Cleantech Daylighting Using Smart Glass: A Survey of LEED® Accredited Professionals

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ABSTRACT

Buildings are an important target of the clean technology movement. According to the U.S. Green Building Council, buildings now account for nearly forty percent of all energy consumed in the United States. Smart glass is an emerging category of high-performing glazings that can regulate the amount of light, glare and heat passing through products such as windows, doors and skylights. When used in architectural projects, these glazings offer the potential for two key daylighting benefits – reduced cooling loads and lower electricity consumption for interior illumination. This paper reports the results of a nationwide market research survey on the clean technology potential of daylighting using smart glass. Survey participants are LEED® Accredited Professionals whose practice area is architecture. In addition to general awareness, interest and specification activity of smart glass, the study also explores the importance of various attributes of smart glass and expectations for its future use.

Keywords: clean technology, daylighting, market research, smart glass, sustainability

1 INTRODUCTION

The world is experiencing a heightened call to address sustainability across many industries. From hybrid automobiles to solar energy systems in buildings, bold advances that support energy efficiency, societal well-being and environmental stewardship are being embraced in exciting ways by governments, companies and individuals. The development and commercialization of clean technology are critical components of the drive toward sustainability. Spurred by strong end-user demand, an expansive array of high-performing clean technology innovations are now commercially available. Many of these innovations will play important roles for decades to come as society's needs for sustainability continue to accelerate and industry's ability to profitably meet those needs grows.

2 CLEAN TECHNOLOGY

Clean technology, commonly called cleantech, encompasses a unique blend of altruistic ideals and pragmatic capitalism. Such an orientation is evident in The Cleantech Network's definition of clean technology as "new technology and related business models offering competitive returns for investors and customers while providing solutions to global challenges" [1]. According to a survey by Ernst & Young, the two primary drivers of the clean technology industry over the next five years will be increasing energy costs and initiatives to raise energy efficiency [2]. These drivers have global influence. Rising energy costs can adversely affect inflation, balances of trade, and the performance of economies. Likewise, efforts to raise energy efficiency, whether government-sponsored or of a grass roots nature, offer direct and indirect benefits when costs are lowered and the environment is protected.

Investments in clean technology have grown substantially. Dow Jones VentureSource reports that in 2007, venture capitalists invested $3 billion in clean technology deals globally, an increase of 43% from 2006. In 2007, the United States' share of total clean technology investments reached 83% and accounted for 8% of the country's venture capital investment [3]. Further, according to Lux Research, R&D spending on clean technology totaled $48 billion in 2006, up 9% from the prior year [4].

3 DAYLIGHTING

Clean technology supports the goals of sustainability. The concept of sustainable development was synthesized by the United Nations World Commission on Environment and Development which claimed "Development is sustainable when it meets the needs of the present without compromising the ability of future generations to meet theirs" [5]. Sustainable architectural design involves efforts to increase the energy efficiency of buildings, improve the well-being of building occupants, and lower the environmental impact of buildings. Pursuit of such design is warranted. The U.S. Green Building Council, for example, observes that U.S. buildings account for 71% of the nation's consumption of electricity, 39% of total energy use, and 38% of its carbon dioxide emissions [6].

Since the earliest civilizations, humankind has relied on the sun's energy. Over time, strategies have developed to capture the benefits of natural light, or daylight, while mitigating its adverse effects. For these reasons, architecture professionals have historically employed designs that introduce natural light into a building's interior while using simple systems to control the light. The use of conventional window systems and traditional window treatments are examples of such designs. The strategic application of daylighting, however, involves efforts to protect occupants from unwanted glare, provide shade from the sun, and redirect natural light as needed [7]. Effective daylighting can provide substantial benefit in terms of energy efficiency, most notably by harvesting natural light in a way that lowers the electricity consumption used to satisfy interior lighting needs. Daylighting also has been found to increase occupant well-being and productivity in educational, workplace and retail settings [8].

4 SMART GLASS

Smart glass is a category of glazing materials that changes its light-control properties in reaction to an external stimulus. [9]. Known also as switchable glazings, dynamic glazings and chromogenics, smart glass is a relatively new category of high-performing glazings with significant clean technology characteristics. Smart glass can be used in a wide range of everyday products such as windows, doors, skylights, partitions, sunroofs, sun visors and more. Expectations for growth in smart glass demand are very high. The Freedonia Group projects the value of smart glass demand in the United States to reach $1.34 billion by 2015, an increase of 250% from 2005 [10].

Smart glass is composed of two major segments. Passive smart glass does not involve an electrical stimulus. Rather, it reacts to the presence of other stimuli such as light or heat. Photochromic lenses used in self-dimming eyewear, for example, change their light-control properties in response to the presence of ultraviolet light. Active smart glass does involve an electrical stimulus and it is this segment where the prospect for widespread adoption among large-format applications is greatest. Active smart glass is now being offered as an innovative design solution for products ranging from aerospace windows to architectural skylights and automotive sunroofs.

