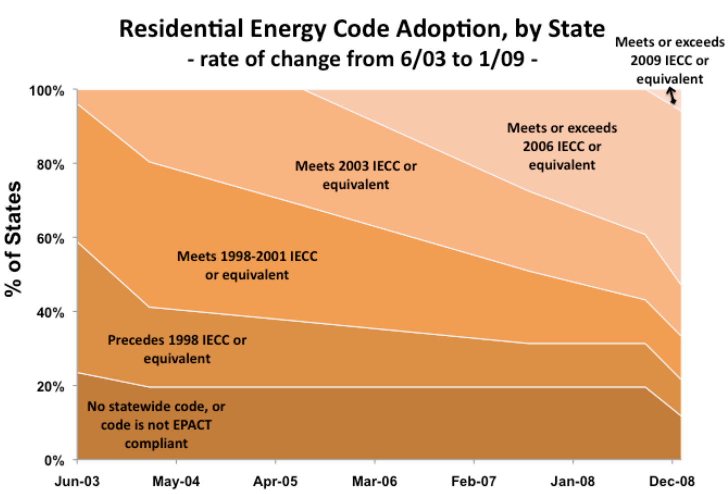
areas to ensure safe and effective building operation. Energy codes determine minimum insulation levels, HVAC and lighting system requirements, fresh air rates, and control systems. Codes are also an important indicator of the direction of industry change, because they are prescribed and agreed upon collectively through a consensus-driven voting process.

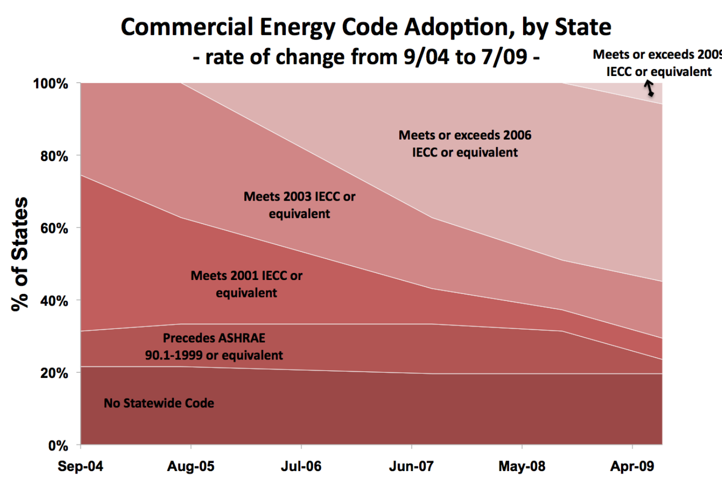
Tracking the states' adoption of building energy codes, one can see accelerated increases in both minimum insulation thresholds and the number of states adopting new code versions over the past few years, compared to what was done previously. Notably, the minimum insulation threshold for above grade wood framed walls for both residential and commercial within the 'middle of the road' climate zone increased for the first time within the 2006 codes, and over half of the states have adopted this stricter code for both commercial and residential building. Furthermore, ASHRAE, DOE, and many other groups are proposing even higher energy efficiency thresholds within the next several code revisions.

The charts below give an indication of the of rate of change for stricter minimum insulation requirements within the US residential and commercial energy codes. The graphs below the charts show the rate of change that US states are adopting the newer, stricter energy codes into law. Source: ASHRAE, DOE, Internet reseach 2009.

Residential Insulation Requirement Changes	
Above Grade Wall, Wood Framing, Zone 5 (up to Chicago)	
r-20	2009 IECC
r-19	2006 IECC
r-18	2003 IECC
r-18	2000 IECC
r-18	1998 IECC

Commercial Insulation Requirement Changes	
Above Grade Wall, Wood Framing, Zone 5 (up to Chicago)	
r-13 + 3.8 cont insulation	90.1-2010-ASHRAE, proposed
r-13	2006 IECC / ASHRAE 90.1-2004
r-11	2003 IECC / ASHRAE 90.1-2001
r-11	2000 IECC / ASHRAE 90.1-1999
r-11	ASHRAE 90.1-1998

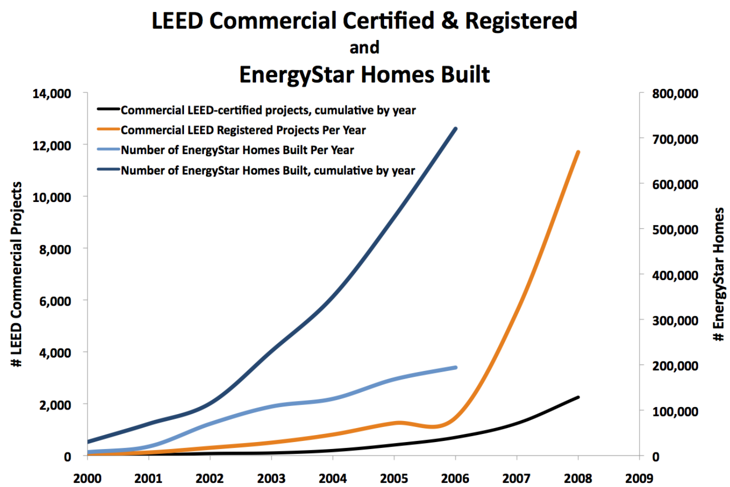




MARKET INDICATORS

Today, there are a number of voluntary building certification programs around sustainability or energy performance of residential and commercial buildings. These programs have grown tremendously over the past several years, indicating a changing market. While these certifications are growing in demand for economic, policy, competitive and even bragging reasons, the message is clear that there is a change in demand for building better.

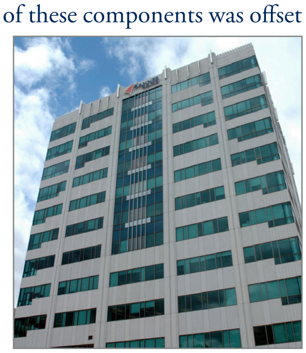
Voluntary programs have seen tremendous growth even during the market downturn. The USGBC LEED program, for example, certified five commercial projects in 2001 and as of May 2008, there were 1,540 cumulative LEED-certified commercial projects. Additionally, the National Association of Home Builders (NAHB) voluntary program for homes and the US EPA's ENERGY STAR program for homes and commercial buildings have seen tremendous growth.[14]



Much of the recent growth in voluntary certifications has been partly due to a better understanding that certification can be achieved for little to no price premiums at all while also enhancing building valuations and the ability to charge higher rent or lease rates.[15] For LEED certified residential and commercial buildings, for example, costs are different but not necessarily more. Gold and Platinum LEED-certified residential or commercial buildings that do require cost premiums often failed to make effective cost tradeoffs – most likely the result of using the traditional, compartmentalized construction process to achieve certification. Other cases where construction premiums are seen include owner-occupiers that want to incorporate highly visible attributes such as building integrated photovoltaics, auto-dimming windows, or other expensive cutting-edge features. The motive here is typically one of PR: a desire to show the outside world that the building is advanced and 'green.'

The 195,000-sqft Banner Bank Building in Boise, Idaho, for example, was built for a very standard amount of $128 per square foot and earned a LEED Platinum rating. The building included a reflective roof, a water reclamation system, computer-controlled lighting and other efficiency technologies. The higher cost of these components was offset partly by the savings in HVAC units, which can be sized smaller in ***Better Buildings***.[16]

Banner Bank, the top picture to the right, achieved Platinum LEED, immediate ROI, higher value, lower operational costs. The bottom picture on the right is Acciona's NZEB Solar HQ, which, on the other hand, has very visible and advanced state of the art features and includes cost premiums with an anticipated 10 year pay back from energy savings.



