Green Buildings, Organizational Success, and Occupant Productivity

Judith H. Heerwagen, Ph.D.
J.H. Heerwagen & Associates, Inc.
2716 NE 91st St.
Seattle, Washington 98115

j.Heerwagen@worldnet.att.net

Published in a special edition of
Building Research and Information
Vol. 28 (5), 2000:353-367
London, UK

GREEN BUILDINGS: A Strategic Perspective

A recent survey by U.S. Green Building Council shows that many of its members believe sustainable building design will become a more common practice once the human benefits are identified, primarily the productivity gains believed to be associated with the provision of high quality interior environments (USGBC, 1999). However, there is little understanding of how such benefits might accrue. That is, what are the key green building features and attributes? How do these physical elements affect the physiological, psychological, cognitive, and social functioning of building occupants? Just as important from a business perspective: can green buildings affect high-level organizational outcomes, such as profitability, customer satisfaction, and innovation? If so, what are the linkages?

A full understanding of the human and organizational benefits of green buildings demands a broader perspective that links building design, organizational performance, and human factors research. Recent research on the biophysical foundations of organizations also suggests that a better understanding of business-society-nature links could provide beneficial insights about green buildings and business strategy (Gladwin et al, 1995). As the most visible manifestation of corporate values and ethics, buildings provide a unique insight into the workings of an organization – a view that is not well understood. This paper explores the wider context of sustainable design, integrating work from organizational effectiveness and human factors in an effort to broaden our understanding and lay the foundation for future research on the costs and values of sustainable design. At the present time, the conversation is dominated by costs because methods for calculating costs are more highly developed and more readily accepted than methods for assessing benefits and value. As a consequence of this imbalance, much of the work cited in this paper is theoretical rather than empirical. However, good research depends on good theory to guide the selection of questions and methodologies.

An Overall Framework

Green Buildings and Interior Environmental Quality:
It's not how green you make it – it's how you make it green.

The past decade marks a shift from thinking of facilities as a way to house the workforce to thinking about the entire building portfolio of a company in strategic terms (Horgen et al, 1999). In part this is due to the re-engineering and downsizing of the past decade; but more importantly, CEOs are beginning to think of their buildings as a way to achieve strategic corporate goals. Although the theory and research in this area has not

specifically addressed sustainable design, there is reason to believe that sustainability may become a strategic asset in the future (Hart, 1995; Johnson, 1996; Weinberg, 1998; Magretta, 1997; Russo and Fouts, 1997).

Proponents of sustainable design argue that green technologies and design strategies will enhance interior environmental quality and thus be more conducive to human health and productivity than buildings that use standard practices (Browning and Romm, 1995). Common green building features likely to influence indoor environmental quality include:

- Advanced ventilating and mechanical systems to increase air flow and reduce occupant contact with air borne microbial agents;
- Selection of building materials and furnishings that have low toxicity;
- Increased use of daylighting to reduce energy demands and enhance interior lighting quality;
- Inclusion of high quality, energy efficient lighting to reduce computer glare and increase visual comfort;
- Increased contact with the natural environment through more open views to the outdoors (also associated with daylight) and through the inclusion of plants indoors for psychological reasons and for air quality enhancement;
- Greater attention to construction, maintenance and operation of buildings to reduce build up of microbial agents, especially in HVAC systems and construction materials.

As this list demonstrates, the benefits of green building design currently focus on interior environmental quality and individual performance, health, comfort, and overall satisfaction. Although these outcomes are a critical component of the overall benefits perspective, the focus on these topics has lead researchers to ignore the potential and far reaching relationship between buildings and strategic performance. This latter perspective is likely to be a critical factor in the market growth of green buildings.

Green Buildings and Strategic Performance

The potential connections between green buildings and overall organizational success are still in the formative stages; nonetheless, case studies as well as theoretical considerations suggests multiple links. In order to identify performance impacts, it is useful to consider what constitutes high performance at the organizational level. Although management specialists approach the concept of “success” from many different perspectives, there appears to be considerable agreement regarding the domains across which success is measured (Sink, 1985). These include:

- Product quality
- Customer satisfaction
- Capacity for innovation
- Quality of work life (including employee work attitudes and job satisfaction)
- Employee retention

- Perceived value of goods and services
- Operational efficiency
- Social responsibility

The list can be divided into strategies that primarily "reduce costs" or that primarily "add value." Surprisingly, only one of these dimensions (resource efficiency) is clearly oriented toward the cost side. All of the other dimensions are concerned with adding value to goods and services, work life, customer relationships. Ironically, however, when it comes to facility decisions, costs are almost always the predominant consideration. . This is due primarily to the ease of documenting cost reductions compared with the difficulty of documenting benefits and value. Furthermore, productivity benefits or other organizational outcomes may not be immediately apparent whereas cost reductions are. This presents a dilemma for decision-makers who have one ear focused on shareholders, and the other on their internal operations. They want to use facilities to enhance organizational effectiveness and productivity, but often do not want to make investments in the kinds of changes needed until they have proof that it will payoff.

