Green Building Technologies: Should a Developer Implement Photovoltaics, Underfloor Air Distribution, and Natural Ventilation?

by

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Submitted to the Department of Urban Studies and Planning in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development

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GREEN BUILDING TECHNOLOGIES: SHOULD A DEVELOPER IMPLEMENT PHOTOVOLTAICS, UNDERFLOOR AIR DISTRIBUTION, AND NATURAL VENTILATION?

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ABSTRACT

This thesis explores implications of green, or environmentally sensitive, development in the commercial real estate industry. Developers, as building owners, will respond to ideas that can improve their profits, not necessarily to an environmental call to arms. The ability to lease up a development quickly is a competitive advantage that a developer can realize as increased net operating income. Green building strategies may increase the productivity of occupants, which may also help a developer differentiate a project from the competition.

Three green building technologies, underfloor air distribution, photovoltaics, and natural ventilation, are examined in detail to determine if they are financially feasible for a developer to include in a commercial real estate office project. This thesis attempts to use a financial argument, to address the issue of environmental sustainable, or green, development. The results of the study are that natural ventilation and underfloor air distribution are currently promising technologies that should be seriously considered by developers. The high cost of photovoltaics, however, does not justify their current use in a commercial development.

A large part of the decision to include green developments is dependent on the developer understanding his/her clients, the tenants. This thesis includes a survey of both developers and tenants in an effort to gauge their interest in green technologies and willingness to pay for them. The results of the survey are presented, and suggestions for the future of green building practices are laid out.

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Real estate development was once a revered profession and a high calling. It can be so again.
- Amory Lovins, Rocky Mountain Institute

CHAPTER 1 – Introduction to Green Building Technologies

This thesis examines the incorporation of green building technologies in the development process. Three such technologies will be examined in detail: underfloor air distribution, photovoltaic power, and natural ventilation. In many ways, developers are the ones who shape what our cities look and feel like more than any others. Architects design a structure to meet a purpose that has been determined by the landowner, often the developer. Engineers design the structure to be safe and feasible to build. Contractors construct from blueprints and follow the direction of the designers. While building officials have the ability to control the nature of a project through the approval process, they set only the outer bounds for a development.

Developers, however, make the most important decisions, which are often based on economics. There are many risks inherent to the development process and developers require commensurate reward for assuming these risks. This thesis will address green technologies from the developer’s perspective. Current literature is primarily based on what is technologically feasible and what is most beneficial to the environment. Much less has been done on the role that the developer has in bringing these ideas to fruition. Rather than focus on the manufacturer or designer of a product, this thesis will attempt to show whether the developer can use green building techniques as a smart business practice to increase profit.

The term “green development” carries various connotations. Each person interprets the term differently. Other terms are used as well, such as “sustainable development,” “high performance building,” and “environmentally friendly” to name three. This thesis will use the terms interchangeably. Green Building is not one specific idea or building type. For example, it can mean energy conservation, non-polluting electricity production, health of occupants, and site selection to minimize impacts to ecosystems. The idea is that a building incorporates some form of environmentally sounds practice.

There is a perception that high performance or sustainable building practices will cost more money up front. This thesis will examine three such technologies in detail to quantify cost.
Beyond first cost, there will be an examination of the payback of such building options. Developers historically have weighed the benefits of any added building costs using the financial concepts of payback, return on investment, and net present value.

*Environmental Concerns*

The United States is the world’s largest consumer of electricity per capita. Of the 3.2 billion kWh that the U.S. expends annually, the EPA estimates that 16% is consumed by commercial real estate. With such a large share, there is a need for U.S. commercial buildings to reduce their energy use. Buildings can produce their own electricity, relying less on the power grid, or can be designed and constructed more efficiently.

![U.S. Energy Consumption Chart](chart.png)

Source: U.S. Environmental Protection Agency

*Figure 1.1*
With air conditioning and heating system improvements in the 1950’s, buildings were designed and constructed with airtight envelopes. Rather than integrating buildings to interact with the climate, designers came to rely on the mechanical engineer to maintain comfortable indoor environments. Up to this point, buildings throughout history were designed to operate without the use of mechanical cooling systems. They took into account the building’s relation to the sun and natural ventilation.\textsuperscript{3} It wasn’t until the energy crisis during the 1970’s that the mainstream design community take a second look into improved energy efficiencies of buildings. Solar cells were now seen on rooftops in response to high energy costs. When energy prices plummeted in the 1980’s, the emphasis was again on consumption and growth, not efficiency. The 80’s fueled a bigger is better attitude, and building construction skyrocketed.

Figure 1.2 shows that 45% of the existing stock of buildings was constructed before 1969. With so many structures over thirty years old, there will be a large need for new construction and renovation to replace these aging buildings.

\begin{figure}[ht]
\centering
\includegraphics[width=0.6\textwidth]{image}
\caption{Square Footage of Existing Building by Year of Construction}
\label{fig:buildingage}
\end{figure}


\textbf{Figure 1.2}
Why should a developer care about the environment? The argument can be made that with green building technologies there is an opportunity for higher profit. A developer does not have to buy into the environmental justification if the bottom line warrants green development. However, that does not lessen the environmental benefits. In this case, the ends do justify the means. If financial reward can be recognized through green development, then the options for “green” must be understood. The basic elements are: environmental responsiveness, resource efficiency, community and cultural sensitivity, and the integration of ecology and real estate.

Environmental responsiveness refers to the practice of restoring and enhancing the resources of the natural habitat. It includes the proper selection of the site, how the building is situated on the site, and how the building will improve its surroundings. It could also mean using the forms of the natural landscape and vegetation for infrastructure: erosion control, storm runoff management, and protection from the elements.

Resource efficiency is the practice of directly reducing the amount of resources that a building consumes. Although the primary target is electricity production, which requires large resource input, it also includes material consumption and waste during the construction process. Virtually all systems of a building can be made more efficient, such as reducing and reusing materials throughout construction and design. A design process that incorporates resource efficiency will have a direct and positive effect on the environment. Proper specifications can lead to energy savings that the developer benefits from.

Community and cultural sensitivity is an idea that connects a developer’s project with the larger community of that particular neighborhood, town, city, state, and even globally. It refers to making the end users’ lives more fulfilling and satisfying. Properly planned green developments can reduce negative impact to the public. It includes being responsive to the local history and culture to create a project that will be embraced. Affected may be the design of the building, its use, or even where and how the building materials are purchased. The integration of ecology and real estate connects the project to the ecosystem in which it sits. This refers to the interaction between people and their environment. A development is part of the ecosystem and a developer who embraces that idea can create successful projects.
How a Commercial Building Uses Electricity

The breakdown of average commercial office building electricity use is shown in Figure 1.3. Space heating, cooling, and ventilation systems account for 39% of the building’s usage. No other system consumes more electricity. Therefore, the greatest efficiency gains can be made through reduction of consumption by the HVAC system. For that reason, each of the three technologies selected for study in this thesis deal with resource efficiency. Natural ventilation and underfloor air distribution address HVAC system consumption, while photovoltaics address renewable electricity production.

![Office Building Energy Consumption](image)

Source: U.S. DOE, Energy Information Administration Commercial Building Energy Consumption Survey, 1999

Figure 1.3

Photovoltaics, Underfloor Air Distribution, and Natural Ventilation

Improvements in each of these technologies can increase the overall performance of an office building. Chapters 2, 3, and 4 focus on underfloor air distribution, photovoltaics, and
natural ventilation, respectively. Each chapter describes the technology, how it is incorporated in a project, and measures financial performance.

Photovoltaics (PV) do not reduce the consumption of a building. Rather, they use solar energy to supplement the electricity produced by the utilities. In the year 2000, the US generated 3.8 trillion kWh of electricity for its own consumption. Of that, only 88 billion kWh, or 2.3%, was produced by the “geothermal and other” category that includes geothermal, wind, solar, wood, and waste. It is estimated that PV cells could provide 15% of U.S. power by 2020.4 Because PV cells do not consume fossil fuel or emit pollution, they are harmless to the environment. Although resources are used to manufacture PV cells, they fit into the category of resource efficiency because no natural resources are depleted in the electricity production process.

Underfloor air distribution is also a type of resource efficiency. It increases the temperature at which cooled air can be delivered, which greatly reduces the amount of energy required to cool that air. This affects the design of the system, reducing the size of cooling equipment and virtually eliminating ductwork. Another benefit of underfloor air is that the improvement of indoor air quality can improve the community and cultural sensitivity by reducing sickness and increasing productivity, as shown in studies which are described in Chapter 2.

The final technology that this thesis will examine is natural ventilation. This technology covers three categories: environmental responsiveness, resource efficiency, and the integration of ecology and real estate. Allowing outside, “fresh” air to circulate throughout the building for cooling and ventilation will certainly reduce the energy and equipment that is needed for the HVAC system. Natural ventilation allows for “breathing” building that will work with the natural ecology of its surroundings, and become an integral part of it. In addition, indoor air quality is improved.

**A Survey of Developers and Tenants**

In addition to the quantitative analysis of the costs and payback of green technologies that are outlined above, this thesis will also attempt to explain other factors that affect whether a developer will use these green technologies. The first step is to compare how developers
perceive green technologies to how their customers, tenants, view the same technologies. This is essential to understanding why these systems are, or are not, included in a development.

Two surveys were created and the results presented in Chapter 5. One survey is for developers and the other for tenants. The main purpose is to gain a qualitative understanding of how the important players in the process view environmental technologies. This will help to clarify where future gains can be best made.

The thesis concludes with Chapter 6, which is a summary of results from the cost analysis of photovoltaics, natural ventilation, underfloor air distribution, and the surveys. A discussion of where to go in the future will end the thesis.
Chapter 1 Endnotes


CHAPTER 2 – Underfloor Air Distribution

Underfloor air distribution is the practice of supplying conditioned air from below rather than above, as in today’s standard systems. Raised access flooring allows underfloor air distribution to be possible. The space between the concrete floor slab and a raised access floor acts as a plenum to distribute the supply air for the building. Air is delivered through the floor via diffusers that are integral to the panels. The technology was originally utilized to effectively cool computer and equipment rooms. However, in the 1970’s its use began in office buildings. The technology has been used extensively in Japan, Europe, and South America for the last decade, but only in the last couple of years has it begun to take hold in the U.S.¹

The traditional approach to HVAC design is shown in Figure 2.1. A complete system of ductwork above the ceiling provides conditioned air to the space below. Air is usually returned through unducted space above the ceiling acting as a plenum. The HVAC system’s job is to provide a constant volume of conditioned air. It is designed to provide a given number of fresh air exchanges with outside air on an hourly basis. The system does not accommodate differences in thermal comfort by the occupants – the space is intended to be at one constant temperature.

Because the supply air and return air are both located at ceiling height, improperly designed systems will have little mixing with air at the floor. Much of the air flows directly from supply diffusers into return grilles. Occupants often get little benefit of exchanges with fresh air. The air can become stagnant in layers, which can reduce indoor air quality.¹


Figure 2.1 Standard HVAC Design

Chapter 2 – Underfloor Air Distribution
In contrast, an underfloor air distribution system is shown in Figure 2.2. Floor panels are typically two feet square and sit on pedestals six to twelve inches above the concrete floor slab. The tiles can be mechanically fastened or held in place by gravity. Tiles with diffusers are placed throughout the space as needed to supply sufficient air. Occupants are able to individually adjust floor diffusers for maximum comfort. The space below the raised access floor is used as a plenum to distribute the air to the tenant spaces.

With underfloor air distribution, stratification of the air is actually desired.¹ The air will be warmer near the ceiling, due to the natural fact that heat rises. This will allow for a better flow of air throughout the space, because as cool air is introduced to cool the space, warm air is returned from above.