Along with clarity around the true costs of building better, the market is gaining confidence in building better because of a growing list of quantified and demonstrated building valuation benefits from building better. One example of documented, credible benefit data comes from the CoStar Group.[17] In 2008 the CoStar Group tapped into its database, which covers billions of square feet of commercial buildings in the US, and released a report, which analyzed green-labeled commercial buildings and non-green labeled commercial buildings. The analysis showed statistical evidence that green buildings achieve higher rents, higher occupancy rates, lower operating costs and higher prices per square foot than their peers. While cause and effect relationships can be debated in these analyses, the findings are nevertheless encouraging preliminary indicators.

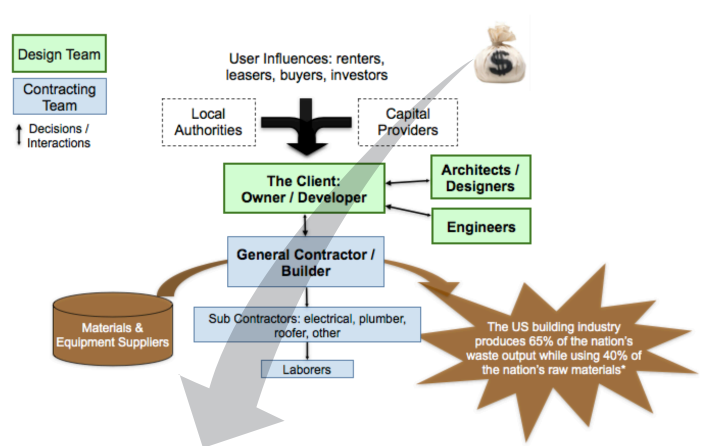
[14] Data from publically available sources: USGBC; EnergyStar.
[15] Studies are available on the USGBC website.
[16] Source: www.allbusiness.com/environment-natural-resources/environmentalism/11462610-1.html
[17] A company that provides information services to the commercial real estate industry.

Financial Metrics for Green vs Conventional Buildings[18]			
Building Type	Occupancy Rate	Rental Rate Per Ft^2	Sale Price Per Ft^2
Energy Certified	91.5%	$30.55	$288
Non-Energy Star Peers	87.9%	$28.15	$227
LEED Certified	92.0%	$42.38	$438
Non-LEED Peers	87.9%	$31.05	$257

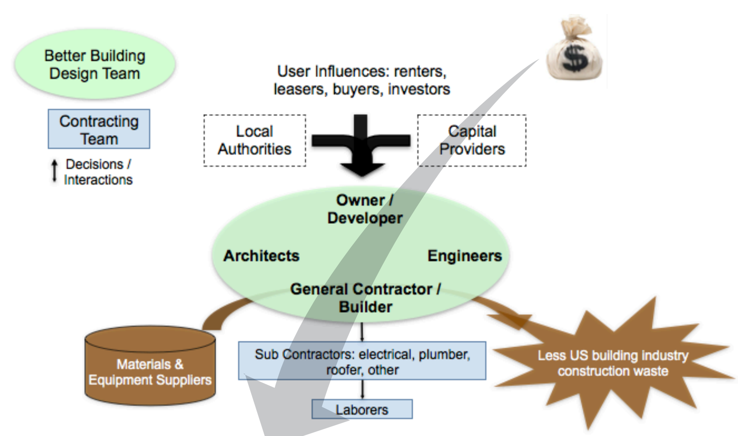
INDUSTRY'S REACTION IN HOW TO BUILD BETTER

The industry pressures and the enabling groundwork are enticing dynamics for an industry shift towards ***Better Buildings***. The question of how the industry builds better is an important one. The typical building development process is very inefficient and facilitates the broken innovation model. The compartmentalized, non-standardized traditional process for residential or commercial buildings includes a significant amount of excess or 'fat' (i.e. market inefficiencies) that can be trimmed and needs to change in order to build better economically. Consensus is forming around a process called *Integrated Design*.

Traditional US Building Value Chain & Decision Chain
System of Compartmentalized Experts = A Broken Innovation Model



Better Building US Building Value Chain & Decision Chain
System of Integrated Parts = A Working Innovation Model



Above, the traditional building progress is compared with the Integrated Design Process. The illustrations are more representative of commercial building projects, but they illustrate that the Integrated Design Process emphasizes a collaborative approach to design, planning and construction. It can add effort and costs upfront, but has been shown to save costs overall by making better-informed technology trade off decisions, minimizing delays and budget changes. Statistic from: Lenssen and Roodman, 1995, "Worldwatch Paper 124: A Building Revolution: How Ecology and Health Concerns are Transforming Construction," Worldwatch Institute.

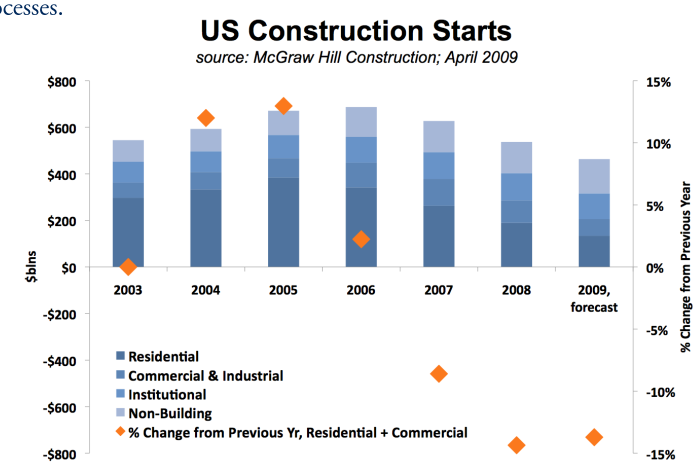
Integrated Design uses a highly collaborative and standardized construction process and prioritizes setting a common goal for the project that is shared amongst all of the construction stakeholders. The general contractor, for example, is now part of these discussions and offers input as part of the design team. This enables the industry to build better and cheaper, and facilitates collaborative learning amongst stakeholders, helping to establish an industry learning curve. This type of interaction brings with it a working innovation model for the industry. The increased stakeholder interaction may require extra time upfront, but it facilitates cost-benefit tradeoffs not otherwise possible, reducing total project costs, liabilities and enabling the implementation and diffusion of new technologies and approaches.

[18] Source: CoStar Group, "Commercial Real Estate and the Environment"; All Figures are as of first quarter 2008.

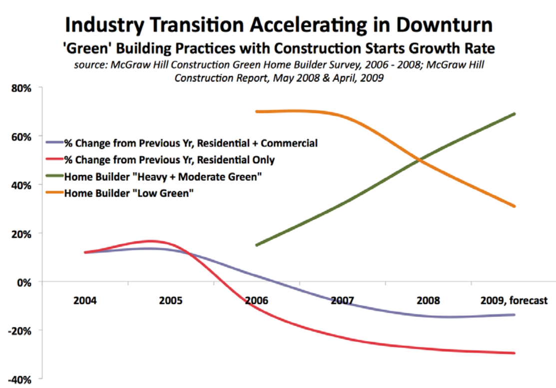
The McGraw Hill Construction Company surveyed industry professionals and found that on average, 3.1% of all project costs today are related to software non-interoperability from the non-standardized construction process and stakeholders not interacting. This translates into $36 billion of annual wasted costs, of which owners bear nearly two thirds, according to Gallaher, O'Connor, Dettbarn, Jr., and Gilday, "Cost Analysis of Inadequate Interoperability in the US Capital Facilities Industry," NIST 2004, pp. 6-1 – 6-3.