Theory and research on "green organizations" addresses these more elusive connections and suggests some potential measures of green buildings impacts (Makower, 1992; Hart, 1995). Sustainable practices have gained increasing attention in the mainstream organizational management literature, including the *Harvard Business Review* (Magretta, 1997) and the *Academy of Management Review* (Hart, 1995; Russo and Fouts, 1997). These studies provide evidence that sustainable design and operations associated with increased resource efficiency and pollution prevention can have far reaching impacts on an organization, including:

- Reduced legal and insurance costs associated with reduced risks to current and future generations
- Reduced regulatory inspection load
- Enhanced community livability
- Enhanced relationships with stakeholders
- Process innovation associated with the quest for resource efficiency
- Improved ability to market to pro-environmental consumers
- Reduced operating costs

These strategic benefits are likely to be linked to such green building factors as:

- Reduced use of resources, especially water and energy
- Use of recycled materials in building construction and an in-house recycling program once the building is occupied
- Commissioning to assure the building operates as intended
- Re-commissioning following changes in building use
- Use of renewable resources, such as solar power and wind
- Pollution prevention and waste reduction

- Reduced use of fertilizers for landscape maintenance
- Habitat restoration and use of native plantings in landscape design
- Integration of the natural environment with the building environment
- Locating buildings close to public transportation and other services to reduce commutes

Another benefit of green buildings may be enhanced ability to rent or sell space, especially if interior environmental quality is appreciably better, as noted in a recent study by BOMA (Baier, 1999). The BOMA survey found that tenants in class A buildings were much more satisfied overall with the environment than tenants in class B and C buildings. Class A spaces are likely to sell and rent faster than lower class spaces, especially among businesses that want to maintain a high quality image. Discussions with managers and members of the design team for a new green building in Holland, Michigan, also suggest that technology transfer and learning may be a hidden benefit of sustainable design and construction, especially when techniques and technologies are new. If these benefits are accrued at the local level, then the transfer of skills to other building projects can benefit the community as a whole.

Strategic Performance, Human Resource Development, and Sustainable Design

One way to conceptualize green building benefits is to adopt a framework used by organizations to evaluate their performance. One such approach is the "Balanced Scorecard" (Kaplan and Norton, 1996). The Scorecard assesses four categories of performance: financial, business process, customer relations, and human resource development (which they call "learning and growth").

Table 1 shows potential links between sustainable design features and organizational performance outcomes, using the BSC framework.

Table 1. Potential Links between Green Buildings and Organizational Performance	
FINANCIAL OUTCOMES • Reduced resource utilization • Reduced operating/maintenance costs • Reduced risks/avoided costs • Increased overall productivity • Increased resale value of property • Reduced absenteeism	BUSINESS PROCESS OUTCOMES • Process innovation • Increased work process efficiency
STAKEHOLDER RELATIONS • Improved public image • Increased ability to sell to pro-environmental customers • Community outreach and education • Improved ability to work with community stakeholders	HUMAN RESOURCE DEVELOPMENT • Improved quality of work life • Improved personal productivity • Improved well being • Reduced turnover and increased ability to attract high quality workers

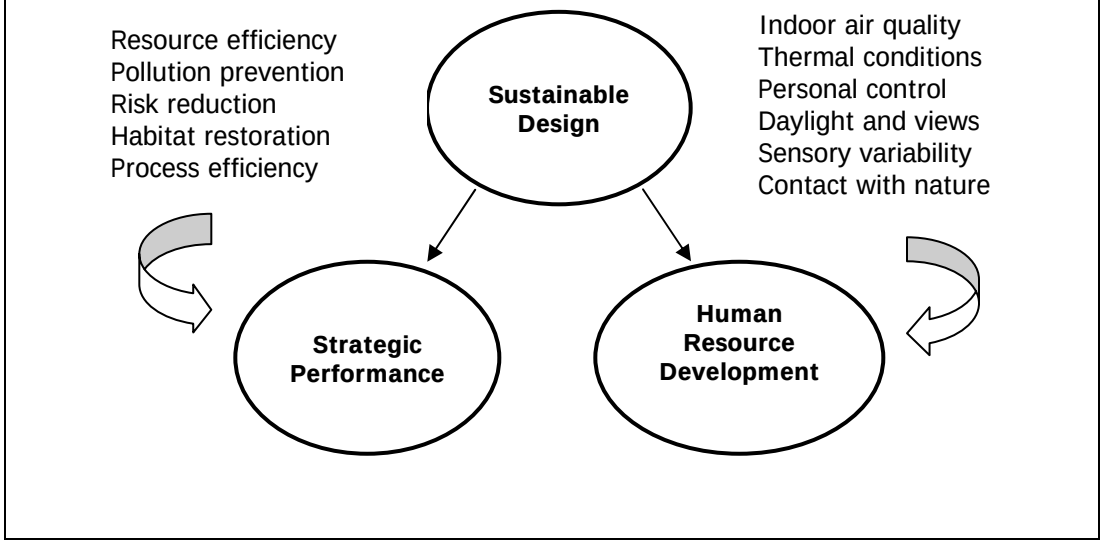
The balanced scorecard approach shows that factors other than the financial bottom line are of interest to organizations and should thus be considered as important benefits of green buildings. (The notion of the "balanced" scorecard, as Kaplan and Norton stress, is that it includes factors other than financial considerations. Furthermore, it utilizes both quantitative and qualitative methodologies as part of the balanced mix.)