In most applications, one of two configurations is used. First, the plenum under the access flooring is pressurized as a central air handling unit provides supply air to the space with passive grilles and diffusers. In this case, the entire space under the flooring is under the same pressure. Floor diffusers simply require to be opened, and conditioned air will flow into the space. Or, second, a zero pressure plenum is used, with the air from a central air handling unit

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¹ Source: UCal Berkeley Center for the Built Environment, http://www.cbe.berkeley.edu/underfloorair/techOverview.htm

**Figure 2.2 Underfloor Air Distribution System**
delivered to the space through local fan driven supply outlets. With this system, fans are used in conjunction with the floor diffusers to pull air from the air handling unit to propel it into the room.¹

**Benefits of a Underfloor Air Distribution System**

The main benefits of underfloor air distribution are occupant comfort, energy efficiency, and - maybe most important to developers – space planning flexibility.² The benefits to the occupants are outlined below.¹

- Improved thermal comfort – occupants can adjust temperature of workstations independently.
- Improved ventilation efficiency – Cool air can be delivered at a temperature of 60° to 65° F, about 5° to 10°F higher than conventional HVAC systems.
- Improved Indoor Air Quality – Floor to ceiling airflow more effectively removes contaminants from the space.
- Reduced energy use – Supply air can be delivered at higher temperatures because it is distributed in a pattern of natural convection, with the warm air rising.
- Improved occupant satisfaction and productivity – Research is mounting to suggest that employees are more satisfied and productive.

While these are important reasons for installing an underfloor air distribution system, particularly if the building is owner-occupied, there are other benefits that can accrue directly to a developer that acts as owner-landlord. The most important of those is that the space can be refitted much easier than with standard construction. By reducing Tenant Improvement (TI) costs, a developer can see significant returns as soon as rents roll. Rather than eight weeks to reconfigure the office partition layout, it may take only two weeks. There is less down time between leases, and it is a selling point to be able to turn vacant space around quickly for a prospective tenant that is looking to move sooner rather than later. The developer uses this swift turnaround as a tool to market the property.

Faster reconfiguration is accomplished by making fixtures, diffusers and grilles more like exchangeable component of a system. In a conventional HVAC design, the supply and return diffusers and grilles are designed based on a specific wall layout. When the walls are moved, the
HVAC system may need to be reconfigured as well, which means that ductwork has to be reworked and redesigned. Reconfiguring ductwork requires additional material and is labor intensive and expensive. If diffusers and grilles are hard ducted to the system, it takes much time to reconnect new diffusers in the ceiling when the walls are moved. The ceiling, walls, and HVAC are affected. With underfloor air distribution, however, when the partitions are rearranged, the ceiling is not affected at all, and the new duct connections are not required.

Carpet tile is most often the covering of choice for the raised access floor system. In order to reconfigure the floor diffusers because walls are moved, all that is required is to lift four carpet tiles and replace a panel without a diffuser with one with a diffuser, or vice versa.

Although the ductwork can be the most expensive part of the TI, it is not the only system that is affected. Modular electric outlet panels and lighting fixtures can also be moved with relative ease for TI. With underfloor air distribution, electric outlets can be installed in floor panels instead of walls. A floor panel with outlets built in is dropped in exactly the right location, and the electrical connections are made “plug and play” so that the new outlet is plugged into the system under the floor panels. This greatly reduces the labor costs for an electrician to hard wire each new electric outlet into the system, as well as the time required to make the reconfiguration.

In addition, other telephone, cable, and computer systems can be more easily moved and reconfigured. All of the wiring and cabling is easily reached below the access flooring. Reduced cost and time is an enormous benefit, particularly to tenants with sophisticated computer systems that are constantly upgraded and changed.

*Indoor Air Quality and Employee Productivity*

Another advantage of utilizing an underfloor air distribution system is that the Indoor Air Quality (IAQ) is higher than in typical HVAC systems. Because office workers spend 90% of their time indoors, and approximately 33% of their time at the office, improved IAQ can reduce many health risks. With a conventional system, air is supplied at the ceiling level, and also returned from the ceiling level. If the system is properly designed, supply air will mix throughout the space. While mixing helps to maintain temperature, it will also spread contaminants throughout the room. The dispersion of harmful pollutants will decrease IAQ.
With underfloor air distribution, however, the conditioned air is delivered where it matters most – at the floor-level zone of occupants’ breathing, not at the ceiling height overhead. During cooling, cool, dry, and clean air is discharged through the floor grilles and captures heat loads. Natural convection takes the warm air, and its contaminants, to a level above occupants where it is returned from the system via the ceiling grilles. Pollutants are not mixed with the air and spread throughout the space.

Indoor air quality can directly affect the productivity of the occupants, and therefore be a source of major savings for the building owner. If the building is owner-occupied it will be easier to recognize gains in productivity. A developer who acts as landlord can only benefit from increased occupant productivity only if tenants recognize it as a benefit, and are willing to pay a rent premium for increased productivity. Below is a discussion of studies that demonstrate that there is a direct benefit from improved indoor air quality to the occupants.

In the operation of a business, energy costs are minimal compared to labor costs. Salaries exceed building energy and maintenance by a factor of one hundred and exceed annualized construction and rental costs by a factor of ten. There are four links between indoor air quality and productivity: transmission of infectious disease, allergies and asthma, sick building syndrome, and human performance. For each of these, risks can be reduced and performance increased by incorporating increased ventilation, better air filtration, and reduced air circulation.

Infectious diseases are often transmitted through aerosol contaminants from sneezing and coughing of the occupants. Underfloor air distribution provides better ventilation with little cross ventilation, which can reduce the occurrence of infections by 10% to 30%. Allergies and asthma are aggravated by moldy and damp conditions that can exist under poorly ventilated and filtered air. Underfloor air distribution provides better ventilation and can reduce allergies and asthma symptoms by approximately 10% to 30%. Sick Building Syndrome refers to the irritation of eyes, nose, and skin, headache, fatigue, and difficulty breathing. These symptoms are clearly linked to building features and indoor environments. The estimate is that a 20% to 50% reduction in Sick Building Syndrome symptoms can be achieved by improving ventilation and reducing air recirculation, which underfloor air distribution will do. Finally, human performance can be directly affected by indoor air quality. The previous three factors demonstrate how poor indoor air quality can make the occupants sick, and cause them to miss workdays. Sometimes, a building may have poor air quality that results in reduced occupant
performance, not in sickness directly. By giving independent temperature control to occupants, employees that are performing mental tasks can improve productivity by as much as 20%. The research above did not study underfloor air distribution directly, but it illuminates how IAQ relates to employee productivity. The challenge is for the developer to translate this information into a competitive advantage or marketing tool to attract tenants. If tenants begin to see the tangible evidence that productivity can increase with better indoor air quality, they may be willing to pay a rent premium. Currently, developers likely do not profit from improved employee productivity since this benefit accrues to the tenant. Developers, however, can recognize an immediate gain when it comes time for TI. Here, shorter construction timeframes mean faster lease-up and less vacant space.

The basic accounting that is generally used in studies of employee productivity show that only the employer (tenant) will benefit. One approach to allow building owners (i.e. developers) to share in the productivity gains is to employ a performance lease. A performance lease allows both the tenant and the owner to benefit from improved productivity. The lease can stipulate particular measures of tenant productivity that will be the benchmark for observed productivity. If surpassed, then the increased revenue is shared with the owner. The details can be complicated and need to be an integral part of lease negotiations, but much like a retail lease, the owner and tenant can financially benefit from improved occupant productivity.

Cost Benefit Analysis of Raised Access Flooring and Underfloor Air Distribution

As stated above, the cost benefit of underfloor air distribution using raised access flooring not only includes energy savings due to the improved performance of the heating and cooling of the space. In addition, there are savings because the time required for fitout of the space can be greatly reduced. The result is less down time between leases and lower tenant improvement costs for the owner.

A Case Study

At one project developed in Pennsylvania, a developer installed raised access flooring in one floor of a 4-story office building. The entire building was approximately 100,000 sf, and the raised access flooring was installed in about 25,000 sf on the first floor. The floor system includes pedestals that raise the flooring panels six inches above the concrete floor slab. The
panels are 2’x 2’ and covered by carpet tiles to further seal the joints. The system was furnished and installed for a cost of roughly $5 per sf, or a total of $115,000. This included the floor panels and pedestals only.

To analyze the entire system, we must examine more than simply the cost to install the flooring. The electrical, HVAC, structural, and wall partition systems are all affected by the choice to use raised access flooring. In this case, electrical costs were approximately the same with the new system as would be for the conventional. The developer believes that there should have been an electrical savings, but could not obtain it because underfloor air distribution is a relatively new technology and the Contractors were unfamiliar with the work. Therefore, to reduce risk from unknown installation, bids were high. Underfloor air distribution eliminated ductwork above the ceiling, which freed that space up for a flexible lighting system. The system included “plug and play” components for all of the lighting fixtures. This means that the lighting can be installed by simply plugging a whip, or cord, from the lighting fixture into a main junction box that was located above the ceiling. This system was adopted to allow for flexible locations of lighting when it came time to rearrange the walls, during lease rollover or other renovations of the space.

The HVAC costs for the project were a little bit higher for the first floor than for the other floors. The ductwork cost was much lower because other than the one main riser coming from the rooftop unit, there was no ductwork. All of the air distribution was done under the access flooring, and the air discharged into the space via floor diffusers. The cost to furnish and install HVAC on the three conventional floors was about $7 per square foot, or $525,000. The HVAC for the first floor underfloor air distribution system cost $6 per square foot or $150,000.

<table>
<thead>
<tr>
<th></th>
<th>Square Feet</th>
<th>$ / Square Foot</th>
<th>Total Cost</th>
<th>HVAC Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 conventional floors</td>
<td>75,000</td>
<td>$7</td>
<td>$525,000</td>
<td></td>
</tr>
<tr>
<td>1 underfloor air floor</td>
<td>25,000</td>
<td>$6</td>
<td>$150,000</td>
<td>$25,000</td>
</tr>
</tbody>
</table>

Since this was the first underfloor air distribution system used by the developer, thermostats and variable air volume (VAV) boxes were added to serve as a “test” of the system. VAV’s heat and circulate air on the north side of the building, where there is little solar gain. This extra equipment is not necessary for the system to operate, but as a way to test how the
occupants use and control the underfloor air. Comfort in areas with thermostats and VAV’s can be compared to those without for future planning. The idea is to identify how often the occupants change their own air diffuser, and whether the use of thermostats is more or less efficient in office areas with this type of access flooring.

The underfloor air distribution system required no revision to the structural requirements because the floor-to-floor height did not change. The underfloor air distribution eliminated ductwork in the ceiling above. This space made up for the fact that an addition 6-8” was taken up at the floor by the pedestals and panels. Therefore, underfloor air distribution did not add or reduce the cost for the buildings structural elements.

Likewise, the carpet costs were the same as the costs for conventional HVAC. The developer chose to use a 2’x 2’ carpet tile, which works best with the raised floor system. Carpet tiles, however, are also commonly used in offices with standard flooring systems. With a raised floor system, it is necessary to have carpet tiles in order to be able to lift the panels to access the space below for reconfigurations and added equipment. The carpet tiles are laid so that the seams of the floor panels do not coincide with the carpet tile joints. This allows for a better seal and feel underfoot. Four carpet tiles must be lifted to get to a single floor panel below. Therefore, carpet costs are not increased or decreased by the use of underfloor air distribution.

The developer tried many wall systems that could easily be interchanged when it came time to reconfigure the space. Some interesting materials were examined, including recycled hay bale wall systems and structural wall components, but were not suitable for use on this particular project. The project team decided to use conventional metal studs, acoustic insulation, and gypsum wallboard for the partitions. The studs are installed on top of the floor panels, so that when the space is reconfigured, there is no more work required than would be for conventional flooring.
Excluding extra “test” equipment installed by the developer.