There are three primary types of active smart glass, each with its own unique chemistry, production requirements and performance characteristics. Liquid crystal (LC) smart glass is primarily used for interior partitions in architectural applications. Possessing two light transmission states – translucent and transparent – and adjustable in milliseconds, LC smart glass diffuses incoming light and thus offers a privacy benefit in its translucent state but very little in the way of shading. Suspended particle device (SPD) smart glass is a shading system with light transmission levels that can be controlled to any point between dark and clear. In its dark state, SPD smart glass can block at least 99.4% of incoming light, a level that is 20 to 40 times darker than standard tints for windows. When SPD smart glass is in its clear state, light transmission is similar to that of a conventional non-tinted window. All adjustments to light transmission levels take place within seconds regardless of the size of the glazing. Electrochromic (EC) smart glass is similar in one respect to SPD smart glass in that it also offers light transmission levels from dark to clear. Primarily used in self-dimming automotive mirrors, switching speeds for EC smart glass are disproportionately slower as panel size increases, with larger glazings for architectural applications often taking many minutes to change their light-control properties. Because of this, EC smart glass for architectural projects is generally offered with just two states – dark and clear.

Active smart glass will play an increasingly important role in the world’s drive toward sustainability. Requiring very low amounts of power to operate, architects and designers can integrate smart glass into their projects in ways that offer unprecedented control over incoming light, glare and heat. In doing so, electrical energy consumption can be lowered, cooling loads reduced, environmental impact mitigated and occupant well-being increased. These outcomes can be achieved by the integration of smart glass into various daylighting strategies. Most fundamentally, smart glass transforms conventional windows into smart windows with expanded daylighting utility and value. For example, curtains, blinds and other treatments have traditionally been used to provide shading and glare reduction through incoming windows. These solutions typically block one’s view to the outside, an undesired outcome for many building occupants. Windows with smart glass allow users to control incoming light, glare and heat without the loss of view to the outside, an option generally not available with standard treatments but one that improves occupants’ levels of comfort and connection with the outside world.

Systems that use both smart glass and conventional glazings can effectively achieve daylighting objectives. For example, two tiers of glazings can be used in a typical commercial office setting. A small, upper glazing of the non-smart type can be integrated with a light shelf to reflect natural light deep into the room. A larger smart glass window below this glazing could be used to adjust light, glare and heat transmission in the work area closest to the building’s façade while providing occupants with privacy or view preservation as desired. Lastly, active smart glass can be integrated with intelligent building systems to yield optimally performing daylighting systems. One of the great limitations of daylighting strategies that use non-smart glazings is that, in the absence of purposeful shading using view-blocking products, these glazings continue to introduce natural light and its attendant heat into a building even when lighting is not needed (e.g. when a room is unoccupied). This has the effect of raising solar heat gain levels and thus adding to the building’s cooling costs. With the use of photosensors, timing devices or other advanced building control systems, smart glass can block unwanted natural light to any desired level when a room is unoccupied, thus providing user benefits when desired while also minimizing heat gain and cooling demands.

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5 RESEARCH STUDY

5.1 Methodology

During January 2008, an offer to participate in an online market research study was presented to a study population of 10,407 United States Leadership in Energy and Environmental Design (LEED) Accredited Professionals whose practice area is architecture. LEED is a program administered by the U.S. Green Building Council (USGBC). Among other activities, the USGBC rates buildings along various sustainability criteria and accredits professionals working in functions related to the design and operation of buildings. By February, 1,510 usable surveys were completed, yielding an overall response rate of 14.5% and a margin of error of +/- 2.5% (α=0.05). To mitigate any effects of non-response bias, surveys were weighted by the region of the country in which the respondent is located such that the weighted regional distribution in the sample reflects that of the population at large.

5.2 Profile of Respondents

Of those surveyed, 90.6% are employed by an architectural, design or engineering firm, 50.7% are licensed architects and 84.1% have worked on at least one sustainable design project in the past year. Almost one-third (32.2%) report having evaluated, recommended or specified solar power in the past year. In terms of the type of work in which they are involved, 94.6% and 54.3% report working with commercial and residential projects, respectively.

5.3 Sustainable Architectural Design

The professionals surveyed have a very optimistic outlook regarding sustainable architectural design. When asked to share their expectation of how the proportion of U.S. architectural design work that involves sustainability will change over the next five years, 73.6% said they expect it to increase greatly while 25.4% expect it to increase somewhat. Again looking ahead over the next five years, levels of agreement with various statements regarding sustainability and clean technology also signal the likelihood of strong growth in several areas related to clean technology. Data for the items with the highest levels of agreement are summarized in Table 1.