From the perspective of green building impacts, these four categories can be usefully divided into two broader dimensions: strategic performance and human resource development. Human resource development focuses on improved indoor environmental quality and its relationship to human factors outcomes. Strategic performance, on the other hand, relates sustainable design to financial outcomes, stakeholder relations, and business process improvements.

Building features and attributes associated with strategic performance are likely to be a somewhat different set of factors than those associated with improved interior quality, although some overlap is inevitable (see Fig. 1). For instance, restoring habitats or building on brown fields is likely to affect community livability more than interior environmental quality. On the other hand, improved indoor air quality is likely to have the greatest impact on well being and personal productivity, with less impact on process improvement or stakeholder relationships.

.

Fig 1. Potential Impacts of Sustainable Design on Human Resource on Strategic Performance and Human Resource Development



Human Resource Development

What evidence exists now exists for these potential benefits? The brief overview in this section is divided into evidence for human resource benefits and evidence for strategic performance benefits. It is not meant to be a full literature review. The purpose is to demonstrate that evidence exists for links between green buildings, human resource benefits and strategic benefits.

Buildings and Productivity.

A recent survey by the American Society of Interior Designers of 200 business decision makers found that 90% of respondents believe that improvements in office design can increase employee productivity (Wheeler, 1998). Furthermore, 97% said the investment would be worth the costs if a correlation could be made to productivity. The

ASID respondents identified five aspects of the environment that they believed affected worker productivity: comfort and aesthetics, privacy, distractions, flexibility of space and customization, and access to people and resources. All of these are factors in interior environmental quality.

A key issue in non-industrial work settings is how to measure productivity, especially for non-repetitive work. This problem is exacerbated by the fact that few organizations have performance metrics in place for workers involved in what is normally called "knowedge work" such as problem solving, policy development, writing, analyzing, and product development. While one could count the number of articles written or problems solved, the real value of such work to an organization may not be known for some time in the future.

As a result of these problems, research in office settings often resorts to self ratings of productivity or to combinations of self administered methods. For instance, in the UK, the Office Productivity Initiative developed a "tool kit" that includes measures of "down time" and other self-assessments of productivity (the Office Productivity Network, 1999). Although self-measures tend to be overestimated (Veitch and Newsham, 1997), when the measure is used in a comparative manner to assess responses to baseline environments and change initiatives, the self assessments are easy to administer and provide useful information (Leaman, 1999; Menzies et al, 1997).

Studies using self-assessments of productivity have found strong relationships to thermal and air quality factors. In a review of occupant surveys over a 20 year period in the UK, Leaman (1999) reports that comfort and perceived productivity are greater in buildings where occupants have more control over the environment and in mixed mode buildings that have both natural ventilation and air conditioning. Two cross sectional studies of more than 11,000 workers in 107 buildings in Europe also found increases in perceived productivity, fewer illness symptoms, and less absenteeism in buildings which provide workers with control over temperature and ventilation conditions compared to a control group (Preller et al, 1990).

Similar results are reported for an intervention study in Canada by Menzies et al (1997). The study consisted of two groups of workers in a mechanically ventilated building. The intervention group was given control over the ventilation at the workstation with a hand held infrared device that could regulate amount and direction of air flow from four inch air outlets in the ceiling (similar to that on airplanes). The research team measured environmental factors, comfort perceptions, illness symptoms, and self assessed productivity. Workers in the intervention said their productivity had increased by 11% at 16 months after the study; in contrast, workers in the control group said their productivity had decreased by 4%. Sick Building Syndrome (SBS) symptoms also significantly decreased in the intervention group, but not in the control group. Environmental assessments of the two spaces showed that air velocity in the intervention space tripled and that both temperature and ventilation variability across the space increased also (an indication that workers were making adjustments according to their personal preferences and needs). Air quality measurements in the intervention space also

showed increases in air borne dust and fungal spores. Although not discussed in the article, the dust particles may have come from surfaces near the worker; thus increased ventilation may have moved the particulates into the general ambient spaces and decreased them near the workers faces. If so, this could account for the decrease in illness symptoms found in the intervention space (see Raw, 1998a, for a discussion of indoor surface pollution).