** Electrical cost should be reduced as contractors gain experience.

*** Conventional stud and drywall system used, but there is potential to use more cost effective wall type.

In conclusion, underfloor air distribution was used on this project to save costs when leases expire and the space is renovated for a new tenant. However, the cost analysis above demonstrates that there is, indeed, a capital cost savings due to reduced HVAC cost. The original tenant is still in place, so the actual savings from reduced down-time between leases has not yet been measured, but the developer estimates that construction time for tenants fitout could be reduced by as much as 75% of time required for conventional HVAC system due to the elimination of ductwork. This will result in both a substantial construction savings and a reduction in forgone rent. In this case, the $25,000 saved by installing underfloor air distribution is bonus for the developer.
Chapter 2 Endnotes


6 Soininen, John, Leggat McCall Properties LLC, All information on Case Study provided through Personal Interview, June 2001.
CHAPTER 3 – Photovoltaics

Renewable energy does not deplete natural resources through its production. It includes bioenergy, wind, hydrogen, ocean, geothermal, hydropower, and solar.\(^1\) Solar energy is used by photovoltaic (PV) cells to generate electricity from sunlight while releasing no pollution. The Department of Energy estimates that if 0.3\% of the land in the U.S. were covered with PV cells, it would be sufficient to provide all the electricity the nation consumes. PV power is a promising technology for use in commercial buildings.

It is important to understand how PV cells generate electricity in order to know how they can be incorporated into a building. PV technology was discovered in 1839 by French physicist Edmund Becquerel, but was not fully understood until 1958 when solar cells were used on the U.S. Vanguard space satellite.\(^1\) Today, PV cells provide power for virtually all of our satellites, including weather, communications, and military. Unlike electricity generated by coal, gas, oil, or nuclear power, with PV cells there are no moving parts. Because there are no turbines and no bearings, the maintenance costs of PV cells are extremely low. All that is required is basic cleaning for the panels themselves. However, other parts of the system that distribute the electricity require maintenance similar to conventional electric systems.\(^2\)

PV cells contain a semiconductor, usually silicon, which is the earth’s most abundant mineral. As sunlight hits the cell, the semiconductor absorbs some of the sunlight’s energy, and reflects the rest. The portion that is absorbed transfers energy to the semiconductor, which, in turn, frees electrons from the semiconductor. The cell contains an electric field that forces the electrons to flow in a certain direction. By placing metal contacts at both ends of the cell, those electrons are channeled and used externally as electricity.\(^3\) Many cells are placed adjacent to one another in a panel, and many panels are placed next to one another in an array. As the array grows, the power generated becomes greater and greater, and if large enough can power an entire building.
How a Building Uses PV

There are basically three types of PV cells that are most widely used commercially: single-crystal, polycrystalline, and amorphous. They range in cost, efficiency, and reliability. The single-crystal cells are made by sawing thin wafers from a single large silicon crystal. The wafers are typically about 4 inches in diameter. These are used in the cells in the manner described above, and a group of cells are encased in a weather tight module. This is the most expensive of the processes because it requires that the silicon crystals be grown extremely pure. However, they have the highest efficiencies, able to convert 15% of the sunlight striking them into electricity in commercial building applications.3

Polycrystalline cells were in the early 1970’s. In this process, molten silicon is cast into forms where it solidifies into the polycrystalline form. These cells can be shaped into any geometry, not just round, because they are cast and not cut. Their efficiency is only slightly
lower than the single-crystal, at 14% in commercial uses. However, the production process is less expensive because pure silicon crystals do not have to be grown.  

Amorphous PV cells do not use silicon in crystal form at all. Amorphous (non-crystalline) silicon atoms are deposited in a very thin layer on glass or other substrate. The result is a very thin, flexible cell that can be used in a wide range of pliant applications. Because the layer of silicon is so thin, the efficiency is greatly reduced with this method. To increase efficiency, multiple layers of amorphous silicon can be stacked one on top of the other, but even then the efficiency only reaches a high of 7%. This technology is relatively new, and there have been problems with the stability of the cells, as efficiency tends to drop over time. However, a much lower manufacturing cost can make the decreased performance more acceptable in some applications.

PV cells can be made of materials other than silicon, such as cadmium-telluride, but the abundance of silicon makes it the obvious choice for use. None of the newer superconductors used have resulted in a higher efficiency than silicon, so there is no justification for the higher production costs.

**Building Integrated PV**

Although the technology has been around for decades, only in the 1990’s did manufacturers and designers begin to utilize Building Integrated PV (BIPV). A conventional building material can be replaced with PV panels that perform the traditional function as well as generate electricity. Roof shingles, curtainwall, and skylights are good examples of BIPV.

When PV panels generate electricity, it is in the form of DC current. Some large appliances and other direct wired systems can utilize DC, but most of the power needs of a building are AC current, including all computer equipment, most lighting, and anything else that is going to be plugged into an electric outlet. The energy generated by utilities comes through in the form of AC. In order to provide AC current, as well as to distribute the electricity throughout the building, there are other system components required, often called “Balance of System” (BOS). Below is a diagram of a typical residential system, which is virtually the same as a commercial system, only smaller.
The additional components consist of structures, enclosures, wiring, switchgear, fuses, ground fault detectors, charge controllers, batteries, and inverters. The BOS usually account for about half of the cost of the entire system, but virtually all of the maintenance costs.  

There are two ways that the system can produce power to the building: stand-alone system or grid-connected system. A stand-alone system is shown in Figure 3.2. Because the power generated by the PV cells is optimal during the height of sunny days, the system needs a battery to store the excess electricity generated during sunny conditions for use at night and on cloudy days. The battery simply stores excess electricity and supplies it when needed. In this type of system, there is no need to be connected to the utility grid.  

In a grid-connected system, excess electricity generated by the PV panels is sold back to the electric utility. The Public Utilities Regulatory Policy Act of 1978 (PURPA) requires that electric utilities buy excess electricity generated by independent producers such as with a PV system. During peak production by the PV panels, the excess electricity is sold back to the utility. At night and on cloudy days, the building receives its electricity from the grid.  

The advantages and disadvantages of a BIPV system are outlined below.
**BIPV Advantages**

- **PV serves a Dual Role** – The upfront cost of the system can be figured as the PV system minus the cost of the system it replaces (such as skylights, curtainwall, shingles, or glazing).
- **Easier Financing** – PV can be financed as part of the entire project so there will not be a need to necessarily justify the system to skeptical lenders.
- **Aesthetics** – While subjective, BIPV can be an inventive way for the Architect to improve the building’s detailing.
- **Public Relations / Marketing Value** – BIPV provides a visible statement that the company is committed to the environment, and this can generate good will among the customers and the community.

**BIPV Disadvantages**

- **Capabilities of Trades** – Particularly with roofing systems, it may be unclear what trade will install the components. For example, does the roofing contractor or the electrician install BIPV roof shingles? Who has ultimate responsibility for leaks?
- **Orientation and Tilt Not Optimized** – The PV panels will have to work at the angle of the building, often vertical, which can reduce efficiency.
- **Performance May be Compromised** – It may be difficult for BIPV to optimally mimic the system it replaces, and therefore does two jobs acceptably, while doing neither very well.
- **Dual Role Components Makes Redevelopment of Building Difficult** – By keeping building systems separate from the skin, remodeling and reconfiguration of the space is easier.

**Cost Benefit Analysis of Photovoltaics**

Cost benefit analysis is used to measure the financial performance of photovoltaic systems. The up-front cost of the PV system is weighed against what it can save in operating costs through the life of the building. Life-cycle cost is a measure that should take into account the useful life of the building, and not solely the first costs. In the case of PV, first time costs are
usually higher because it is an added feature to the building. The use of BIPV, however, can reduce the cost of ordinary building material it will replace. For example, the use of PV roof shingles or PV integrated glass spandrel panels will replace ordinary materials with PV. The benefit of PV is in the reduced operating costs that will occur in the form of reduced electric utility bills. In this section, the financial performance of a PV system is estimated. The first piece of information needed is the amount of energy that a typical building will consume. It is assumed that PV system will generate sufficient electricity during peak hours to support the entire building around the clock.

Using the average energy consumption of an office building, the amount of energy that a 100,000 sf office building will require is estimated. The size and cost of the PV system is estimated based on energy requirements of the building. Savings are presented from the amount of energy that is produced by the PV system rather than purchased from the utility. The simple payback is the amount of time that it will take to recover the costs of the initial system.

**BIPV System Size and Cost**

The cost of BIPV system is approximately $60 per sf including material and installation. The material is about half of the costs, and the installation and balance of systems is the remainder of the costs. Annual energy consumption of a typical 100,000 square foot office building is given 22.7 kWh per sf. For the entire building, the annual consumption is,

\[(100,000 \text{ sf}) \times (22.7 \text{ kWh/sf}) = 2,270,000 \text{ kWh.}\]

The entire building will use 2.27 million kWh on an annual basis.

A typical BIPV panel generates 12 watts, or 0.012 kW, per square foot of PV area at peak sunlight. There are 202 annual days of sunshine in the Boston area, and that on those days, there is an average of 6 hours of sunshine per day. Converting the kW power of these panels into energy intensity:

\[(202 \text{ days}) \times (6 \text{ hours per day}) \times (0.012 \text{ kWh per sf of PV}) = 14.5 \text{ kWh per sf of PV annually}\]
Each square foot of BIPV panel will provide an average of 14.5 kWh per year. Based on the buildings needs, the total area required for PV panels can be found:

\[
(2,270,000 \text{ kWh required}) \div (14.5 \text{ kWh per sf of PV}) = 156,500 \text{ sf of PV}
\]

If the PV is to provide all of the building’s power, then there needs to be 156,500 square feet of PV on the surface of the building. At $60 per sf, this is a total cost for the system of:

\[
($60) \times (156,500) = $9,393,000
\]

Energy Savings

As of June 11, 2001, the cost for commercial power in Cambridge, Massachusetts was 11.6 cents per kWh. The BIPV system described above would provide all of the power for the entire building, so that no power from the utility is needed. Therefore, the consumption savings is the amount that the BIPV panels produce. In this example, it equals 2,270,000 kWh.

\[
(2,270,000 \text{ kWh}) \times ($0.116 \text{ per kWh}) = $263,300 \text{ savings annually or } $21,900 \text{ per month}
\]

The annual savings that are realized represents only 2.8% of the up front cost of the system. This system would require, at a minimum, batteries as part of the balance of systems to capture electricity for use at night and on cloudy days.

Return on Investment

The real estate industry typically uses return on investment (ROI) to value added costs to a building. Another index is NPV analysis to examine the life-cycle cost of the building. The median age for a commercial building is 31 years. Using that as a lifespan, below the return on investment and NPV are calculated. It is assumed that the energy costs will grow at 3% per year, as will the energy savings.

The initial payment is $9,393,000 and the annual savings starts at $263,300 (growing 3% annually):
Initial Cash Flow, $CF_0$, is the cost of the system, which is negative, $=-\$7,566,000$

Annual Cash Flow, $CF_1$ to $CF_{31}$, is annual energy savings, which starts $= \$263,300$ and grows 3% each year.

The return on investment is only 1.9%, which indicates that the energy savings and PV are a relatively poor investment. The simple payback period is 35.7 years – longer than the building’s life. Using NPV analysis, the NPV of the investment in BIPV, over the 31-year life span is:

At 6% discount rate, $NPV = -\$3,963,229$
At 8% discount rate, $NPV = -\$4,929,278$
At 10% discount rate, $NPV = -\$5,662,120$

**Other Factors**

The calculations above assume that the BIPV will be able to supply all of the power that the building requires. However, in order to do that, the building will require 156,500 square feet of PV. The building is only 100,000 square feet total, so the challenge becomes finding the required surface area on the building. The following assumptions about the building are made: it is five stories tall, 100’ by 200’ in plan, and has a floor-to-floor height of 12’. The building is assumed to sit so that the 200’ dimension is parallel to the east-west axis, ensuring that one of the larger sides faces south. If the PV panels are installed on the west, east, and south faces of the building, there would be only 24,000 square feet available for PV. If the entire roof houses PV, another 20,000 square feet could be added for a total of 44,000 sf of BIPV. This is only 28% of the total surface area that is required to power the entire building. Clearly, even if the configuration of the building is changed, there will still be a substantial discrepancy between what is required to provide power to the entire building and what is physically possible.