The Market Meltdown and the Industry's Transition

With residential new build starts at a near standstill, and growing delays in commercial projects in 2009, the general consensus is that the market downturn is a bad thing for all involved. From an entrepreneur's perspective, however, this is not necessarily the case. The downturn may prove to be a positive accelerator for the adoption of innovation. While not fundamental to the opportunity, the market downturn has nonetheless increased some of the pressures for change – adding urgency, increasing competition, and also providing a slowdown, making more time for industry stakeholders to improve their current models and processes.



The US building industry is under going a market downturn. To date, the residential sector has been hit the hardest. There are signs that the commercial sector will undergo a severe valuation correction in 2009.



Nth Power and Fraunhofer have overlapped this data with residential and commercial construction project-start data (real and forecasted). The resulting graph suggests that it is reasonable to extrapolate that the downturn is correlated with, and accelerating, the transition of industry decision makers away from the 'old' and adopting the 'better.' The data shown here is far from conclusive, but it should entice entrepreneurs and investors alike to further investigate the opportunity of getting involved during the market downturn.

As part of the market downturn, residential and commercial building valuations are resetting and competition amongst the process stakeholders and product developers are increasing. With the steep valuation corrections, the pressure to build even cheaper but better buildings is mounting and the general response has been a flight to quality, accelerating the adoption of some ***Better Building*** innovations. As fewer projects continue or get initiated because of the downturn, general contracting firms, engineering firms, architectural firms, and homebuilders are in search of differentiation that will win the increasingly competitive project bids. As a result, ***Better Building*** innovations can find very receptive potential customers and product demonstration partners. Key decision makers (general contractors, architects, developers, distributors) also have more time to investigate new technologies and approaches and to reposition their own businesses for the future. When inundated with business during boom times, industry decision makers have less incentive to alter what they are currently doing.

Data support these claims and the theory that the downturn is accelerating the industry's transition towards ***Better Buildings***. An annual McGraw-Hill Construction (MHC) residential builder survey shows that in 2008, a majority of the 400+ residential builder respondents reported that they were moderately or heavily invested in ***Better Buildings*** for the first time ever – almost two years into the residential market downturn.[19] MHC projects that the 2009 results will show a significant majority – up to 70% of survey respondents – as embracing better practices and products to a significant degree. Though these results are qualitative and only address the smaller homebuilder, they nonetheless signify a positive effect for entrepreneurs during the downturn. It should also be noted that the smaller homebuilders play an important demonstration role for getting new technologies adopted by the larger homebuilders.

[19] Survey has been gauging the attitudes of the US residential building community on approaches and technologies related to energy efficiency, indoor air quality, water efficiency, resource efficiency and site management, since before the meltdown. Their annual surveys have been conducted since 2006 and have ~400 respondents, primarily smaller production builders.

The Perfect Storm – Adding It All Up

The US building industry has set itself up for disruptive change. Today, there is a convergence of forces accelerating a major transition that will lead to successful innovation adoption. As seen in the illustration below, downward market pressures related to operational performance issues, supply issues, and demand issues are converging. The initial knowledge base that was started through demonstration projects, cost-benefit studies, and frameworks over the past decade is now providing the needed confidence and direction for the industry to actively respond to the growing pressures. The market downturn is actually accelerating this shift, highlighting inefficiencies and giving stakeholders the time they need react and reposition for competitive advantage. The result is an industry in flux, but one that is progressing quickly towards massive innovation through a better construction process that facilitates a working model for the adoption of innovation economically.

The authors believe that this dynamic makes for an attractive investment space when compared to other Cleantech areas. Within ***Better Buildings***, innovations compete on their own merits – on value propositions, business models and execution – without the influence or need for government market manipulations. At the same time, code requirements, mandates and a growing number of incentive-based programs are supporting the adoption of ***Better Building*** innovations. The authors believe that this scenario is suggestive of an industry in quick transition towards ***Better Buildings***, where technology and process innovation will be adopted because of natural demand-pull.

III. How to Innovate for Better Buildings

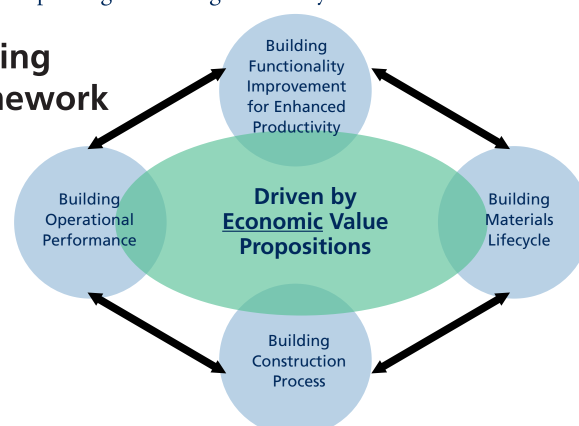
From an entrepreneur's perspective, the opportunities for ***Better Building*** today are compelling. Still, the industry has unique challenges, especially with its complex and sometimes self-defeating decision chain, and so requires care and strategic thinking to innovate successfully. Entrepreneurs must understand how to enter and sell into the market, they must possess intimate knowledge of the key decision makers within the collective decision making unit (DMU), and finally they must understand how each member of the DMU is motivated towards a decision.

The Better Building Innovation Framework

Representative of the innovation opportunities within the US building construction industry today is the Better Building Innovation Framework below. The momentum behind the industry's relative quick transition is triggering a proliferation both of new products and of old products repositioned as 'green' or 'sustainable.' There are also a number of labeling programs entering the market to offer consumer confidence that a product is in fact 'green' or 'sustainable.' The need for these products and labels are real, but many are misleading, which is diluting the credibility of products that truly live up to their claims. This 'greenwashing' has contributed to a level of market confusion and distrust, which raises the bar in proving something to actually be 'better.'

The Better Building Innovation Framework

source: Nth Power, LLC



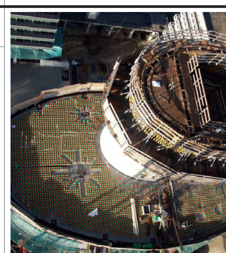
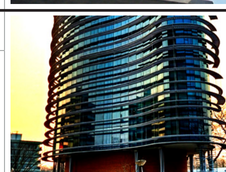
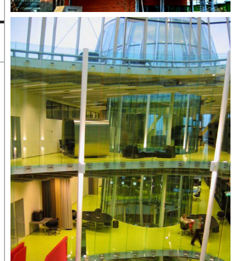
To help entrepreneurs navigate through the rising noise of greenwashing, the innovation framework above identifies four primary and interlinked disruptive innovation categories and highlights that they all must have compelling economic value propositions to be successfully adopted by the market. There is a growing need for better materials and building products, better optimized environments created by buildings, better operational performance, and a better design and construction process.

Understanding and Selling to the Decision Makers

Understanding how the decision-making unit (DMU) members interact with each other is essential to successful sales and innovation commercialization. Sales are improved by securing 'champions' within the DMU who can then sell to the collective DMU. As a rule of thumb, however, decision-making inefficiencies make it necessary to sell an innovation to all stakeholders – developers, architects, general contractors and owners and occupiers. All ***Better Building*** practices and technologies should be evaluated according to each DMU member's decision criteria to assess the DMU's overall receptiveness. Given the different perspectives encompassed by the DMU, it is always best to have multiple benefits – as previously discussed, energy efficiency is a key driver for change, but does not always have market appeal when compared to more compelling economic value propositions for productivity, health, retail sales and even comfort improvements. Below is a decision framework for DMU members.