There are relatively few studies of objective productivity outcomes in field settings due to the difficulty of doing such research. Nonetheless, the existing studies show a strong link between environmental factors, SBS symptoms and work performance. For instance, researchers from the International Center for Indoor Environment and Energy in Denmark conducted a field experiment to assess the impact of a 20-year-old carpet on work performance (Wargocki et al, 1999). The researchers hid the carpet behind a screen so that workers did not know what was being tested. Temperature and ventilation were kept constant during the experiment. Results show that workers performed 6.5 % better on a text entry task when the carpet was absent. This study is significant for showing a direct effect of air quality on performance. Other researchers have assumed the impact of poor air quality on performance is indirect, moderated by illness or absenteeism.

Similar results were reported in another field intervention, although the focus was on the relationship between symptom expression and performance (Nunes et al, 1993). Workers reporting SBS symptoms worked 7.2% more slowly on a vigilance task and made 30% more errors on a symbol-digit substitution task.

Another frequently cited field study with objective measures of productivity assessed the impact of workstations with personal controls. Kroner et al (1992) found productivity increases with the use of personal control workstations in an insurance company in Midwestern United States. In this study, the measure was of actual work output (total number of forms completed each week per employee), not self assessed productivity. The study tracked worker performance in both a baseline building (where workers did not have personal control) and a new building with the individually controlled ambient systems. Productivity in the new building increased by16%, of which 3% was attributed to the personal controls. The personal control workstation erased gender differences in comfort by increasing the percentage of females who rated themselves as comfortable in the new building. The new building also showed a 40% reduction in energy consumption, compared to the old building.

The existing research on personal control over environmental conditions, especially temperature and ventilation, shows a strong link to enhanced work performance as well as to comfort and acceptability (Brager and deDear, 1998). Drawing on a review of research on indoor environmental quality, Wyon estimates that providing workers with temperature control of just three degrees (plus or minus) would result in a productivity increase of about 7% for typical clerical tasks, 2.7% for logical thinking tasks, 3% for skilled manual work, and 8.6% for very rapid manual work (Wyon, 1996, p 9).

Personal control could affect performance also by reducing the amount of time and effort given to achieving comfort. Research by Heerwagen and Diamond (1992) found that occupants who were uncomfortable engaged in a number of coping behaviors that were in themselves distracting and reduced their ability to concentrate on work (e.g., leaving their desk to go for a walk, get a drink, complain to coworkers, track down the facility manager). In a presentation to the National Summit on Building Performance, Bill O'Dell reported that comfort complaints dropped to zero in a new green building with personal control workstations (National Summit on Building Performance, 1999). This statistic is relevant to building managers because it reduces the costs of dealing with comfort complaints.

The relationship between control and comfort is fairly straightforward: people who are uncomfortable will adjust ambient conditions until they reach satisfactory levels. However, the relationship between personal control, comfort, and productivity is more complex. As Wyon points out in a review article on air quality and productivity (Wyon, 1996) comfort does not always lead to the highest performance outcomes in experimental research. In fact, there are times when being cooler or warmer rather than in a neutral comfort state may enhance performance. The critical factors appear to be the nature of the task and optimal psychophysiological arousal levels. For instance, performance on creativity tasks is improved when temperatures are a bit warmer rather than neutral with respect to thermal sensation (Wyon, 1996). Slightly warm temperatures reduce arousal and may generate a feeling of wakeful relaxation – an emotional state that is associated with creative problem solving (Melnechuck, 1988).

Although most of the attention related to productivity focuses on thermal factors and air quality, lighting is also an important contributor to performance and to energy consumption. Thus, there is much attention these days to identifying productivity gains of high quality, energy efficient lighting. Studies of lighting and productivity focus on the computer environment and glare reduction, with mixed results regarding the features of the lighting system. Some studies show self productivity ratings increase with indirect lighting (Hedge et al, 1995), while others show increased objective productivity with a parabolic louver system (Veitch and Newsham, 1999a). The research by Veitch and Newsham, in a simulated office environment at the National Research Council of Canada, found that verbal-intellectual performance and clerical work were higher with parabolic louvred luminaries than with recessed lensed luminaries. They also found that performance on verbal-intellectual tasks was higher when electronic ballasts were used, regardless of the lighting system.