Using this 44,000 sf surface area:

Cost of BIPV system: $\$2,640,000$

kWh produced annually by PV: 638,000 kWh

Total annual energy savings, year 1 (grows at 3% per year): $\$74,008$

Return on Investment, over 31-year lifespan of building: 1.9%

at 6% discount rate, $NPV = -\$1,113,817$
at 8% discount rate, \( NPV = -\$1,385,356 \)

at 10% discount rate, \( NPV = -\$1,561,317 \)

The above discussion aggressively assumes that all faces of the building receive the same amount of sunlight. In reality, only PV on the south face of a building in Massachusetts will approach the peak performance. If today’s price of electricity were to raise 26.8 cents/kWh, or 2.3 times what it is currently, then the NPV would equal zero. This is the point at which developers will begin to even consider the use of PV as a shrewd investment.

**Standard PV Cells**

Standard, non-BIPV panels can be bought off the shelf, from manufacturers, and installed in existing buildings or new construction. The principal of their operation is the same. However, they do not replace another building material, as the BIPV do. Instead, they are typically units mounted on the existing roof.

This thesis examines one particular model of standard PV panel, the BP Solar (Solarex) SX-65U. This particular panel generates peak power of 65 watts at maximum exposure to the sun. Each panel is six square feet, so that the maximum power generated is 10.8 watts per sf.\(^8\) This particular model sells for a price of about $320 each. In addition to the cost of the panel alone, inverters, brackets, wiring, and other accessories are need for the full installation.\(^8\) The cost of accessories can equal the price of the panels so that the total cost for this system is about $650 per panel, or $108 per sf of PV. In order to properly design and size a PV system, the month with the minimum daily average sunlight is used. In Boston, December averages 3 sun-hours per day.\(^11\) For electricity generating capacity, however, a more accurate measure is to use the annual average, not the month with the least sunlight. In Boston, the annual average is 4 sun-hours per day.\(^11\) This number is an estimate of the amount of peak hours of sunshine each day. It represents the equivalent number of peak hours from the amount of actual sunlight. Therefore, each panel generates .26 kWh of electricity as shown below.

\[
(4 \text{ hrs}) \times (65 \text{ Watts}) = 260 \text{ Watts or .26 kWh per day of sunshine}
\]

Annual electricity generated by each SX-65U panel is,
(365 days per year) x (.26 kWh/day) = 94.9 kWh per year

To power the 100,000 square foot building, would require 24,000 SX-65U panels at a total cost of $15.5 million. In addition to the prohibitive cost, the panels would require an area equal to roughly three acres. Regardless how environmentally conscience he or she may be, no developer will buy three acres to house PV panels for a 100,000 square foot office building.
Chapter 3 Endnotes


CHAPTER 4 - Natural Ventilation

The term ‘natural ventilation’ refers to the use of natural means to remove heat from a building, rather than through mechanical cooling systems. It is a type of passive ventilation. No matter how it is accomplished, removing heat provides cooling to a building. With natural cooling, the environment is used to discharge heat through convection, evaporation, or radiation. These are the same processes that are used by mechanical systems, but natural ventilation eliminates or reduces the need for them.¹

Historically, buildings were designed and built to allow for sufficient fresh air to enter the space, and provide the necessary air for occupants’ comfort and health. Modern architecture and technology, however, allow buildings to be constructed that are entirely sealed off from infiltration of outside air. The HVAC is independent of the weather outside, which allows indoor temperature to be more easily controlled, but does not necessarily improve system performance. As HVAC technology has improved since the 1950’s, the amount of outside air allowed to freely pass through a building has virtually reached zero. This is highlighted with the construction of large glass office buildings with inoperable windows.²

Natural ventilation, with proper outdoor climates, can:²

- Reduce cooling load
- Enhance thermal comfort by increasing heat dissipation from the human body to the environment
- Maintain proper indoor air quality
- Remove heat stored in building and its materials

Features of Natural Ventilation

The most effective ways to incorporate natural ventilation have low capital cost and require very little maintenance. They are cross ventilation, stack ventilation, thermal mass/cooling, and design considerations.³
**Cross Ventilation**

The idea of cross ventilation is simple and intuitive. Windows are designed to be operable on all sides of a building. As wind hits one face of the building, it creates positive pressure on the windward side, and negative pressure on the leeward side, thus forcing air through the space. The major consideration for this design to work is that the outside air must be cooler than the inside air to provide the necessary cooling. Other factors are the interior layout of walls, partitions, and other obstructions to the flow of air.  

**Stack Ventilation**

Stack ventilation works like a chimney. An opening, like a skylight, is included in the ceiling, or upper part of the structure. When it is open, warm air that accumulates in the building will rise and escape through natural convection. Escaping air creates a vacuum, and, as it does, a vent at the bottom of the building’s envelope allows fresh, cooler air to enter. This process does not need wind. The action of rising warm air and sinking cool air will cool the space.

**Nighttime Cooling / Thermal Mass**

Because temperatures fall at night, it is the best time to flush out the warm air that has accumulated throughout the day and replace it with cooler nighttime air. Thermal mass involves the building materials that are used. Exposed brick and concrete can be used on the interior finishes to absorb heat that is created within the occupied space during the day. These materials are have a high thermal mass, and will naturally absorb heat. This method can reduce temperature fluctuations between interior space and the exterior from 10° F or 15° F to 2° F or 3° F.

**Design Considerations**

A designer of the typical HVAC system does not have to consider what the weather on the exterior is like because the interior is controlled separately. The air is kept at a constant temperature and humidity through heating and cooling, relying very little on outside conditions. The designer of a naturally ventilated building does not have that luxury. The climate has to be accounted for in the design of the cooling system, including air temperature, wind speed, wind direction, and humidity. The interior layout of the building becomes a factor, as well as how it is
situated on the site. These factors assure that the designer must have an understanding beyond
the thermodynamic considerations of the building’s interior.³

Cost Benefit Analysis of Natural Ventilation

The most effective natural ventilation systems are incorporated into the building during
the design stage. It is at this point where costs will be minimized because very little is added to
the building. Since natural ventilation is integral to the building’s design, it is difficult to
determine its cost. Natural ventilation ideas like operable windows, narrow floor plates, chimney
shafts, and stacks can be built with minimal added costs to the base building.⁴ Therefore, the
best way to measure the financial performance of natural ventilation systems is to examine the
energy savings that result from the reduced energy use.

In a research study of natural ventilation, Henry Spindler of MIT has created a model that
estimates that amount of energy that a naturally ventilated commercial building saves. The
building in the model is a 1000 square foot square structure with 40% of its façade windows that
are equally distributed on all four sides. The study shows that, in Boston, energy consumption
can be decreased 37% simply by including natural ventilation. Although it is a study of a small
building, the results can be interpolated to a much larger structure. If projected to a 100,000
square foot building, the energy usage savings will also be 37%.

In Cambridge, Massachusetts in June 2001, the commercial electricity rate was 11.6 cents
per kWh.⁵ To arrive at energy savings, annual consumption of 2,270,000 kWh, as shown in
Chapter 3, is used. Annual consumption, if reduced by 37% through natural ventilation, would
be 1,430,100 kWh. At $0.116, this represents a savings on electricity costs of $97,428. This
savings will go directly to the bottom line of the building owner.

<table>
<thead>
<tr>
<th>Annual Energy Consumption, kWh</th>
<th>Standard Building</th>
<th>Naturally Ventilated Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Cost, at 11.6 cents per kWh</td>
<td>$263,320</td>
<td>$165,892</td>
</tr>
<tr>
<td>Savings with Natural Ventilation</td>
<td>-</td>
<td>$97,428</td>
</tr>
</tbody>
</table>
**Limitations**

While the energy savings can be great, as shown above, natural ventilation has limits. It has been used extensively in Europe, where mild climate, narrow floor plans, and traditional heavy mass buildings facilitate the use of natural ventilation. In the U.S., natural ventilation has been slower to market. Many new buildings now include operable windows, but few office buildings use stacks and chimneys. In the hot, humid climate of the eastern U.S., it is extremely difficult to eliminate the need for a mechanical cooling system. However, systems can be designed to minimize reliance on mechanical cooling so that when the weather permits, the building is cooled passively.

The disadvantages of natural ventilation are outlined below.

- Occupants must be willing to accept greater temperature swings than with conventional HVAC systems
- Air flow rate will vary with outdoor conditions
- Hands-On System: occupants must be willing to open and close vents to regulate the temperature
- Not effective during hot and humid summer months
- Must be part of initial design process – very difficult to include in renovations and retrofits.
- System must be designed to fit fire codes, which are not flexible.

Given the constraints that are inherent on relying on the climate to cool the building, many developers are reluctant to use an entirely passive ventilation system for cooling. However, even modest changes in the cooling can be recouped by electricity cost savings. The building can be designed so that it is passively cooled whenever possible, and cooled mechanically the rest of the time.
Chapter 4 Endnotes


CHAPTER 5 – Survey

Methodology

The goal of this thesis is to determine whether a developer can obtain a higher return and/or more profit by implementing green building technologies. There are several ways in which a greater value can be realized:

- Reduced operating costs
- Increased sale price upon disposition of property
- Higher than market rent
- Visibility and publicity for the developer (i.e. branding)

These options depend on how the user – the tenant – views green development. If the tenant is willing to pay more rent for a building with green technologies, then the developer can recoup added first costs in the form of more valuable leases. On the other hand, if the tenants are not willing to pay more for green buildings, then the developer may be unable to justify the expense. Further, some tenants may not even be aware of green technologies or how they affect the occupants.

In order to compare developer views and tenant views, two surveys were created and distributed. One is for developers and the other for tenants. The questions parallel one another by addressing the same issues, but are worded to emphasize the two different audiences. The survey was completed by alumni of the Center for Real Estate at Massachusetts Institute of Technology who are spread throughout the United States in various positions and companies. Four tenants and nine developers completed the survey. Copies of actual responses are included in the Appendix.

Promising Green Building Technologies

One of the questions in the survey asks both the developers and tenants what “green building technologies are most promising?” The results are summarized in Figures 5.1 and 5.2. For the most part, the developers and tenants agree that energy efficiency and recycled materials are possibilities for future buildings. Also, both groups agreed that daylighting (the use of natural light rather than electric lighting) was quite promising: 88% of developers and 78% of tenants cited it as a promising technology.
**Raised Access Flooring**

While 50% of tenants responded that raised access flooring and underfloor air distribution are a promising technology, only 33% of developers agreed. Since the tenant typically pays utility costs, the occupant will recognize the benefits of underfloor air distribution in a standard lease. Tenants are more willing to rent space in a building with underfloor air distribution if they benefit with lower lease costs. The potential benefit to the developer is that the space can be reconfigured for tenant improvements more quickly when leases roll. Only 33% of developers cited decreased lease-up time as a consideration for the implementation of green building technologies. There appears to be a lack of knowledge among developers that raised access flooring and underfloor air distribution is a technology that can be used not only to reduce utility costs, but also to reduce down time between leases. There is an opportunity for developer education.

![Most Promising Green Building Technologies in Tenants' Views](image)

**Figure 5.1**
Natural Ventilation

In the survey, 25% of tenants and 56% of developers responded that natural ventilation was a promising technology. Developers are more open to this option because it would clearly reduce the capital cost of the project. If in the proper climate and with high-quality design, natural ventilation will reduce the amount and/or size of HVAC equipment needed with little or no increase in the cost of the building shell. Therefore, the developer will recognize an immediate increase in the bottom line by curbing construction costs. Tenants, on the other hand, may be less open to this technology because they fear that it will result in an inadequate system that will not properly cool the space. This is apparently not offset by the fact that operating expenses will be reduced also. The tenants are more skeptical about this perceived unproven technology than developers.

Photovoltaics

The majority of both groups (75% of tenants and 89% of developers) did not cite photovoltaics as a promising technology. Earlier chapters of this thesis confirm that PV is not
cost effective, currently. In the future, as electricity prices soar and PV prices plummet, there will be a point when PV is economically feasible, in fact desirable, but we are not at that point now.