The architecture professionals exhibit a variety of viewpoints regarding sustainable architectural design. These items reflect attention to both economic and non-economic outcomes. When asked to choose the three items from a set of nine they consider most when evaluating the sustainability of buildings, the items most often named are energy consumption, occupant health or well-being, and life cycle/lifetime costs. Table 2 summarizes these results. Items named least frequently are not shown and include occupant productivity and community impact.

Table 1: Sustainable design over the next 5 years.

Statement	% Agreeing
Demand for sustainable buildings will increase.	99.3%
Use of passive solar energy strategies in buildings will increase.	94.3%
The prevalence of building codes or standards mandating sustainable building will increase.	93.3%
Returns on investment in sustainable design will increase.	93.0%
Demand for solar control architectural building products will increase.	92.5%
Use of active solar energy strategies in buildings will increase.	88.6%

Table 2: Importance of items to sustainability of buildings

Item	% Naming Item
Energy consumption	82.6%
Occupant health/well-being	43.3%
Life cycle/lifetime costs	43.0%
Waste or pollution	34.3%
Payback period/ROI	33.2%
First/upfront costs	29.5%

Using the full set of nine items associated with the sustainability of buildings as inputs, a hierarchical cluster analysis of the sample was conducted based on a between-groups clustering method and squared Euclidian distance for intervals. Two primary segments were identified. The larger of the two accounts for 47.2% of the sample and, for purposes of this paper, is labeled Impassioned Altruists. The second segment, Economic Pragmatists, represents 23.0% of the sample, while the balance of the architecture professionals surveyed are dispersed through several small clusters. There are substantial differences in the values of Impassioned Altruists and Economic Pragmatists, and to the degree that one type is more influential than another on a particular project, choices of what, if any, clean technologies will be used may vary. While consideration of energy consumption is a point of commonality among both groups, Impassioned Altruists are more likely to consider occupant health and well-being, waste and pollution, and community impact. Economic Pragmatists downplay the aforementioned items, and instead value first or upfront costs, life cycle or lifetime costs, and payback period or return on investment.

5.4 Smart Glass and Daylighting

Of the professionals surveyed, 73.8% report having evaluated, recommended or specified architectural glazings in the past year. Respondents were shown a list of twelve items that pertain to glazing for architectural projects and asked to identify the three most important items to them. The leading item was energy efficiency (cited by 81.1% of those surveyed), followed by daylighting (73.1%), aesthetics (32.9%), shading (22.1%) and view preservation (21.4%). Just over three-quarters (75.6%) claimed they were aware of smart glass before participating in the study. Interest appears strong for this relatively new category of glazings, with 10.4% and 2.4% of the sample saying they've evaluated, recommended or specified smart glass for commercial and residential projects, respectively. When asked whether they would recommend or specify smart glass for a project if costs were reasonable and the smart glass met performance requirements, 87.6% said they would be highly likely or somewhat likely to do so. Like that for energy consumption, interest in smart glass is an area of common perspective among the distinct segments of those surveyed, with 87.8% of the Impassioned Altruists and 86.1% of the Economic Pragmatists saying they would be likely to recommend or specify smart glass for a project. These essentially equivalent interests in smart glass suggest that it offers architecture professionals and building owners value on both economic and non-economic levels.

Respondents were given twelve performance attributes and asked to choose the three most desirable to clients interested in integrating smart glass into an architectural daylighting system. Table 3 summarizes citation levels for the top five attributes.

Table 3: Desirability of smart glass performance attributes with regard to daylighting

Item	% Naming Item
Energy efficient operation of the smart glass panel	28.6%
Solar heat gain control that varies with the tint level of the smart glass	26.5%
Elimination of the need for window treatments and coverings	24.3%
Ability to change the light transmission of the glazing quickly	18.7%
Integration with building intelligence systems	16.7%

Finally, respondents were asked to assume that the incremental costs of smart glass in daylighting are reasonable and then to assess the expected return on investment of smart glass-based daylighting systems when compared to other products or systems used to support sustainability objectives. If costs are reasonable, 39.8% expect better returns when compared to other products or systems. Almost three-quarters (73.1%) expect returns that are equivalent or better. Similar to earlier findings, the multi-dimensional benefits of smart glass results in essentially equivalent expectations of return on investment for both Impassioned Altruists and Economic Pragmatists.

6 CONCLUSION

Clean technology is poised to propel sustainability to new levels. Such meaningful gains are needed in this period of rising energy costs and growing environmental concerns. When part of a daylighting strategy, smart glass can help the architectural community achieve its sustainability goals by reducing electricity consumption used to power interior lighting, lowering cooling costs and improving the health and well-being of occupants. As adoption of smart glass accelerates and prices decline, it is likely the category will move from one being used by early adopters to one being sought after by the mainstream. En route to that time, a growing number of smart glass users will embrace its benefits while investors enjoy its growing returns.

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