The mixed results on lighting suggest that the specific system used may not be as important as the overall design and the actual lighting conditions created within the space through the integration of the lighting with windows, furniture, colors, placement of computers, and use of antiglare screens. It is also evident from these studies that different kinds of tasks may require different kinds of light – thus the issue of personal control becomes increasingly important. The Canadian NRC studies also show personal control over lighting increases satisfaction and reduces energy consumption due to the high individual differences in lighting preferences (Veitch and Newsham, 1999b).

Although the Canadian researchers did not discuss the origins of individual differences, it is possible that preferred light levels are linked to Seasonal Affective Disorder (SAD). In a longitudinal laboratory study at the University of Washington where subjects could adjust task, wall, and simulated window brightness, Heerwagen (1990) found that subjects who experienced symptoms associated with SAD preferred much brighter light than subjects who did not experience seasonal symptoms. Further, one subject who had "summer depression" selected very low levels of light across the seven months of the study.

To summarize the brief overview of productivity as it relates to green building design:

- Interior ambient quality can affect work performance.
- The key factors associated with differential performance are the thermal environment (especially temperature, humidity level, and ventilation), air quality, and lighting.
- Personal control over ambient conditions is especially important to reduce discomfort coping and to achieve conditions appropriate to personal preferences and task needs.
- Personal control over ambient conditions, especially temperature and ventilation, influences work performance on a variety of tasks.
- Improvements in the ambient environment are a substantive component of green building design.
- Such improvements include high quality HVAC systems (especially improved air intake, filtration and ventilation), construction practices that eliminate moisture build up in the building infrastructure, selection of materials to reduce indoor pollutant loads, increased use of energy efficient technologies, improved maintenance and cleaning, and building commissioning.

Health and Well Being

The vast majority of research on health in buildings has focused on Sick Building Syndrome and its relationship to indoor air quality and the thermal environment. Occurrences of Sick Building Syndrome (SBS) or Building Related Illness (BRI) can be very costly to an organization, especially when symptoms are associated with reduced work performance, absenteeism, or temporary abandonment of the building to locate and fix the underlying problems. One of the driving forces behind the Green Building movement is to improve indoor air quality.

Fisk and Rosenfeld (1997) propose that improved air quality could result in significant reductions in illness and absenteeism associated with respiratory disease, asthma and allergies, and sick building syndrome symptoms. They estimate productivity gains of $17 billion to $164 billion annually associated with improved air quality. They also estimate improved worker performance from enhancements of the thermal environment and lighting to be in the range of $12 billion to $125 billion annually. Similarly, Preller et al (1990) drawing upon large samples of workers in Dutch office

buildings, predict that absenteeism associated with SBS is likely to be 34% lower if employees are given control over temperature and ventilation conditions at their workstation.

Symptoms associated with Sick Building Syndrome (headache, lethargy, nausea, dizziness, lack of concentration, irritability, and irritation of eyes, throat, nose and skin) occur commonly in the population and are caused by many factors, including the psycho-social environment at work and high individual variability in response to environmental conditions (Raw, 1998; Valbjorn et al, 1995). The causal complexity, along with the generality of the symptoms, frequently makes it difficult to find specific reasons for outbreaks of SBS. Nonetheless, there is growing consensus on the range of building factors related to symptom expression.

In a review article, Raw (1998) lists these building factors as:

- A deep building plan
- Sealed windows
- Poor provision of daylighting as well as uncontrollable solar gain (which increases temperatures and glare)
- No separately ventilated area for photocopying machines
- Air inlets too close to exhaust or outdoor pollution sources
- Inadequate filtration
- Inadequate ventilation overall
- Poor distribution of air in the space overall
- Building services not designed for easy maintenance
- Inadequate commissioning or re-commissioning
- Poor maintenance of building systems (which can lead to buildup of bacteria and other pollutants in the air ducts, or water leakages in walls or ceilings)
- High temperatures and low humidity (which affects the release of organic dust and allergens from carpets and other building surfaces)
- Lack of personal control over ambient conditions (which reduces tolerance for discomforts and increases environmental sensitivity)
- New furniture, carpets or painted surfaces that produce gaseous substances and particulate matter
- Large areas of soft furnishings (carpet, partitions, chairs) and shelves/files – especially if they are not cleaned regularly to reduce dust and allergens that exist on the surfaces
- Luminaire type and placement that produce high glare, computer reflections, and flicker
- Insufficient cleaning and general neglect
- Open plan offices (due to the increased surface areas from partitions and increased cleaning difficulties; open offices may also make it easier to spread viruses and other airborne illness causing substances.)
- Changes in the use of the building and addition of office partitions after commissioning

None of these factors alone is likely to create high levels of symptoms associated with Sick Building Syndrome due to high individual variability in environmental sensitivities. However, as more of these factors are present in an environment, the more likely it is that symptoms will occur which are disruptive enough to lead to absenteeism or reduced personal productivity. Furthermore, high individual differences, related to existing health conditions (such as allergies or heart conditions), individual preferences, or expectancies may increase the occurrence of both symptoms and performance decrements in sensitive individuals (Wyon, 1996).