**Why Implement Green Technologies?**

This survey asked respondents to identify main reasons they have, or would desire, green building technologies. Results are presented in Figures 5.3 and 5.4. For both groups, the largest percentage (67% of developers and 75% of tenants) stated that utility cost savings were a reason that they would look for green technologies in a building. Tenants likely are concentrating on the bottom line costs for the lease, since a reduction in operating costs will benefit them directly. On the other hand, developers may be considering more innovative ways to structure leases so that they, too, can see an increase in the bottom line by reduced utility costs.

Developers’ responses indicate that they consider the green segment of the market to be growing and it is in their best interest to get on board early. For example, 56% said that green building technologies are a good marketing tool for their company. Even if they do not occupy the space themselves, they will look to use it as a way to gain publicity for their company. Only 25% of tenants stated that marketing was a reason. Also, 44% of the developers who responded stated that a reason for green is to gain more experience in environmentally sustainable practices. This points to a developers’ attitude that green building will only increase in the future and they want to be able to capitalize on it as a business opportunity.

Few of the respondents (22% of developers and 0% of tenants) stated that environmental concern was even an issue. If this is indicative of the industry as a whole, then green building will not thrive, if left to the market. Regulation and building codes may be required to encourage developer and tenant participation.

Tenants did respond that employee satisfaction and increase in productivity (75% and 50%, respectively) were a major force in their decision to lease space in buildings with green technologies. Developers were not given that option as a specific reason, but were encouraged to note other reasons. Responses focused on the financial performance of the added technology. One respondent stated, “*Only if doing so would yield additional return on investment, respond to regulatory requirement or put [the] building in economically advantageous position over competition.*”
Another stated, "[If] it would somehow reduce development or operating costs."

The typical developer will respond to financial gain or to a regulation that requires action. The survey underscores that attitude.

Figure 5.3

Tenant Reasons for Renting Space in a Building with Green Technologies

<table>
<thead>
<tr>
<th>Reason</th>
<th>% of Respondents Who Cited Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee Satisfaction</td>
<td>100%</td>
</tr>
<tr>
<td>Utility Cost Savings</td>
<td>80%</td>
</tr>
<tr>
<td>Increase in Productivity</td>
<td>60%</td>
</tr>
<tr>
<td>Faster Tenant Improvements</td>
<td>40%</td>
</tr>
<tr>
<td>Marketing Tool</td>
<td>20%</td>
</tr>
<tr>
<td>Developer Driven</td>
<td>0%</td>
</tr>
<tr>
<td>Gain Green Experience</td>
<td>0%</td>
</tr>
<tr>
<td>Environmental Concerns</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>0%</td>
</tr>
</tbody>
</table>
Reasons Developers Would Include Green Technologies on a Project

![Chart showing reasons developers would include green technologies on a project.](image)

**Figure 5.4**

**Obstacles**

The survey asked both groups to identify what were the largest obstacles to the practice of green building. The responses are outlined Figure 5.5 and 5.6. Not surprisingly, cost is named as a major obstacle on the vast majority of the responses (100% of tenants and 89% of developers). Coupled with cost, 44% of the developers are concerned that tenants will be unwilling to pay for rent increases to make up for added costs. Of minor concern to developers is financing (11% of respondents cited). Developers also noted construction delays and uninterested clients as obstacles.

All of the tenants responded that availability of space in buildings with green technologies was a major obstacle. This indicates an opportunity for developers to fill the void in markets where tenants want to be located. Major urban markets that have little space may be a good opportunity for a developer to redevelop and include green technologies.

Chapter 5 – Survey of Tenants and Developers
An interesting comment that was included by one tenant was that although the idea of increased employee productivity was promising, there are “No good studies to definitively prove that these type of buildings have anything to do with employee productivity.” As shown
previously in this thesis, there are studies and some evidence that, in fact, productivity of employees can be increased with improved indoor air quality. However, the tenants have not embraced the idea. Education of the technology’s benefits is critical for it to make sense for the developer.

_Ten-Year Prediction_

The survey asked respondents to guess at the number of projects/buildings they will have in ten years that are considered green. The term “green” did not specifically refer to natural ventilation, underfloor air distribution, or photovoltaics in this case; it was used to mean any of the technologies that can be considered environmentally sustainable. Developer responses were extremely inconsistent with one another: they ranged from 5% to 100%. The more pessimistic responses focused on the attitudes of the users and marketing of the ideas rather than on the financial feasibility of green projects.

“Less than 5% - only in specific markets like southern CA and CO where there appears to be a perception that a rent premium can be justified for environmentally conscience development.”

This response centers on the argument that only where the culture will allow higher than market rent will there be a push for green. This will happen in only areas that are considered “environmentally conscience.” Another respondent noted:

“Current federal attitude will require extremely pragmatic approach or I think the new fashionable intrigue with ‘green’ will diminish.”

The government’s role in promoting and requiring green development is a major factor in whether developers use the technologies.

Tenant responses were much more conservative for the most part, and clustered at 10%. One respondent noted that most of their office leases are long term and will not expire in the near future, so that it would be difficult to greatly increase the amount of green space that they rent. However, no indication was given of the plans when those leases expire.
Payback

Payback refers to how and when each group of respondents expects to recoup added costs that may be due to green technologies. Developers’ responses ranged from 3 to 10 years, with the majority between 3 and 5 years. As one respondent stated,

“I think a 3-year simple payback is something most developers would consider. Anything longer is a hard sell.”

Even if they plan to hold the building for a long period, developers require short payback.

Similarly, tenants demand short payback as well. At most, one respondent said that energy savings were required to outweigh extra rent, “over the course of the lease.” Other respondents were unwilling to go the full lease term. Two responses were:

“Not more than three years”
“Energy savings should equal or exceed increased rent on an annual basis.”

Even those not willing to give a specific time-line stated, “Not sure, would have to be quick.”

In order to make green technologies financially feasible, one of two facts must be true. First, the capital cost must be minimal, so that the added cost to the project is trivial. Second, the annual savings in operating costs must be substantial.

Profit Opportunity?

Of the Developers, the survey asked if they viewed green building technologies as a profit opportunity. This is question is aimed at the heart of the puzzle. If a developer senses that there is an opportunity to make money, then green technologies will proliferate based on developer supply. On the other hand, if there is the perception that there are no opportunities to make additional profit, green technologies will flourishing only with tenant demand.

The results, shown in Figure 5.7, indicate that only 22% of developers view green building technologies as a profit opportunity. The vast majority will choose to wait until tenants are willing to pay higher rent, or are forced to go green by building codes.
Building Codes and Regulations

One respondent to the survey stated that unless required by codes and/or regulation, developers would not implement green building technologies.

"In my experience, developers react better if there is a level playing field which means that green buildings will prosper only with regulations forcing all to behave the same way."

Survey Conclusion

Developers and tenants view green building technologies differently. Tenants want environmentally sustainable buildings, but are generally unwilling to pay in the form of added rent. They will only begin to consider added lease costs if the operating expense savings is greater than the rent increase. This assumes that the operating costs are passed on to the tenant, which is the standard office lease format. Tenants generally consider the green market segment much smaller than developers do, none predicting more than 20% of occupied space to be green
in ten years. Tenants are unaware of the advantages to occupying space in a building with green technologies.

Developers are more aware of the positive features of green building practices. Although the minority, some predict that in ten years, 98-100% of their projects will incorporate some green technologies. Tenants need to be educated and made aware of the reasons that some developers see profit opportunities. Developers major concern with green technologies is the cost. The capital costs are perceived to be too much, and in some cases this is still true. However, even if there is added capital costs, developers are willing to use green technologies, as long as they can be assured that the tenants are willing to pay for them in the form of added rent. Since the survey shows that tenants are unwilling to do that, the developers’ fears are justified.

Daylighting, efficient lighting and office equipment, and low water plumbing fixtures are the technologies that both groups of respondents agree are the most promising in the future. Other, more radical and novel approaches will take time to mature and develop into feasible options. Ultimately, the ability of a developer to install green building technologies rests on the financial performance of the project. There is very little environmental concern on the part of either the developers or the tenants. Certainly, not concern to the point that profit will be compromised on either side.
CHAPTER 6 – Conclusion

This chapter is a summary of points from the previous five. Speculative office development will support some of the green technologies presented here, but not all. Since this thesis is not targeted at corporate owners, the conclusions drawn here do not necessarily apply to owner-occupied buildings. This chapter will conclude with ideas on how developers can profit from green building technologies in the future.

Underfloor Air Distribution

Underfloor air distribution and raised access flooring is the most promising technology studied in this thesis. Developers can profit by implementing this technology today.

Main Points

- **Cost Effective.** The energy savings from HVAC can offset the cost for the installation of the raised access flooring. Annual energy consumption will be reduced because underfloor air systems are more efficient and can deliver the same comfort level while using less electricity.

- **Turnover Costs.** While utility savings are shared with the tenant, the developer will recognize immediate increase in Net Operating Income by decreasing downtime between leases. Underfloor air systems will reduce time required for new tenant fitout and the renovation costs will be much less because ductwork does not have to be redesigned and other systems can be more easily moved underfoot rather than overhead.

- **Increase Indoor Air Quality.** Underfloor Air will improve IAQ, which can increase occupant productivity. If this can be quantified, the developer can justify to tenants a rent premium.

Photovoltaics

Photovoltaics are not currently cost effective and, unless electricity prices more than double in the near future, developers should not invest in PV.
Main Points

- **PV Cost.** Currently, PV costs are too high to justify their use. The BIPV example from Chapter 3 will not pay for itself over the life of the building, so it is a poor investment for the developer. In fact, at a discount rate of 8%, the NPV for a PV system that the building will physically support is negative: -$1,385,356.

- **Electricity Cost.** While many are predicting rises in the cost of electricity in the future, at today’s prices, use of electricity from the utility is smarter than an investment in PV. Electricity prices in Cambridge would have to increase 2.3 times in order for PV to be competitive.

- **Building Integrated Photovoltaics.** BIPV are a promising use of PV. They can replace another standard building system, but currently, they are not cost effective for the developer. Increased efficiency of the panels will help as the technology improves in the future.

- **Off-Peak.** A speculative office building cannot be expected to provide all its power via PV. At night and on cloudy days, an office building will need to draw is electricity from expensive batteries or the utility grid.

Natural Ventilation

While the drier climate of the west coast of the U.S. is more ideal for natural ventilation, buildings in all regions can benefit from some natural and passive ventilation technologies. Currently, there is not a clear ‘yes’ or ‘no’ for developers. Each project should be individually examined to determine if profit would be derived from natural ventilation. There are some major ideas that need to be considered.

Main Points

- **Cultural.** Occupants must accept larger temperature swings, smaller floor plates, and be willing to use operable windows if that is part of the system. Developers need to be aware of these differences and be prepared to address them.

- **Lost Floor Area.** To make the most efficient use of natural ventilation, building width is usually about 45’-50’, which is about 30’ narrower than what we are used to in the U.S.
Smaller floor plates reduce rentable area and are difficult to market. With a nontraditional building size, developers take on added leasing risk.

- **Still Requires some HVAC System.** Generally, even if natural ventilation is used, there is still a need for an HVAC system when the weather is too warm or humid to sustain occupant comfort. Further, banks may be unwilling to finance a building without HVAC, so they will require a system to be included.

- **Improved Indoor Air Quality.** Natural ventilation improves IAQ. As more studies conclude that improved IAQ increases worker productivity, then developers can market projects with natural ventilation to a more accepting audience.

**Survey Results**

The survey presented in Chapter 5 reveals that, in general, developers require payback of three to five years for green building technologies, and that tenants are unwilling to pay additional rent for space in green buildings. In order to close this gap, developers and tenants need to be moving forward in the same direction.

The survey shows that developers should concentrate efforts and money on the following green building technologies:

- Daylighting
- Efficient Lighting and Plumbing Fixtures
- Underfloor Air Distribution

Tenants show very little interest in natural ventilation and photovoltaics, so without education of the tenants, developers should stay way from using these two technologies.