Decision Framework with an Example[20]

The example used here for demonstration purposes is a proprietary biaxial semi pre-cast concrete slab technology for commercial high-rise construction, extensively used in Europe. The technology utilizes plastic spheres to reduce weight by displacing concrete that adds weight but no carry effect. It is exemplary of an innovation that has compelling value propositions to each of the DMU members.

DMU Members	Value Proposition To Each DMU Member	
The Developer / Construction Manager • ROLE Taking raw land or an existing piece of property, improving it on budget and on schedule and then selling the developed assets or keeping them to produce cash flow (thereby becoming the owner). • DECISION METRICS Spreadsheet decision style with a rational objective of maximizing asset value with a given budget and time schedule.		• Semi pre-cast allows for quicker build times. One day is saved per floor, meaning that a 10-story project could be finished 10 days sooner. • Can contribute to 9 LEED credits.
The Architect • ROLE Designs physical and functional aspects of buildings that meet code and client expectations. • DECISION METRICS Professional, objective, client-driven decision style with the objective of winning customers by offering best designs that meet customer needs.		• Semi pre-casting allows for efficient and precise manufacturing, enabling innovative building designs, including non-traditional shapes. • Lighter floors require fewer support columns and beams, opening up the floor space for new architectural designs, including cantilevers.
The General Contractor / Builder • ROLE Construction management services, encompassing scheduling, building product quantities, cost estimates, management of day-to-day build tasks, labor. • DECISION METRICS GCs carry many of the project liabilities and therefore make decisions in context of minimizing liabilities and maintaining project timelines and budgets.		• Installation at the job site is practical (no new tools required) and easy (assembly like LEGOs instead of construction), which minimizes liabilities for the general contractor. • The technology simplifies the placement of ducts, heating / cooling systems, etc, so management of the 'relatable trades' is simplified.
The Owner • ROLE Asset owner and manager; project oversight. • DECISION METRICS Maximize Net Operating Income (NOI) of the asset by minimizing operating and maintenance costs and maximizing leasing rates.		• Enables a reduction in the structural costs compared to more conventional techniques. • Offers greater thermal insulation and noise dampening because of the air cavities. • Can result in thinner concrete floors, giving the owner more floor levels to sell or lease out. • No drop beams and fewer support columns and carrying walls allow for spacious and flexible interior layouts, increasing the utility of the floor space. • Semi pre-casting allows radiant heating and cooling within the concrete floors to save on ownership costs.
The Occupier (sometime also the Owner) • ROLE Occupier of space. • DECISION METRICS Sensitive to location, while minimizing costs and maximizing productivity, sales, health and comfort.		

[20] Information and pictures are used with the approval from technology owner in Europe.

DMU Members	Value Proposition To Each DMU Member
Engineering Firm	
• ROLE Design building structural and other systems and analyze characterization of systems. • DECISION METRICS Professional, client-driven decision style.	• Structural properties easily verified given the build experience in Europe. • Allows firm to recommend something innovative but proven to clients.
Regulatory Authorities	
• ROLE Ensure codes and mandates are met. • DECISION METRICS By the book enforcement.	• Resulting floors are lighter and have very good seismic performance (good for CA and other markets). • Not categorized as 'something new' by code officials. • Better lifecycle attributes because the amount of materials and energy is reduced in construction. • All components can be recycled.

Nth Power Innovation Screen

Nth Power uses a preliminary filter to help determine which (green building) innovations fit the ***Better Building*** definition of large scale, relatively quick adoption. Opportunities that pass this filter tend to have a compelling value proposition for each of the key stakeholders and therefore to the collective DMU.

- **Cheaper**: does the technology or solution have lower up front costs and lower lifetime costs while maintaining reasonable margins?
- **Better**: is the technology stronger, longer lasting, more recyclable, more energy efficient?
- **Quicker**: does the technology speed up project completion times?
- **Familiar**: does the technology require new tools or training?
- **Defendable**: are there sufficient barriers to entry from wishful competitors?
- **Scalable**: can the business (manufacturing, supply chain, operations, etc.) scale efficiently?
- **Experienced Management**: does management have experience in terms of valuable relationships, sales, managing high growth and raising money?
- **Business Model Innovation**: is the company leveraging technology innovation into business model or construction process innovation thereby capturing more value?

Better Building products require a significant price advantage, performance advantage, or both to succeed at displacing an established technology. If there is a price advantage without a performance advantage (or vice versa), or if the advantages are marginal, then the innovation faces the risk of drowning in the noise. A viable solution should enable faster, easier construction; save time, labor, and materials; and reduce construction costs and liability. Solutions also need to be practical to the appropriate trades, such as electrical, plumbing, etc. Requiring new tools or procedures for installation will require training for trades-people, which is costly and time consuming. The solution must also be defendable and scalable in a cash efficient way from a manufacturing, sales and distribution perspective. Lastly, the market has two buckets of innovation – one for the process itself and one for building performance and functionality. Some of the most compelling solutions leverage a technology innovation with a business model innovation that somehow streamlines the construction process. These types of business can capture significant value if successful.

Some Important Go-To-Market Considerations

Even with a compelling value proposition, going to market at scale can be tricky within the US building industry. Much of the go-to-market strategy will be dependent upon the value proposition itself, but below are some considerations that entrepreneurs will want to bear in mind.

***Big vs. Small*:** Big builder-developers write the big checks, but the smaller ones can play an important role in proving new building technologies. Smaller builder-developers such as themed developers can be more accepting of new technologies and techniques. Production homebuilders, for example, suffer from a compounding effect where one 'mistake' is multiplied a thousand times making them less likely to try untested ideas. The same innovation-averse mentality can be seen in big-budget commercial projects.

East vs. West: The US building industry varies strongly from region to region. It is always best to enter the market where the entrenched technique (wood framing, Cement Masonry Unit [CMU], steel, concrete slab, etc.) best matches the new. If commercializing a new building block, for example, target the Southwest, where CMU block construction is most prevalent.

Product vs. System: Builders often have an affinity towards 'product lines' rather than specific products. Material companies entering the building industry should consider launching a system or line of products instead of a single product offering.

Avoid Channel Conflict. It can be enticing to sell products directly to general contractors/ builders through retail channels as well as through distributors who sell to general contractors in an attempt to accelerate scaling. This, however, can create damaging conflicts between a company's sales channels. Given the relationship-driven nature of the US building industry, this type of self-inflicted conflict can have damaging long-term consequences. Unless handled carefully and openly, channel conflict is best avoided.

Build vs. Buy. Creating a distribution network from the ground up for the building industry can improve product margins, but will likely be costly and time-intensive. Giving up some margin to align with a large brand-name distributor will undoubtedly be quicker. If the new product is more regionally focused (CMU replacement, for example), acquiring a company with existing regional distribution relationships may be the more economical option.