The literature on indoor air quality is far too vast to cover adequately in this article. However, several recent studies illustrate the relationship of building conditions to symptoms, worker perceptions of ambient conditions, and work performance. A study by Raw et al (1990) in Britain found that increasing symptoms (e.g., more than two) had a significant negative effect on self-assessments of productivity. Symptoms were associated in that study with number of persons in the room; ratings of temperature, ventilation, and air quality; and presence of environmental tobacco smoke.

A study of workers in three newly renovated office buildings housing the administrative services of the European Parliament (Valbjorn et al, 1995) found high levels of general symptoms (headache, lethargy, loss of concentration) and mucosal symptoms associated with high temperatures, odors, and organic compounds in dust. Symptom prevalence ranged from 40% for general symptoms and 35% for mucosal symptoms to about 20% for eczema and skin symptoms. The researchers found that psychosocial conditions (related to job, management, and relationships between colleagues) were associated also with symptoms and complaint rates. In fact, the perceived psycho-social work environment was the dominant risk factor for mucosal irritation and skin symptoms. The findings on the psychosocial factors underscore the complexity of the person-environment relationships in buildings.

A Swedish office study described by Wyon (Krogstad et al, in Wyon, 1996a) shows the widespread effect of temperature increases on SBS symptoms. Researchers in this study systematically increased indoor temperatures from 20^{o}C (68^{o}F) to 24.5^{o}C (76.2^{o}F). Temperatures were increased gradually and kept at each level for a week. Incidence of headache and other SBS symptoms increased steadily from 10% at 20^{o}C to 60% at 24.5^{o}C.

Although most of the attention to building health factors is associated with indoor air quality and thermal factors, lighting also affects health. Data from a field experiment by Wilkens et al (1989) shows that incidence of headaches vary among workers as a function of the flicker frequency of the fluorescent lamps (as described by Collins, 1993, in a major review of subjective responses to lighting systems). The researchers compared workers' responses to lighting with three different types of ballasts that control the flicker characteristics in the lamps: a conventional ballast with a switch start; a choke ballast with an electronic start; and a high frequency solid state ballast. The high frequency ballast results in less 100 Hz fluctuations in light output than does the conventional

ballast. The results show that headaches and eyestrain were significantly reduced with the use of high frequency ballasts.

Glare from electric light, particularly glare on computer screens, is also associated with headaches, muscular skeletal problems, and eyestrain. Although there is widespread belief that color rendering of fluorescent lamps is also associated with symptoms (e.g., daylight spectrum lamps are healthier), an extensive review by Veitch and McColl (1994) found no support for this claim.

As noted in the above discussion, a great deal of research has focused on building related *illnesses*. Much less attention has been given to the environment as a *health promoting* factor. That is, does the absence of symptoms by itself mean that one is in a state of well-being? Or is the sense of well-being associated with the presence of particular features and attributes, rather than just the absence of harmful ones? Although there is not as much research on this topic, it appears that illness and well-being are influenced by different building features and conditions. Thus, just getting rid of building problems may be necessary, but not sufficient, to promote highly positive states of well being.

Boyce suggested a similar idea in a discussion of lighting quality (1998). According to Boyce, *poor lighting* produces problems, discomforts, or does not meet the needs of the context. Eliminating these problems produces *indifferent lighting*, that does not offend or distract – but which also fails to lift the human spirit. *High quality lighting*, by Boyce's definition, eliminates distractions and discomforts, provides appropriate conditions for the context, and also adds an aesthetic element that lifts the spirit. There is growing evidence that the presence of particular, positive, "spirit lifting" features in the interior environment may promote positive emotional functioning and serve as a buffer to discomforts or stresses. These features include daylight, sun patches, window views, contact with nature, and overall spatial design (see Heerwagen et al, 1999 for an overview of this literature).