**Environmental Concern**

When marketing properties to prospective tenants, developers should concentrate on:

- Employee (Occupant) Satisfaction
- Utility Savings
- Increase in Productivity
- Faster Tenant Improvements
Tenants will only consider paying added rent if the green building technology will result in an overall cost savings. Tenants will not pay higher rent because it is “the right thing to do” for the environment. Developers may have environmental concern at the core of why they build green projects, but should not emphasize the environment when marketing it. Developers need to emphasize the opportunity for financial gain by the tenant.

The most effective way that developers can increase tenant interest in green technologies, and therefore create profit, is to make green more available. All of the tenants responded to the survey that one of the largest reasons that they do not rent space in a green building is because it is not available. While this seems to contradict their sentiment that cost is an obstacle, it speaks to the greater need for tenant education. As the number of green projects increase, tenants will become more aware of their potential benefits. Indeed, tenants will eventually become so well versed that they will drive the speculative office market towards green by demanding it.

If that happens, the developers who are first-movers into the market will stand the chance to reap the largest rewards. The survey indicates that only 22% of developers see green technologies as a profit opportunity. These risk takers will benefit most from the expansion of the green building market.

**Final Thoughts**

Intentionally left out of this thesis is a discussion of how green technologies benefit the environment. While environmental consciousness may drive many, the majority of developers are driven by sound business practice. As it can be shown that they can gain a competitive advantage or increase in profits, developers will take it upon themselves to perform green developments. Below are listed several ways that green will become the rule rather than the exception.

**Align Developer and Tenant Incentives** - Developers are rightfully reluctant to take on added first costs if the major benefit is reduced utility costs, which are passed on to the tenant. One possible solution is to use a performance lease. Much like a retail lease, with a performance lease, the tenant and owner will share in productivity and utility cost savings. By sharing the benefits, developers increase profit and tenants improve output of their firm. Care must be taken to establish fair and appropriate benchmarks for improved productivity of the tenant.
**Government Subsidies** – Green Development can benefit not only the developer, but also the general public that uses the space. Therefore, if the government stepped up its support of green buildings, particularly alternative energy sources, there would be more incentive to include those on a project by developers.

**Tenant Education** – Perhaps the most meaningful contribution of developers is to show how green projects are beneficial to their customers, the tenants who occupy the space. Increased tenant education and understanding will spur tenant demand, and will increase the profit opportunity to developers.

**Building Codes** – As indicated by several of the respondents to the survey, many developers are unwilling to undertake what is perceived as new technology unless all are required to use it. Unfamiliar techniques are a risk that many developers will not assume. Therefore, if codes required all projects to include some green aspects, developers would be forced to learn the methods as a matter of survival.
Works Cited


Coad, William J. “Conditioning Ventilation Air for Improved Performance and Air Quality.” Heating/Piping/Air Conditioning 71.9 (1999): 49-56.


Works Cited


Spindler, Henry. “Not Yet Published.” Diss. Massachusetts Institute of Technology.


Works Cited
Appendix A – Survey Responses
The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Developer

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many projects with “green” building technologies do you currently have, or have completed in the last five years?</td>
<td>0</td>
</tr>
<tr>
<td>Of those, how many are office buildings?</td>
<td></td>
</tr>
<tr>
<td>Did those projects include:</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td></td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td></td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td></td>
</tr>
<tr>
<td>What is the reason (or would be a reason) for using green building technologies?</td>
<td>Check all that apply.</td>
</tr>
<tr>
<td><em>X</em> Tenant Driven</td>
<td></td>
</tr>
<tr>
<td>____ Marketing Tool for your company</td>
<td></td>
</tr>
<tr>
<td>____ You were working for a client who pushed it</td>
<td></td>
</tr>
<tr>
<td>____ To gain experience with the hopes of doing more green projects</td>
<td></td>
</tr>
<tr>
<td>____ Save on Utility Costs</td>
<td></td>
</tr>
<tr>
<td>____ Hope it would help in the leasing of the space</td>
<td></td>
</tr>
<tr>
<td>____ You are an environmentalist</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Would you install these technologies if the first cost was higher than for other designs?</td>
<td></td>
</tr>
<tr>
<td>If payback was within desired holding period.</td>
<td></td>
</tr>
<tr>
<td>If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?</td>
<td></td>
</tr>
<tr>
<td>See immediately preceding response.</td>
<td></td>
</tr>
<tr>
<td>How do/would you measure financial performance of added building costs?</td>
<td></td>
</tr>
<tr>
<td>Increased IRR over holding period.</td>
<td></td>
</tr>
<tr>
<td>What is the largest obstacle to green building projects? Check all that apply.</td>
<td></td>
</tr>
<tr>
<td>Financing</td>
<td></td>
</tr>
<tr>
<td>X Costs</td>
<td></td>
</tr>
<tr>
<td>Risk</td>
<td></td>
</tr>
<tr>
<td>X Tenants unwilling to pay for green improvements</td>
<td></td>
</tr>
<tr>
<td>X Other: potential construction schedule delays</td>
<td></td>
</tr>
</tbody>
</table>
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

- Photovoltaics (Solar power)
- Natural Ventilation
- Raised access flooring
- Daylighting
- Efficient equipment
- Efficient lighting fixtures
- Fuel Cells
- Recycled building materials
- Low water plumbing fixtures performance has been very poor
- Other:

Will you use any green technology options in projects currently in your pipeline? If so, how many? NONE

In ten years, take a guess at what percentage of your projects will be “green”? Current federal attitude will require extremely pragmatic approach or I think the now fashionable intrigue with “green” will diminish

Do you see green development as a profit opportunity? Why or why not? No, I do not think most tenants will pay any premium for it.

Other comments, please:
The most promising opportunities are applications for interested corporations and institutions in their own space. Commercial development for profit must be highly market responsive, budget conscious and delivered with shortest construction period possible.
MIT Center for Real Estate Thesis 2001

Author: Rick Donovan

The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Developer

| How many projects with “green” building technologies do you currently have, or have completed in the last five years? | None |
| Of those, how many are office buildings? | None |

Did those projects include:
- Photovoltaics (solar cells)? NA
- Natural Ventilation? NA
- Raised Access Flooring? NA

What is the reason (or would be a reason) for using green building technologies? Check all that apply.

- [x] Tenant Driven
- [ ] Marketing Tool for your company
- [x] You were working for a client who pushed it
- [x] To gain experience with the hopes of doing more green projects
- [x] Save on Utility Costs
- [ ] Hope it would help in the leasing of the space
- [x] You are an environmentalist
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would you install these technologies if the first cost was higher than for other designs?</td>
<td>Yes, as long as the project was still feasible at the higher cost.</td>
</tr>
<tr>
<td>If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?</td>
<td>10 years</td>
</tr>
<tr>
<td>How do/would you measure financial performance of added building costs?</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>What is the largest obstacle to green building projects? Check all that apply.</td>
<td>Financing  Costs  Risk  Tenants unwilling to pay for green improvements  Other: I have not had the opportunity to explore green buildings yet. My projects have been for clients who have not expressed an interest. As I do more projects, perhaps I’ll find out what the obstacles are.</td>
</tr>
</tbody>
</table>
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

- Photovoltaics (Solar power)
- Natural Ventilation
- Raised access flooring
- Daylighting
- Efficient equipment
- Efficient lighting fixtures
- Fuel Cells
- Recycled building materials
- Low water plumbing fixtures
- Other:

Will you use any green technology options in projects currently in your pipeline? If so, how many?
Not sure

In ten years, take a guess at what percentage of your projects will be “green”?
No idea – most of my projects are for clients, so it is not my option.

Do you see green development as a profit opportunity? Why or why not?
Yes, because there is a segment of the market that will be attracted to green buildings and you will have the advantage of capturing this segment of the market.

Other comments, please:
I would like to learn more about green development, so that I can discuss it with clients as an option. If and when I get to the point of developing a building that I have control of, I will certainly implement some green building techniques.

MIT Center for Real Estate Thesis 2001
Author: Rick Donovan
The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Developer

| How many projects with “green” building technologies do you currently have, or have completed in the last five years? | 0 |
| Of those, how many are office buildings? | n/a |
| Did those projects include: |  |
| Photovoltaics (solar cells)? |  |
| Natural Ventilation? |  |
| Raised Access Flooring? |  |

What is the reason (or would be a reason) for using green building technologies? Check all that apply.

___ Tenant Driven
___ Marketing Tool for your company
___ You were working for a client who pushed it
___ To gain experience with the hopes of doing more green projects
___ Save on Utility Costs
___ Hope it would help in the leasing of the space
___ You are an environmentally minded
___ Other:
Would you install these technologies if the first cost was higher than for other designs?

Depends on total cost versus savings; 5% premium on some projects would be acceptable. If the return on investment for the marginal cost of going "green" was acceptable then it would make sense to consider. Problem is in quantifying.

<table>
<thead>
<tr>
<th>If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think a three year simple payback is something most developers would consider. Anything longer is a hard sell.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How do/would you measure financial performance of added building costs?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost to benefit analysis. Sometimes hard to measure; thus hard to sell.</td>
</tr>
</tbody>
</table>

What is the largest obstacle to green building projects? Check all that apply.

When I think of green building, I think of grass parking areas, on-site water retention, white rooftops. ICSC and ULI have good material on "green" developments. Ideas like grass on building roofs which adds insulation and makes for a nicer looking facility. Worries about roof leaks, etc. may discourage such novell approaches.

<table>
<thead>
<tr>
<th>Financing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
</tr>
<tr>
<td>Risk</td>
</tr>
<tr>
<td>Tenants unwilling to pay for green improvements</td>
</tr>
<tr>
<td>Other: City regulations requiring parking, curb/gutters,</td>
</tr>
</tbody>
</table>

Appendix 73
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

_____ Photovoltaics (Solar power)
_x__ Natural Ventilation
_____ Raised access flooring
_x__ Daylighting
_x__ Efficient equipment
_x__ Efficient lighting fixtures
_____ Fuel Cells
_____ Recycled building materials
_____ Low water plumbing fixtures (pain in the rear, toilets that clog)
_x__ Other: green parking, storm water runoff / retention issues.

Will you use any green technology options in projects currently in your pipeline? If so, how many?

Not at this time. Something we’ll look at down the road as opportunities arise.

In ten years, take a guess at what percentage of your projects will be “green”?

All projects will have energy efficient lighting and low water use plumbing. Couldn’t venture a guess on other green technologies.

Do you see green development as a profit opportunity? Why or why not?

No.

Other comments, please:
The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Developer

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many projects with “green” building technologies do you currently have, or have completed in the last five years?</td>
<td>NONE. None in my career of having developed at least 6 fairly large scale office buildings in the New England.</td>
</tr>
<tr>
<td>Of those, how many are office buildings?</td>
<td></td>
</tr>
<tr>
<td>Did those projects include:</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td></td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td></td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td></td>
</tr>
<tr>
<td>What is the reason (or would be a reason) for using green building technologies? Check all that apply.</td>
<td></td>
</tr>
<tr>
<td>_____ Tenant Driven</td>
<td></td>
</tr>
<tr>
<td>_____ Marketing Tool for your company</td>
<td></td>
</tr>
<tr>
<td><em>XX</em> You were working for a client who pushed it</td>
<td></td>
</tr>
<tr>
<td>_____ To gain experience with the hopes of doing more green projects</td>
<td></td>
</tr>
<tr>
<td><em>XX</em> Save on Utility Costs</td>
<td></td>
</tr>
</tbody>
</table>
Hope it would help in the leasing of the space
You are an environmentalist
Other:

Would you install these technologies if the first cost was higher than for other designs?
Yes, if the lifecycle cost was attractive enough. If I could show hard evidence to my tenants that the building operating cost would be more competitive than the competition.

If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?
Seven to Ten years.

How do/would you measure financial performance of added building costs?

How much value do you create on the back end? How do the capital markets value the added item? Pay back and/or other operating efficiencies if I plan to hold the asset.

What is the largest obstacle to green building projects? Check all that apply.