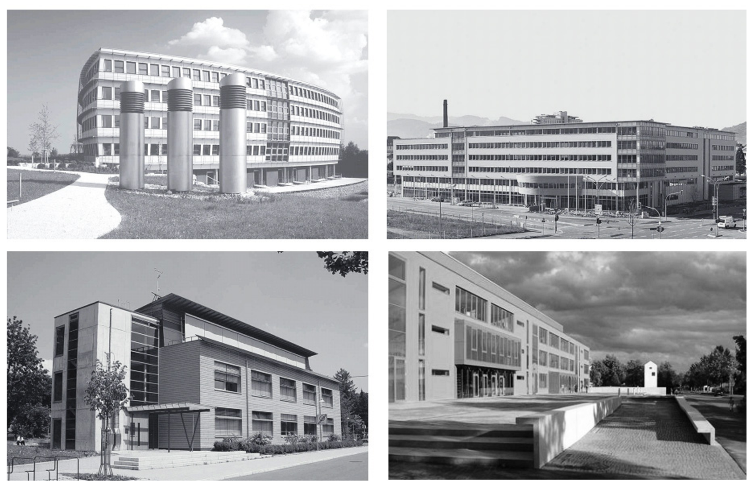
Code Approvals are Essential. Code approvals and certification such the ICC and UL are very important for market acceptance and can be difficult to get. The process should be started as soon as possible, as it can often take more time and money than expected. There are ways of getting into projects without code approvals, but they are cumbersome, expensive and another reason for the DMU to say 'no.' Distribution agreements will often be dependent on code approvals as well.

Global Plan. As with most Cleantech opportunities, there should always be a dedicated effort to succeed in a specific regional market (the US, for example). The opportunities for ***Better Buildings*** technologies abroad, however, are huge and sometimes have peculiarities that further enhance value propositions. Code and standard approvals are generally easier and quicker to get abroad (especially after receiving US approval) and developers can be more progressive in certain regions (Canada, the Middle East, etc.).

Lab to Project. As with many Cleantech opportunities, there is concern about the time and funding required to bring new technologies from the lab to projects and products. Technology risk, and especially product performance and reliability, must be addressed to create ***Better Building*** products that will succeed. For example, a new thin film PV material that performs well under carefully controlled lab conditions may degrade quickly when exposed to a real outdoor environment. Product development and careful testing (in real buildings) must take place to ensure new products will survive and work as expected before builders will consider using them. The associated challenges, time, and costs should not be overlooked.

IV. Coming Attractions —Technologies in the Pipeline

Before we survey the latest technical advances and imagine the buildings of the future, something must be said for the present state of technology. The National Renewable Energy Laboratory (NREL) and the DOE estimate that by 2025, 62% of commercial buildings could achieve net zero energy consumption based on projected performance of currently available technology and design practices.[21] That is enormous potential. ***Better Buildings*** need not appear any different from today's buildings. Innovation is not limited to creating new products or technologies. Successful companies will be those that find innovative ways to deploy technology – new or not – to address the specific industry needs outlined earlier in this report.



To the right are photographs of four net-zero energy buildings. Low energy buildings can be readily achieved with existing technology and without sacrificing aesthetics. Source: Fraunhofer ISE.

Technology plays an important role in every major building system, and there are several key areas that could use substantial improvement. The building's exterior shell must provide a durable separation of the indoor and outdoor environments. The heating, ventilation, and air conditioning systems must keep the indoor environment comfortable while supplying adequate fresh air. Automation and control systems can help optimize energy use and shave or shift peak loads. On-site power generation can reduce dependency on grid-power. Integrated systems like Building Integrated Photovoltaics (BiPV) can provide multiple building functions at reduced cost. Better software tools can help builders select, design, and operate sophisticated building systems. And new materials provide special properties that reduce weight, improve strength, store energy, and save time. Many innovators are looking at nature for ideas on how best to rethink current building practices. Examples include using honeycomb structures for reducing weight while improving strength and using plant extracts for waterproofing paints. Fundamental research will yield improvements to each of these areas, eventually transforming the way buildings are constructed, operated, and used in the future.

[21] Grifith, B. et.al. Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector. National Renewable Energy Laboratory, Department of Energy. Technical Report NREL/TP-550-41957. December 2007.

This section highlights a few promising innovation topics surrounding efficient building technology. The technologies described here are not predictions about which innovations will succeed – they are illustrations of the variety of advances that exist today and may exist in the near future.

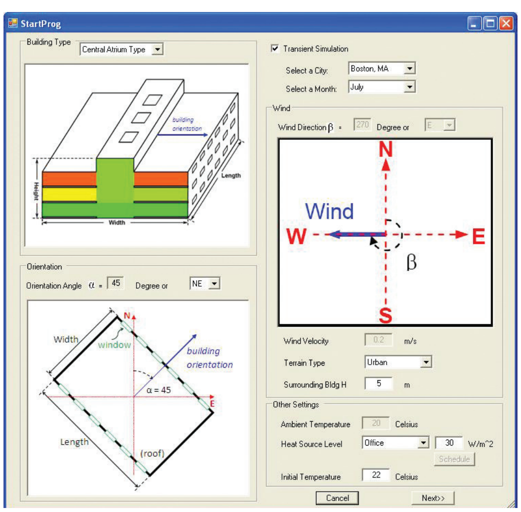
Process Intelligence Innovation

Impressive innovation opportunities exist in adding intelligence and knowledge management to the building design, construction, and operation processes. Building Information Modeling (BIM) software is improving communication between designers and contractors, reducing the need for formal Requests For Information (RFIs). The current lack of interoperability between different software tools remains a large barrier to efficiency. Still, today's best software tools can accurately model buildings in extreme detail, allowing builders to design and size equipment, estimate costs, predict energy use and comfort, and prevent construction conflicts.

One major source of energy and cost inefficiency originates from excessive building equipment oversizing. Since building usage can change over time, it is standard practice for designers to oversize HVAC equipment by 15-25% to satisfy future needs. In practice more than 70% of buildings may have equipment that is oversized significantly beyond this standard level. This leads to higher capital and energy costs, shorter equipment lifetimes, and uncomfortable buildings. With better simulation tools designers can avoid using outdated rules-of-thumb that do not apply to low-energy buildings, reducing equipment cost and operating expenses.

Although the performance of most traditional building materials and systems is fairly well understood, there are many areas of building simulation that need improvement. Reliable models for new materials, systems, and control schemes must be developed and calibrated with field data. Occupant behavior plays a major role in how buildings use energy. Uncomfortable occupants are likely to do things like close blinds, turn on lights, and install electric space heaters. Comfort metrics developed from recent and ongoing studies are expanding what we know about "What makes people feel too hot or too cold?" and "What daylight conditions cause uncomfortable glare?" These metrics will help designers produce comfortable buildings that operate more predictably and use less energy.

Usability of design tools is another major opportunity for innovation. Today's most powerful simulation engines are not accessible to most architects. These tools require specialized technical knowledge, and it can take weeks to prepare simulations and interpret results. Consequently, these tools are rarely used to inform the most important part of the design process – the early stage or conceptual phase. With simplified tools the designer is empowered to rapidly evaluate ideas, and this will change the way buildings are conceived.



Pictured above is the user-interface for CoolVent, a simplified, early-stage building design tool for assessing natural ventilation. Source: MIT Building Technology Department.

Construction quality and building operation have much to do with building performance. For example, if spray-foam insulation is not applied correctly, there may be large gaps where heat will be lost. Using thermal cameras to detect gaps during construction can inexpensively yield great lifetime energy savings. Advanced monitoring and diagnostic tools will make it easier for building managers to detect and fix non-critical failures quickly. For instance, a motor may fail causing an air-intake damper to become stuck in the open position. This allows excess outdoor air into the building, wasting tremendous amounts of energy. Failures like this are common and can easily go unnoticed for months or years. Substantial opportunity lies in finding inexpensive, simple remedies for common operational problems.