Numerous studies in office buildings have found that people value daylight and prefer to be near windows (Heerwagen and Orians, 1986; Collins, 1975). Furthermore, there is growing realization that being near a window can be psychologically and physiologically beneficial, especially if the view contains natural features such as trees and flowers. Studies by Roger Ulrich (summarized in Urlich et al, 1991 and Ulrich, 1993) and Rachel Kaplan (1992) show that visual contact with nature through window views enhances mood, reduces stress, and promotes higher quality of life. Furthermore, studies of indoor air quality indicate that employees near windows experience lower levels of SBS symptoms than those located in building interiors – even though windows are not operable and thus the effect cannot be due to increased ventilation (Fisk and Rosenfeld, 1997).

The work by Ulrich and Kaplan, as well as more recent studies (Leather et al, 1998; Bourberki et al, 1991) provide evidence that the psychological benefits of windows may be more profound than realized, and thus a critical benefit of building design. Given

the high cost of work stress today (Karasek and Theorell, 1990), efforts to reduce stress would be beneficial to workers and to organizations.

There is also evidence that daylight and views have positive impacts on work attitudes and experiences (Heerwagen and Wise, 1998; Heerwagen, 1998). A pre and post occupancy analysis of a new green building in Holland, Michigan, found that workers in the new building had more positive attitudes and work experiences compared to the previously occupied building. The building is a combination manufacturing plant and office for Herman Miller, Inc., a manufacturer of office furniture. The new building, designed by William McDonough has extensive daylighting in both the manufacturing and office areas, an internal daylit "street" lined with bamboo plants, and operable windows throughout the building. The old building, in contrast had high ribbon windows that were inoperable, no skylights, and no interior street or similar gathering place. The study found that workers in the new building felt more positive about coming to work and rated the new building much more positively overall. They also rated job satisfaction, work spirit, and sense of belonging much more positively in the new building. The analysis also showed differences across the manufacturing shifts, with workers in the daytime shift showing more positive attitudes and experiences than those in the afternoon and night-time shifts (Heerwagen and Wise, 1998).

The field study of personal control workstations and productivity (Kroner et al 1992) cited previously also underscores the powerful influence of daylighting and views. Productivity of the workers increased 16% overall in the new West Bend Mutual building, with the personal control workstations contributing about 3% of the increase. The remaining 13% productivity increase was likely related to many other factors, both organizational and environmental. The environmental "upgrades" in the new building included daylighting, increased windows, and increased access to an attractive outdoor view of a prairie landscape area with a pond. The setting is very similar to that occupied by the Herman Miller building. Furthermore, both new buildings increased the access to views by eliminating private offices along the window wall, reducing the heights of workstation partitions, and opening up windows to more workers. In fact, 92% of the employees in the new West Bend Mutual building had workstations near the window wall, compared with only 30% in the old building.

Although not discussed by Kroner et al (1992), the natural view, daylight, and sun penetration may have improved productivity by enhancing moods and reducing work stress. A growing body of research shows that daylight, contact with nature through window views and sun penetration in buildings is associated with more positive moods, stress reduction, and increased job satisfaction (R. Kaplan, 1992; Ulrich et al, 1991; Heerwagen and Wise, 1998; Leather et al, 1998; Boubekri et al, 1991).

Attention to these positive factors must not overlook a looming problem of building acoustics. This is a relatively neglected factor in the green building literature. Numerous studies of office environments show that noise—especially from people and phones – is a major concern, one that is worsened by the growing trend toward open plan offices and team spaces (Sims et al 1998, Heerwagen et al, 1995). Noise from people

talking is particularly detrimental to high level cognitive work that requires logical thinking, continuous access to working memory, and concentration. Noise interrupts these internal processes, particularly when words can be distinguished. Open plan offices also reduce the ability to have private conversations. Although many companies are starting to provide small enclosed spaces for privacy and concentration, recent research suggests these spaces are not as acoustically sound as they should be (Sims et al, 1998).

Green building design strategies that reduce hard walls or surface polluting materials (e.g., carpet, fabric panels) could exacerbate acoustical problems. In many new office designs, walls and semi permanent panels are being replaced by easily moveable and deconstructed furnishings. The use of these lighter-weight, more flexible furnishings will make sound transmission even easier, as was found in a recent study of team spaces (Sims et al, 1998). Even though many of the team spaces generated high strategic performance outcomes (such as reduced time to market), they did so at the cost of individual performance and ability to concentrate on work.

More visually open environments are certainly desirable from the standpoint of window access and daylighting. Nontheless, the benefits need to be balanced appropriately in relationship to the potential human and organizational costs. Optimizing the acoustical, thermal, lighting, and air quality environment for human well being and productivity as well as for environmental sustainability will present designers and engineers with serious challenges in the future.