- Financing
- Costs
- Risk (Unproven technologies)
- Tenants unwilling to pay for green improvements
- Other:
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

____ Photovoltaics (Solar power)
___X__ Natural Ventilation
___ Raised access flooring
___X__ Daylighting
___xEfficient equipment (Energy company offers rebates)
___X Efficient lighting fixtures (In MA there is an energy code you have to use efficient lights)
___ Fuel Cells
___ Recycled building materials
___XX__ Low water plumbing fixtures (Code required in MA)
___ Other:

Will you use any green technology options in projects currently in your pipeline? If so, how many?

Those checked above

In ten years, take a guess at what percentage of your projects will be "green"?

Do you see green development as a profit opportunity? Why or why not?

No, only if all developers have to use green/sustainable products.

Other comments, please:

In my experience developers react better if there is a level playing field which means that green buildings will prosper only with regulations forcing all to behave the same way.
The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Developer

| How many projects with “green” building technologies do you currently have, or have completed in the last five years? |
| Of those, how many are office buildings? |
| Did those projects include: |
| Photovoltaics (solar cells)? |
| Natural Ventilation? |
| Raised Access Flooring? |
| YES |
| What is the reason (or would be a reason) for using green building technologies? Check all that apply. |
| ____ Tenant Driven |
| ____ Marketing Tool for your company |
| ____ You were working for a client who pushed it |
| ____ To gain experience with the hopes of doing more green projects |
| ____ Save on Utility Costs |
| ____ Hope it would help in the leasing of the space (same as tenant driven and marketing tool...let’s be honest, developers mostly do it because they stand to make money. |
You are an environmentalist

Other:

Would you install these technologies if the first cost was higher than for other designs?

Possible. If it showed long term value.

If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?

Depends on the hold strategy for the asset. Some investors are in for the short term other are longer. For the longer it is a no brainer. For the short term investors, they would need to see that it added value…in other words the next buyer would pay you for the improvements.

How do/would you measure financial performance of added building costs?

Will the next buyer pay for it.

Or will tenants value the added cost in the form of a higher rent later on.

What is the largest obstacle to green building projects? Check all that apply.

____ Financing
_x_ Costs
____ Risk
____ Tenants unwilling to pay for green improvements
____ Other: Communicating the actual “unproven” and often future savings or benefit of the green building technique.
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

- Photovoltaics (Solar power)
- Natural Ventilation
-Raised access flooring
-Daylighting
-Efficient equipment
-Efficient lighting fixtures
-Fuel Cells
-Recycled building materials
-Low water plumbing fixtures
-Other: Low off-gassing materials

Will you use any green technology options in projects currently in your pipeline? If so, how many?

There is a new corporate initiative to do so. To say how many project is difficult as we are a large company.

In ten years, take a guess at what percentage of your projects will be “green”? Green has many definitions, but if you mean to say projects than will employ at least one of the current “green” technologies…98%

Do you see green development as a profit opportunity? Why or why not?

Absolutely. Market differentiation.

Other comments, please:
MIT Center for Real Estate Thesis 2001
Author: Rick Donovan

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Survey – Developer

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many projects with “green” building technologies do you currently have, or have completed in the last five years?</td>
<td>NONE</td>
</tr>
<tr>
<td>Of those, how many are office buildings?</td>
<td>N/A</td>
</tr>
<tr>
<td>Did those projects include:</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td>N/A</td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td>N/A</td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td>N/A</td>
</tr>
</tbody>
</table>

What is the reason (or would be a reason) for using green building technologies? Check all that apply.

__X__ Tenant Driven
__X__ Marketing Tool for your company
      You were working for a client who pushed it
__X__ To gain experience with the hopes of doing more green projects
__X__ Save on Utility Costs
      Hope it would help in the leasing of the space
      You are an environmentalist
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would you install these technologies if the first cost was higher than for other designs?</td>
<td>No, not without some a short payback</td>
</tr>
<tr>
<td>If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?</td>
<td>Five years</td>
</tr>
<tr>
<td>How do/would you measure financial performance of added building costs?</td>
<td>ROI</td>
</tr>
<tr>
<td>What is the largest obstacle to green building projects? Check all that apply.</td>
<td>Financing, Costs, Risk, Tenants unwilling to pay for green improvements, Other:</td>
</tr>
<tr>
<td>What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.</td>
<td>Photovoltaics (Solar power), Natural Ventilation, Raised access flooring, Daylighting, Efficient equipment, Efficient lighting fixtures, Fuel Cells, Recycled building materials, Low water plumbing fixtures, Other:</td>
</tr>
</tbody>
</table>
Will you use any green technology options in projects currently in your pipeline? If so, how many? No, not unless our clients push for it.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In ten years, take a guess at what percentage of your projects will be “green”? 100%. I think it will be an all or nothing scenario. I predict 100% because I think that either Building Codes will require it or energy costs will mandate it.</td>
<td></td>
</tr>
<tr>
<td>Do you see green development as a profit opportunity? Why or why not?</td>
<td></td>
</tr>
<tr>
<td>In my city, there is very little public awareness of green developments, so that will need to increase before it can become profitable. Even then, there are only a few companies that will voluntarily pay the increased costs. Older, “brown” space will appeal to the cost sensitive participant.</td>
<td></td>
</tr>
<tr>
<td>Other comments, please:</td>
<td></td>
</tr>
</tbody>
</table>
The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Developer

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many projects with “green” building technologies do you currently have, or have completed in the last five years?</td>
<td>None</td>
</tr>
<tr>
<td>Of those, how many are office buildings?</td>
<td>N/A</td>
</tr>
<tr>
<td>Did those projects include:</td>
<td>N/A</td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td>N/A</td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td>N/A</td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td>N/A</td>
</tr>
<tr>
<td>What is the reason (or would be a reason) for using green building technologies? Check all that apply.</td>
<td></td>
</tr>
<tr>
<td>______ Tenant Driven</td>
<td></td>
</tr>
<tr>
<td>X Marketing Tool for your company</td>
<td></td>
</tr>
<tr>
<td>______ You were working for a client who pushed it</td>
<td></td>
</tr>
<tr>
<td>______ To gain experience with the hopes of doing more green projects</td>
<td></td>
</tr>
<tr>
<td>______ Save on Utility Costs</td>
<td></td>
</tr>
<tr>
<td>X Hope it would help in the leasing of the space</td>
<td></td>
</tr>
</tbody>
</table>
You are an environmentalist

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Other: It would somehow reduce development or operating costs.</td>
</tr>
</tbody>
</table>

Would you install these technologies if the first cost was higher than for other designs?

It depends on what the financial plans / structure are for the project. If it was intended that the building would be held and operated for an extended period of time by us, then we would work in any benefits of building green into our proforma.

If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?

Again, it depends on what the financial plans are with the project. But of course the faster the recapture the better.

How do/would you measure financial performance of added building costs?

It would be worked into the building’s operating proforma and would be reflected in the ultimate sales price of the project.

What is the largest obstacle to green building projects? Check all that apply.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>___</td>
<td>Financing</td>
</tr>
<tr>
<td>X</td>
<td>Costs</td>
</tr>
<tr>
<td>___</td>
<td>Risk</td>
</tr>
<tr>
<td>___</td>
<td>Tenants unwilling to pay for green improvements</td>
</tr>
<tr>
<td>___</td>
<td>Other:</td>
</tr>
</tbody>
</table>

Appendix
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

- [ ] Photovoltaics (Solar power)
- [x] Natural Ventilation
- [ ] Raised access flooring
- [x] Daylighting
- [ ] Efficient equipment
- [x] Efficient lighting fixtures
- [ ] Fuel Cells
- [x] Recycled building materials
- [x] Low water plumbing fixtures
- [ ] Other:

Will you use any green technology options in projects currently in your pipeline? If so, how many?

Probably not.

In ten years, take a guess at what percentage of your projects will be “green”?

20%

Do you see green development as a profit opportunity? Why or why not?

Not currently. Recapture of the increased costs of developing a green building are not within the financial horizon of our project timing.

Other comments, please:
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Survey – Developer

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many projects with “green” building technologies do you currently have, or have completed in the last five years?</td>
<td>Two “green” projects currently in development</td>
</tr>
<tr>
<td>Of those, how many are office buildings?</td>
<td>One</td>
</tr>
<tr>
<td>Did those projects include:</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td>No</td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td>Yes</td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td>Yes</td>
</tr>
<tr>
<td>What is the reason (or would be a reason) for using green building technologies?</td>
<td>Check all that apply.</td>
</tr>
<tr>
<td>Tenant Driven</td>
<td></td>
</tr>
<tr>
<td>Marketing Tool for your company</td>
<td>X</td>
</tr>
<tr>
<td>You were working for a client who pushed it</td>
<td></td>
</tr>
<tr>
<td>To gain experience with the hopes of doing more green projects</td>
<td></td>
</tr>
<tr>
<td>Save on Utility Costs</td>
<td></td>
</tr>
<tr>
<td>Hope it would help in the leasing of the space</td>
<td>X</td>
</tr>
<tr>
<td>You are an environmentalist</td>
<td></td>
</tr>
</tbody>
</table>
**X** Other: For the office development, the project is being marketed as an “E-Building” development – relating to both environmental consciousness and high-tech orientation. The school is more focused on sustainable design and long term operating efficiencies.

Would you install these technologies if the first cost was higher than for other designs? The costs are substantially higher than conventional construction, I don’t think many cost models reflect actual conditions, things as simple as more brick for the façade required due to the higher slab-to-slab for raised flooring.

If there was an energy savings, how long would you expect payback to be in order to offset higher first costs, if there were any? Not less than five years, though it is unlikely in my opinion to ever be cost effective on a present value basis.

How do/would you measure financial performance of added building costs?

*I am utilizing limited green technologies as a marketing tool to attract Boulder, CO based companies. Currently marketing the project at +5% premium to other conventional projects.*

What is the largest obstacle to green building projects? Check all that apply.

- [X] Financing
- [X] Costs
- [ ] Risk
- [ ] Tenants unwilling to pay for green improvements
- [ ] Other:

What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

- [X] Photovoltaics (Solar power)
- [X] Natural Ventilation
- [X] Raised access flooring
- [X] Daylighting
- [X] Efficient equipment
- [X] Efficient lighting fixtures
- [X] Fuel Cells
<table>
<thead>
<tr>
<th>Recycled building materials</th>
<th>Low water plumbing fixtures</th>
<th>Other: Ground water filtration (?) incorporated into parking lot design</th>
</tr>
</thead>
</table>

Will you use any green technology options in projects currently in your pipeline? If so, how many?

*Yes, the two noted above*

In ten years, take a guess at what percentage of your projects will be “green”?

Less than 5% - only in specific markets like southern CA and Colorado where there appears to be a perception that a rent premium can be justified for environmentally conscience development.

Do you see green development as a profit opportunity? Why or why not?

*We’ll see...*

Other comments, please:
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Survey – Developer

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many projects with “green” building technologies do you currently have, or have completed in the last five years?</td>
<td>2</td>
</tr>
<tr>
<td>Of those, how many are office buildings?</td>
<td>2</td>
</tr>
<tr>
<td>Did those projects include:</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td>NO</td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td>NO</td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td>1</td>
</tr>
<tr>
<td>What is the reason (or would be a reason) for using green building technologies? Check all that apply.</td>
<td></td>
</tr>
<tr>
<td>_____ Tenant Driven</td>
<td></td>
</tr>
<tr>
<td><em>x</em> __ Marketing Tool for your company</td>
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<td><em>x</em> __ To gain experience with the hopes of doing more green projects</td>
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<tr>
<td><em>x</em> __ Hope it would help in the leasing of the space</td>
<td></td>
</tr>
<tr>
<td><em>x</em> __ You are an environmentalist</td>
<td></td>
</tr>
</tbody>
</table>
Save time and money on turnover. Raised floor keeps critical systems in place while repartitioning takes place for new tenant.

Would you install these technologies if the first cost was higher than for other designs?
Yes/Maybe. The overall/lifecycle cost would need to be better which we believe it would be.