Thermal Management Innovation

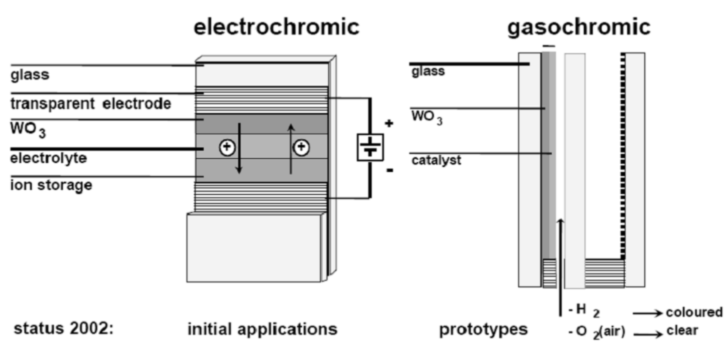
Research and development around thermal management technologies are currently focused on solar control of the façade like shading devices, thermal storage materials like phase change materials, and high-efficiency insulation systems like vacuum insulation and glazing. Depending on a building's usage and environmental conditions, sunlight can be an energy resource or a burden. Accordingly, solar flux control remains a potent topic for building innovation. Passive solar techniques such as fixed sun shading are among the simplest, least expensive ways of reducing energy needs in new buildings. Although these concepts are not new, there remains a need for better integration of passive strategies in building design. Technologies such as photochromic windows that change transparency in response to light intensity, and thermochromic windows that change transparency in response to temperature are in development.

Active solar control is another rich area for technology innovation. Currently designers can use automated blinds or sunshades to regulate sunlight passage into a building, but these mechanisms restrict outdoor visibility, which along with cost and reliability, is limiting the market's appetite. Innovative 'smart windows' use active control systems to resolve this issue. Smart windows can dynamically change their properties to block between 60 and 95% of visible sunlight, thereby preventing glare and reducing cooling demand, without restricting outdoor visibility. Two approaches include:

1. Electrochromic and substrate technologies use an electrical voltage to alter optical properties; and
2. Gasochromic technologies inject hydrogen gas into a sealed cavity, which reacts with a metal layer on the pane to modulate solar transmittance.

Pictured above are gasochromic windows at varying levels of solar transmittance, and to the right is a schematic of electrochromic and gasochromic technologies. Source: FraunhoferISE.

Compared with conventional blind systems, smart windows could reduce lighting energy consumption requirements by as much as 50% in commercial buildings, depending on how glare and sun are controlled.[22] The net energy benefits of these systems depend strongly on well-tuned control system settings. For smart windows to produce energy savings, there is a strong need for better predictive and adaptive algorithms, faster system response times, and interconnectivity with the building's automated systems. Still, the biggest issues are large upfront cost and uncertain product lifetime.



The building envelope, or exterior shell, includes the façade (walls, windows), roofing, foundation, and any other components that separate inside from outside. Because it is the first 'line of defense' against the elements, it is a vital area of thermal management innovation. Today there is much research focused on creating façades that adapt to changing environmental conditions and occupant needs.

[22] Lee, ES.,et.al. Monitored Energy Performance of Electrochromic Windows Controlled for Daylight and Visual Comfort. ASHRAE Transactions. LBNL-58912. 2006.

Ventilated double-skin facades can improve indoor thermal comfort, reduce heating and cooling loads, and still provide highly glazed walls for better outdoor views. These systems use the glazed facade as a large, transparent heat exchanger to capture energy that would otherwise be wasted through air intake or exhaust. When coupled with active blinds, natural ventilation, and automated lights, it is possible for these systems to reduce energy demand in commercial buildings by as much as 65%.[23] As with most highly integrated technologies, however, effective implementation demands careful planning, well-tuned control systems, and favorable climate conditions. Without careful attention, these systems can often increase a building's energy use and allow noise to travel between floors. Inherent complexity leads to high cost and unreliable performance, making these systems hard to implement. Finding ways to simplify component integration, optimize design, and improve control algorithms could speed adoption of any highly integrated building system.

An adaptive wall with variable insulation could increase the energy efficiency of a building by actively permitting or blocking heat flow in climate zones where both heating and cooling are required at different times. During the summer, increasing the amount of heat released at night cuts the need for cooling, while in winter greater heat retention will reduce heating demand. This approach is still in the basic research stage.

There is a lot of development surrounding better thermal materials for use within building envelopes. One major focus is new materials that offer better thermal insulating properties while allowing thinner walls and, therefore, more living, leasable, or sellable space. Innovation focuses include: advanced thermal mass materials, phase change materials, reflective coatings and nanostructures, and high-efficiency insulation systems.

Thermal mass is the ability of materials to store and release heat when there is a temperature differential. This can help stabilize indoor temperatures in buildings, shifting heating and cooling loads and reducing their intensity. Adding thermal mass to a building does not guarantee heating and cooling load reductions. Performance depends on how the building is used, when it is occupied, and a favorable climate (e.g., one that has daily outdoor temperature swings). Today, heavy concrete walls and floors and masonry construction can produce thermal mass benefits. Today's newer materials are lighter, cheaper, and can produce a similar effect.

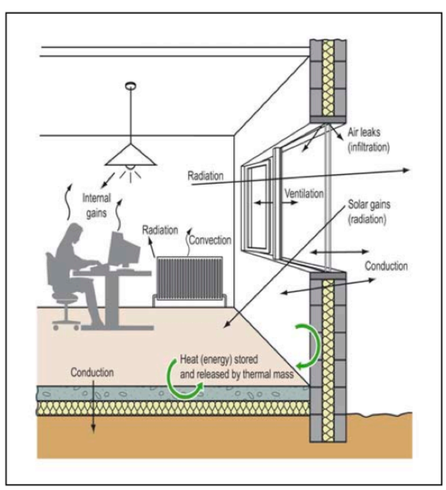


Figure 2c:
Heat (energy) flows within a building.
Heat is gained by solar radiation, and internal gains from lighting, heating, and the occupants and their equipment.
Heat is lost via air leaks, ventilation, radiation through windows and conduction (transmission) through walls, windows and floors.
Heat is stored and released by the thermal mass of the building.

Looking at it practically, there are two important aims relating to energy performance:

1. To minimise the amount of energy that a building consumes.
2. To ensure that the building maintains a level of thermal comfort that is appropriate for its occupants.

Source: "Concrete for energy-efficiency buildings: the benefits of thermal mass" European Concrete Platform, ASBL, April 2007

[23] Wigginton. 2000. http://www.battlemccarthy.com/Double%20Skin%20Website/doubleskinhomepage.htm

Phase Change Material (PCM) offers a lightweight alternative to thermal mass for storing and releasing heat. Although PCM technology has been around for a long time, its use in buildings has been limited. New building products are now being engineered to contain microencapsulated PCMs. When permanently sealed within plaster, fillers, or lightweight building slabs, they offer a large heat storage capacity. If a room overheats, PCMs begin to melt as they reach their activation temperature, absorbing heat and providing a thermal buffer until the entire layer has melted. As with thermal mass, the heat must be rejected at a later time (PCMs must re-solidify). Night ventilation or HVAC assisted pre-cooling strategies can be used to facilitate this discharge, though more study is needed to characterize net energy benefits. Current innovation efforts are improving material stability, integrating PCMs into building materials, and developing better control schemes for discharging excess heat.

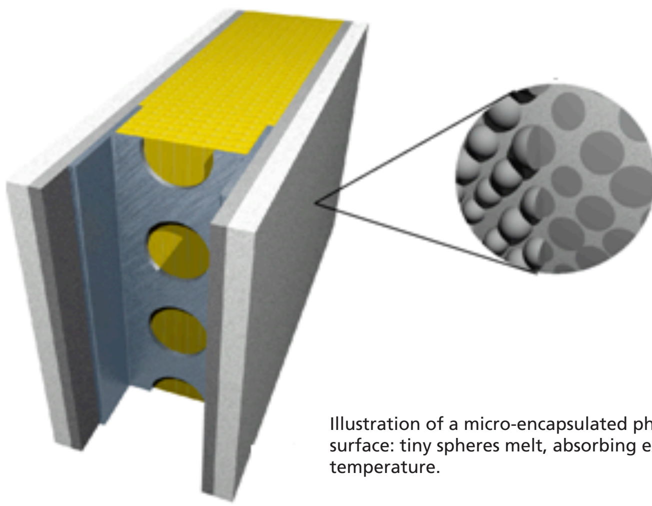
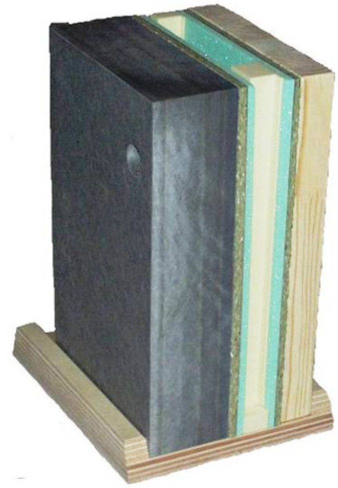


Illustration of a micro-encapsulated phase change material on a wall surface: tiny spheres melt, absorbing excess heat and buffering room temperature.

Reflective Coatings and Nanostructures can be used to reduce or promote heat absorption or emission from building surfaces, and this is important for addressing building overheat, mold and algae growth, and heat-generated pollution. Roofs, for example, often overheat due to their large exposed area. Insulating a roof can keep heat out of a building, but this causes surface temperatures to become very high. Hot roofs have a shortened lifespan, and they cause the surrounding air to heat up, which can force HVAC equipment to work somewhat harder. A 20% reduction in air conditioning energy[24] and an estimated $750 million in annual energy savings[25] could be realized in the US by adopting cool roof technologies. New surface coatings can be integrated with existing materials to produce more efficient, longer-lasting, self-cleaning systems while maintaining the same aesthetic appearance.

High-Efficiency Insulation Systems provide great insulation levels in small spaces. One approach is to use vacuum panels in windows or walls to greatly suppress heat transfer. Current efforts are addressing known performance failures, such as the longevity of the vacuum seal, as well as high cost. Gas filled windows have been on the market for years as advanced insulated products. Researchers are now investigating similar approaches for wall systems. Some gas-filled insulation panels use small, hermetically sealed plastic bags filled with low-conductivity gas (normally argon, krypton, or xenon) and can yield a thermal efficiency ratings of R-7, R-12.5, R-20/inch, compared with traditional fiberglass installation of roughly R-3/inch. Aerogel™ based vacuum insulation panels can yield even higher performance, approaching R-50/inch, though costs can exceed $20/sqft., nearly 20x higher than traditional fiberglass.[26]

[24] Akbari, H.,et.al. Cool surfaces and shade trees to reduce energy use and improve indoor air quality in urban areas. Solar Energy. v.70,3. pp.295-310. 2001.
[25] LBL. http://heatisland.lbl.gov/CoolRoofs/
[26] http://www.glacierbay.com/ultra-r.asp

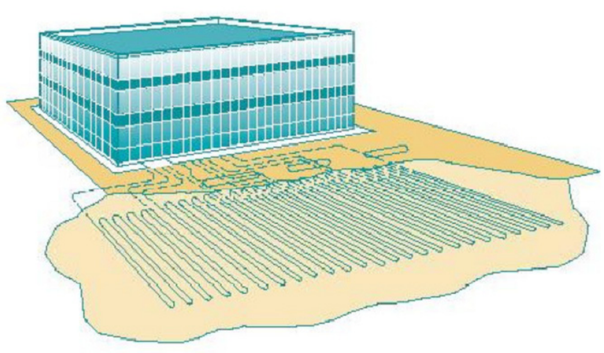


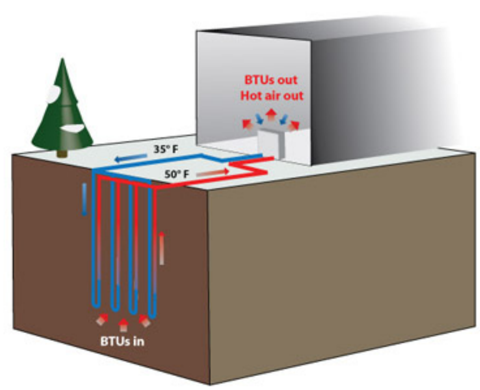
Vacuum panel insulation module pre-assembly (left) can reduce wall thickness, increasing valuable floor area. Panels installed in the field (right) Source: Fraunhofer ISE.

Point of Demand Clean Energy, Cooling & Heating

As the US building industry strives towards low and zero net energy buildings, it is clear from a technology perspective that the only way to achieve this is with a source of clean, distributed energy generation. Building-integrated renewable and/or efficient generation technologies, such as solar thermal, geothermal heat pumps, waste heat recovery, and integrated PV offer possibilities to shave expensive peak grid power or offset base load power requirements.

Geothermal power, using underground heat resources, produces over 44 billion kWh of electricity worldwide each year, and its capacity is growing at almost 10% per year.[27] As with cogeneration, much of today's install base is situated in large central electric plants, and the byproduct heat can be used for commercial, industrial, or district heating and cooling if located in close proximity to buildings. The infrastructure cost of drilling geothermal wells, can amount to 60% of a project's cost[28], which strains the economics. Heat pumps are more common than geothermal power for building applications. These use the fairly constant temperature ground or outdoor air as an energy source to heat and cool buildings with 40 to 70% less energy than buildings with traditional HVAC systems. Unlike large-scale geothermal installations, which generally require deep wells, heat pumps for commercial buildings can be installed in wells under 100 ft deep, and residential heat pumps can be installed in trenches only six feet deep depending on the well configuration. Innovators are focused on reducing heat pump cost, improving efficiency, and reducing the well-drilling costs.





Horizontal (right) and vertical (far right) geothermal fields. Source: AIA, NYSERDA.

27 AIA Sustainability Discussion Group 2007. 50 to 50. 2007.
28 MIT. The future of geothermal energy. 2006.

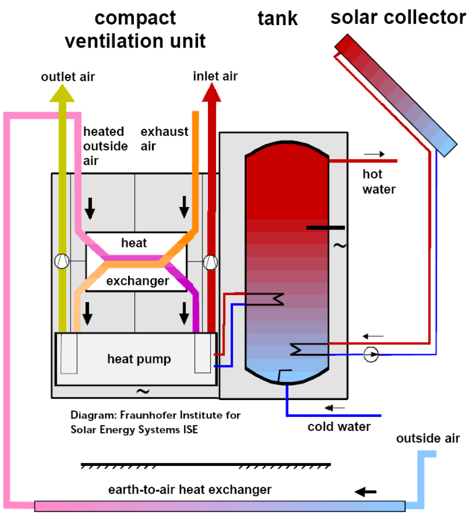
View into concrete ceiling under construction with integrated cooling pipes (left) and geothermal pipes (right) before placement in the ground. Source: Fraunhofer ISE.