If there was an energy savings, how long would you expect payback be in order to offset higher first costs, if there were any?
I think the cost of capital and liquidity is the real issue. Typically, developers want to spend as little as possible so they can do more deals. My guess is that it would have to be less than 3 years for a developer. But that 5-8 would work for owner-occupant.

How do/would you measure financial performance of added building costs?
IRR

What is the largest obstacle to green building projects? Check all that apply.

- Financing
- Costs
- Risk
- Tenants unwilling to pay for green improvements
- Other:

It is expensive to get contractors to try new things because they haven’t done them and don’t want to take any chances. Additionally, they don’t like techniques that might eliminate future work.
What green/high performance technologies, that you are aware of, are most promising to you for use in a project? Check all that apply.

- [ ] Photovoltaics (Solar power)
- [x] Natural Ventilation
- [x] Raised access flooring
- [ ] Daylighting
- [x] Efficient equipment
- [x] Efficient lighting fixtures
- [x] Fuel Cells
- [x] Recycled building materials
- [ ] Low water plumbing fixtures
- [ ] Other:

Will you use any green technology options in projects currently in your pipeline? If so, how many?

Yes. We try to use efficient equipment and would like to use raised floor and recycled or recyclable material where possible. Additionally, want to use fuel cells, but technology not quite there.

In ten years, take a guess at what percentage of your projects will be “green”?

I’d like to think 100% one way or another, but realistically I think it will probably be more like 50%.

Do you see green development as a profit opportunity? Why or why not?

Right now no, but I think it could be. It is a little more expensive to buy the materials, but as disposal costs continue to rise, I think re-use will be profitable. Again, I think for owner-occupants, it is more profitable.

Other comments, please:

MIT Center for Real Estate Thesis 2001
Author: Rick Donovan

The responses to the survey below will be used in a thesis for a Masters in Real Estate Development Degree. All of the responses will be anonymous – individual and company names will not be used in the thesis.

Survey – Tenant

Are you familiar with “green” building technologies and techniques?
Yes

If yes, do you currently rent office space in such buildings?
How much?
No

Would you be interested in:
Photovoltaics (solar cells)? It wouldn't be a deciding factor for us.

Natural Ventilation? It wouldn't be a deciding factor for us.

Raised Access Flooring? It wouldn't be a deciding factor for us.

What could be a reason that you would consider renting in a green building? Check all that apply. We are driven by location and economics. If the economics were to our advantage, it would be a factor.

_____ Developer Driven
_____ Possible increase in productivity
_____ Employee satisfaction
_____ Marketing Tool for your company
To gain experience in a growing segment of the office market

- Save on Utility Costs
- Hope it would help in the Tenant Improvement – i.e. your space may be fitout more quickly
- You are an environmentalist
- Would not be a factor
- Other:

Would you pay more rent for a building with green technologies?
Not unless we knew we could save money.

If there was an energy savings, how long would you expect payback be in order to offset higher rent, if there were any?
Not sure, would have to be very quick.

How do/would you measure financial performance of added lease costs?
Payback.

What green/high performance technologies, that you are aware of, would you most want in a building?

- Photovoltaics (Solar power)
- Natural Ventilation
- Raised access flooring
- Daylighting
- Efficient equipment
- Efficient lighting fixtures
- Fuel Cells
- Recycled building materials
- Low water plumbing fixtures
- Other:

Are you currently pondering a lease in a green office building? If so, how many?
No
In ten years, take a guess at what percentage of your leased office space will be “green”? Not sure.

What are obstacles that you have to overcome to rent green space? Check all that apply.

- [x] Availability in desired location
- [x] Cost
- [ ] Lack of information of potential benefits
- [ ] Not at all interested
- [ ] Have never looked
- [ ] Other:

Other Comments, please:

In is a tight market, we are more concerned about doing deals.
MIT Center for Real Estate Thesis 2001
Author: Rick Donovan

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Survey – Tenant

<table>
<thead>
<tr>
<th>Are you familiar with “green” building technologies and techniques?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generally, yes</td>
</tr>
<tr>
<td>If yes, do you currently rent office space in such buildings?</td>
</tr>
<tr>
<td>How much?</td>
</tr>
<tr>
<td>No</td>
</tr>
</tbody>
</table>

Would you be interested in:

- Photovoltaics (solar cells)? Depends on lots of factors
- Natural Ventilation? Depends on lots of factors
- Raised Access Flooring? Have already built a building with this.

What could be a reason that you would consider renting in a green building? Check all that apply.

- [ ] Developer Driven
- [x] Possible increase in productivity
- [x] Employee satisfaction
- [ ] Marketing Tool for your company
- [ ] To gain experience in a growing segment of the office market
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would you pay more rent for a building with green technologies?</td>
<td>All</td>
</tr>
<tr>
<td>All in, it would have to be no more than total costs for non green buildings</td>
<td></td>
</tr>
<tr>
<td>If there was an energy savings, how long would you expect payback be in order to offset higher rent, if there were any?</td>
<td></td>
</tr>
<tr>
<td>You do the numbers on each deal. The higher cost of rent would have to be offset by decreased energy costs over the term of the lease.</td>
<td></td>
</tr>
<tr>
<td>How do/would you measure financial performance of added lease costs?</td>
<td></td>
</tr>
<tr>
<td>What green/high performance technologies, that you are aware of, would you most want in a building?</td>
<td></td>
</tr>
<tr>
<td>_____ Photovoltaics (Solar power)</td>
<td></td>
</tr>
<tr>
<td>_____ Natural Ventilation</td>
<td></td>
</tr>
<tr>
<td>x ___ Raised access flooring</td>
<td></td>
</tr>
<tr>
<td>x ___ Daylighting</td>
<td></td>
</tr>
<tr>
<td>_____ Efficient equipment</td>
<td></td>
</tr>
<tr>
<td>x ___ Efficient lighting fixtures</td>
<td></td>
</tr>
<tr>
<td>_____ Fuel Cells</td>
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</tr>
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<td></td>
</tr>
<tr>
<td>_____ Low water plumbing fixtures</td>
<td></td>
</tr>
<tr>
<td>_____ Other:</td>
<td></td>
</tr>
<tr>
<td>Are you currently pondering a lease in a green office building? If so, how many?</td>
<td>No</td>
</tr>
</tbody>
</table>

Appendix
In ten years, take a guess at what percentage of your leased office space will be “green”?
Less than 10%. We own most of our portfolio.

What are obstacles that you have to overcome to rent green space? Check all that apply.

- [x] Availability in desired location
- [x] Cost
- [x] Lack of information of potential benefits
- [ ] Not at all interested
- [ ] Have never looked
- [ ] Other:

Other Comments, please:

No good studies to definitively prove that these type of buildings have anything to do with employee productivity.

We own most of our portfolio and have already developed 650,000 of office space with raised floor and under floor HVAC. We expect to do more. There are very few developers out there doing this because I don’t think they can get people to pay the added costs.
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Survey – Tenant

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you familiar with “green” building technologies and techniques?</td>
<td>yes</td>
</tr>
<tr>
<td>If yes, do you currently rent office space in such buildings?</td>
<td>How much?</td>
</tr>
<tr>
<td>Would you be interested in:</td>
<td></td>
</tr>
<tr>
<td>Photovoltaics (solar cells)?</td>
<td>yes</td>
</tr>
<tr>
<td>Natural Ventilation?</td>
<td>yes</td>
</tr>
<tr>
<td>Raised Access Flooring?</td>
<td>yes</td>
</tr>
<tr>
<td>What could be a reason that you would consider renting in a green building? Check all that apply.</td>
<td></td>
</tr>
<tr>
<td>Developer Driven</td>
<td>x</td>
</tr>
<tr>
<td>Possible increase in productivity</td>
<td>x</td>
</tr>
<tr>
<td>Employee satisfaction</td>
<td></td>
</tr>
<tr>
<td>Marketing Tool for your company</td>
<td></td>
</tr>
<tr>
<td>To gain experience in a growing segment of the office market</td>
<td></td>
</tr>
</tbody>
</table>
Save on Utility Costs  
Hope it would help in the Tenant Improvement – i.e. your space may be fitout more quickly  
You are an environmentalist  
Would not be a factor  
Other:  

Would you pay more rent for a building with green technologies?

I am not sure

If there was an energy savings, how long would you expect payback be in order to offset higher rent, if there were any?

Not more than 3 years

How do/would you measure financial performance of added lease costs?

By making field measurements of energy savings.

What green/high performance technologies, that you are aware of, would you most want in a building?

- Photovoltaics (Solar power)
- Natural Ventilation
- Raised access flooring
- Daylighting
- Efficient equipment
- Efficient lighting fixtures
- Fuel Cells
- Recycled building materials
- Low water plumbing fixtures
- Other:

Are you currently pondering a lease in a green office building? If so, how many?

No

In ten years, take a guess at what percentage of your leased office space will be “green”?

10%  Most of our present leased space has long term leases and these buildings are not not
“green”

<table>
<thead>
<tr>
<th>What are obstacles that you have to overcome to rent green space? Check all that apply.</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>

Other Comments, please:

We are at a threshold of a very important market. However I am afraid that unless managed and marketed properly this revolution has a danger of fizzling out. More public awareness is absolutely vital.
Survey – Tenant

Are you familiar with “green” building technologies and techniques?

Not in any great detail...only what I have read.

If yes, do you currently rent office space in such buildings?

   How much?
   Not to my knowledge.

Would you be interested in:

   Photovoltaics (solar cells)?
   We may be interested in them for retail stores and/or warehouses in sunny climates like CA and AZ.

   Natural Ventilation?
   Yes.

   Raised Access Flooring?
   Not sure.

What could be a reason that you would consider renting in a green building? Check all that apply.

   ____ Developer Driven
   ___?___ Possible increase in productivity
   ____x___ Employee satisfaction
<table>
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<tr>
<th>Marketing Tool for your company</th>
<th>To gain experience in a growing segment of the office market</th>
</tr>
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<tbody>
<tr>
<td>Save on Utility Costs</td>
<td>Hope it would help in the Tenant Improvement – i.e. your space may be fitout more quickly</td>
</tr>
<tr>
<td>You are an environmentalist</td>
<td>Would not be a factor</td>
</tr>
<tr>
<td>Other:</td>
<td>Would you pay more rent for a building with green technologies?</td>
</tr>
<tr>
<td></td>
<td>Not unless reduced utilities/operating costs were certain to make up the difference.</td>
</tr>
<tr>
<td>If there was an energy savings, how long would you expect payback be in order to offset higher rent, if there were any?</td>
<td>Energy savings should equal or exceed increased rent on an annual basis.</td>
</tr>
<tr>
<td>How do/would you measure financial performance of added lease costs?</td>
<td>Not sure I understand the question. We always look at total cost – rent, operating expenses, RE taxes, Insurance, utilities – that wouldn’t change.</td>
</tr>
<tr>
<td>What green/high performance technologies, that you are aware of, would you most want in a building?</td>
<td>Photovoltaics (Solar power)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Low water plumbing fixtures</td>
</tr>
<tr>
<td>Other:</td>
<td>Are you currently pondering a lease in a green office building? If so, how many?</td>
</tr>
<tr>
<td></td>
<td>No.</td>
</tr>
</tbody>
</table>

Appendix
In ten years, take a guess at what percentage of your leased office space will be “green”? Office space is a relatively small percentage of our needs and not growing nearly as fast as retail and warehouse – there may be opportunities in those properties as well. In any event, I would estimate 10-20%.

What are obstacles that you have to overcome to rent green space? Check all that apply.

- _x_ Availability in desired location
- _x_ Cost
- _x_ Lack of information of potential benefits
- _____ Not at all interested
- _x_ Have never looked
- _____ Other:

Other Comments, please:

We are, like virtually all of corporate America, under *intense* pressure to control overhead costs. Therefore, adoption of green technology in our real estate decisions is not going to be a high priority unless it can be shown to have economic benefits as well. For example, we have been leaders (and have won national EPA awards) in adopting state of the art energy efficient air conditioning and lighting systems for our stores, although this effort has been motivated by economic payback.