The deployment of photovoltaic (PV) modules on buildings to convert sunlight into electricity has grown rapidly, particularly in Germany and California, though some challenges remain. Without subsidies, traditional rooftop PV systems can have very long payback economics. Building Integrated Photovoltaics (BiPV) integrates the PV module function within building materials, as with the solar shingles pictured. New thin-film modules are less efficient than standard crystalline PV, but may soon be less expensive for large areas like building surfaces. Reliability is a primary concern. Innovators are looking for ways of simplifying installation, improving conversion efficiency, and improving system aesthetics.

Contractors install solar PV shingles on a roof. Source: NREL.

Ventilation and is a major source of building energy use. Designers can use equipment like occupancy sensors, chemical sensors, and control systems to reduce the excess outdoor air intake, thus reducing the energy required to condition that air. Heat and enthalpy recovery units can also be used to reclaim energy and moisture from exhaust air streams to reduce heating and cooling loads. While these technologies are not new, they are becoming more popular. Barriers to implementation include additional upfront cost and added complexity.

Instead of (or in addition to) using electric fans, naturally ventilated buildings use wind and pressure differences to supply and move air throughout a building. The resulting increased air movement can reduce the perceived air temperature, allowing for a wider acceptable comfort range. In some climates, this can reduce or even eliminate the need for cooling equipment. Technical design and operational challenges limit the implementation of such buildings: air may not flow in the desired directions, uncontrolled humidity can lead to moisture-related problems, and comfort may be difficult to control. These challenges demand specialized design tools to help simplify implementation, better control strategies to reliably maintain good performance, and well-monitored demonstration projects to develop best practices.



One of thousands erected in central Europe, the solar passive house (top) uses thick insulation and triple-glazed windows to keep annual heating loads below 15 kWh/m2. This building is equipped with a newly designed compact heating and ventilation device (left) that integrates solar thermal collection, earth heat exchanger, heat pump, and heat recovery systems to efficiently provide domestic hot water, space heating, and ventilation. Source: Fraunhofer ISE.

Revolutionary Integrated Approaches

Integrating building products and systems can yield many performance and cost advantages. Since labor costs are significant for most building products, it could be less expensive to install one product with multiple functions than to install each product independently. This is the case with BiPV roofing and BiPV sun shades shown in the pictures. Both roofing installations and rooftop PV installations are labor intensive. By combining the functions of building components and PV modules into one product, it could be possible to reduce the combined installed cost of the roof and the PV modules.

Innovators must also consider the negative consequences of product integration. Returning to the BiPV roofing example, integrating PV materials into the rooftop could significantly increase the product's surface temperature. Higher temperatures reduce electricity production efficiency, accelerate material degradation, decrease roof lifetime, and increase the building's cooling demand. Further study is needed to quantify these issues and produce reliable, low-cost integrated systems.

More sophisticated approaches are possible, combining several efficiency measures and energy collection systems. For example, the compact heating and ventilation device developed for passive homes in Europe combines a solar thermal collector, a ground-source heat exchanger, a heat pump, and a ventilation heat recovery system to produce domestic hot water, space heating, and ventilation. Using these systems together with an already-low energy passive house enables the elimination of a conventional water-based heating system, providing noteworthy energy savings.

Sun shades produce electricity while providing passive solar shading. Source: ECN / Bear Architects, Netherlands.

Some of the biggest opportunities for innovation in buildings lie in technology and systems integration, however these can be difficult to implement. Finding combinations of technologies that work well and predictably in specific climate zones, building types, and through varying occupant behavior is a real challenge. Additionally, as systems become more complex the ways in which they can fail increase. Testing and optimizing these new, highly integrated systems is critical for practically achieving high performance and gaining market acceptance. These complications should not discourage innovators, especially since the potential payoffs are so significant.

V. Conclusion

The authors believe that the market dynamics within the US new building construction industry are evolving to better adopt needed innovation. The current credit and financial crises may be a common concern for many entrepreneurs and investors today, but the design and planning stages for many commercial and large residential projects take years before financing needs to be secured. Now is an excellent time for entrepreneurs to look at this market and to start developing, positioning, and demonstrating ***Better Building*** innovations.

The industry evolved to incorporate a significant energy-hemorrhaging problem as well as an inefficient process. Today, however, the industry is transitioning through a perfect storm of pressures and enablers. The industry's receptiveness to change around compelling value propositions is high and the market downturn is accelerating the industry's shift. Resistive forces such as information gaps, inaccurate perceptions of high risk and high cost premiums for advanced buildings, industry inexperience, and a lack of enabling partnerships amongst key decision makers are all diminishing. An ever-growing menu of technical solutions exists for creating affordable efficient buildings. Creative entrepreneurs will succeed in bringing these solutions to market by understanding the industry framework outlined in this report. The resulting picture is one of great opportunity for entrepreneurs and investors.

Innovating for Better Buildings

The Magnitude of the Opportunity

Buildings account for the vast majority of the multi-trillion dollar US construction industry. The market for buildings that incorporate resource efficiency practices or technologies (i.e. 'Green Buildings') generated an estimated $12 billion in 2007 and is growing around 30% each year.

Industry Performance Issues

- On average, 3.1% of all building project costs, estimated to be $36 billon annually, are inefficiencies related to software non-interoperability issues.
- The US building industry produces 65% of the nation's waste output while using 40% of the nation's raw materials.
- The US building industry accounts for 70% of the nation's power plant electricity consumption and 39% of the nation's total energy use.
- Buildings account for nearly half of all greenhouse gas emissions in the US – more than transportation and industry.
- Today, a staggering 34% of the energy consumed by buildings is lost directly through building envelopes, much of it through unnecessary integration inefficiencies.
- 55% of US households (63 million families) with incomes under $50,000 will spend 20% of their pre-tax income on energy.

The Difficulty

The industry has historically invested less than 1% of revenue in innovation, but never has innovation been needed more.

The Question We Answer

How does one successfully innovate for Better Buildings?

Nth POWER
Energy | Vision | Capital

Nth Power, LLC (www.nthpower.com) is a venture capital firm based in San Francisco and is the first and most experienced venture capital firm funding promising startup companies in the Cleantech space. With $420 million under management in four funds and an investment record that begins in 1997, Nth Power is widely known and well regarded as the driving force behind many of the most successful Cleantech companies. The firm's leading history in Cleantech-related venture capital is the result of a deep network of entrepreneurs, universities and research institutions, unmatched corporate relationships and the backing of institutional capital. Nth Power has a concerted effort to be the leading investor within ***Better Buildings***.

For follow ups or more information, contact: **betterbuildings@nthpower.com**

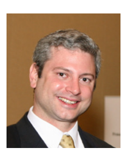
Bryant Tong
Managing Director

Brian Walsh
Senior Associate

Fraunhofer
USA

Fraunhofer Center for Sustainable Energy Systems (CSE) (cse.fraunhofer.org) is one of six Fraunhofer USA research centers. Fraunhofer USA is a wholly-owned subsidiary of Fraunhofer-Gesellschaft which has over 80 research units at more than 60 different locations throughout Germany. CSE is based in Cambridge, Massachusetts serving the sustainable energy industry in the areas of building efficiency, PV modules, and energy device prototyping. CSE is focused on technology development, materials testing, design, and demonstration. CSE's parent institute, the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany has over 25 years of experience in efficient building concepts, design, simulation, solar cooling, advanced thermal materials, daylighting, advanced HVAC systems, and building monitoring systems.

For more information, contact: **betterbuildings@fraunhofer.org**



Nolan Browne
Managing Director, CSE

Bryan Urban
Project Manager, CSE

Sebastian Herkel
Group Leader, ISE