To summarize the potential implications of green building design on health and well being:

- Design strategies that reduce factors associated with Sick Building Syndrome are likely to have positive impacts on health and work performance.
- Increased access to daylight and window views is likely to have positive impacts on psychological functioning and well being. Whether or not these building features affect performance is not known at the present time.
- Views, especially of natural settings or urban settings with trees, are associated with stress reduction and positive emotional states and may also influence cognitive functioning.
- Daylight, views and contact with nature are key features of most green building designs and are seen as major components of human resource sustainability (Berkebile and Williams, 1999).
- These naturalistic features are increasingly being viewed as employee benefits rather than costs (Heerwagen et al, 1997).

Strategic performance

Improvements in strategic organizational performance through building design is a topic of growing interest among designers and building owners (Romm, 1999; Toreg et al, 1998; Vischer, 1996.) In his book entitled, *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emmissions*, Romm presents a number of case studies of companies that have consciously used building design to foster strategic goals, such as increased productivity, reduced operating expenses, and improved corporate image. Many of these companies also cite building design as a factor in their concerns over attracting and retaining high quality workers. Although the results presented in these case studies are intriguing, the studies have been conducted in-house without external scientific review or application of quality assurance methodologies to data collection and analysis. The area of strategic performance is clearly in need of scientific inquiry if the results are to be taken seriously in the business world. The sections below provide an overview current research on topics of relevance to strategic performance.

Turnover and Retention. As the economy continues to grow and unemployment decreases, many U.S. companies are discovering that attracting and retaining high quality employees is not as easy as it used to be. In response to the downsizing and job insecurity of the 1980's, many workers are focusing on their own careers at the expense of their companies. Job turnover is at an all time high in many professions as employees switch positions whenever a better prospect appears. As a result, many organizations are looking for ways to attract high quality employees and to keep them better connected to the company. Turnover is costly to any company (Phillips, 1990), but especially in knowledge fields where the "product" is human brainpower that goes with the worker when he/she leaves. In this new climate, building design that contributes positively to human well being and performance may be perceived by decision-makers as one of many strategies to attract and retain workers. There is growing evidence that buildings are used strategically as a sales and marketing tool (Petzinger, 1997) and as an employee "benefit" to attract and retain high quality workers (Becker and Lynn, 1986; Leiber, 1999). In addition, the building itself as a symbol of the corporation's environmental and social performance may be a powerful attraction for potential employees (see studies reviewed in Turban and Greening, 1996).

In a pre-post study of a laboratory renovation at the Pacific Northwest National Laboratory, researchers were able to track absenteeism and turnover for the year prior to renovation and the year afterward (Montgomery et al, 1994). The upgrade was undertaken in large degree because of the morale and turnover problems experienced in the lab. The redesign involved the HVAC system, acoustics, spatial layout and aesthetic upgrades. The researchers found significant differences pre and post in both absenteeism and turnover. Turnover decreased by 60% in the year following the renovation, and absenteeism was reduced from 96 hours/person to 45 hours/person.

Absenteeism Improvements in indoor air quality can affect the economic bottom line by reducing absenteeism and health care costs (Fisk and Rosenfeld, 1997; Holcomb and Pedelty, 1994; Sesharma et al, 1998). Improved indoor air quality is associated with materials selection, construction techniques and increased ventilation. In their macro

analysis of improved air quality, Fisk and Rosenfeld (1997) estimate that productivity increases from reduced absenteeism and illness could be as high as $6 billion to $19 billion from reduced respiratory disease; $1 billion to$4 billion from reduced asthma and allergies; and $10 billion to $20 billion for reduction in symptoms associated with Sick Building Syndrome.

Organizational Image. There is a growing recognition that "green" buildings may play a significant role in promoting the organization as a whole. As noted by Hodgkinson (1993), in an extensive evaluation of companies in Great Britain and Europe:

> Businesses will increasingly want their flagship premises to present a shining example of environmental friendliness in terms of energy efficiency, the use of building materials, and the impact on the wider environment….New aesthetics will undoubtedly be developed to make more visible the fact that green principles have been adopted. Key determinants of these aesthetics may include the use of more durable or recycled materials, or showing off energy efficient plant and passive solar design features, for example. (p:103).

A recent survey by BOMA International and the Urban Land Institute (Baier, 1999) found that 72% of building tenants surveyed about building quality said building image was of "highest importance" to them.

Makower (1994) foresees increasing pressure from customers and from competitors who are striving to be "greener than thou" (p:14). Thus, public awareness of a firm's environmental record may have a cascading effect and may speed up the commitment to organizational sustainability. Makower also notes that companies with the best environmental records not only have a higher standing with the public, they also develop more positive relationships with regulators who are more likely to leave them alone if they proactively comply with the law.

Organizational Level Productivity. Studies cited in the section on personal productivity deal with individual level performance. From a strategic perspective, improved individual output matters most if it has higher level value. That is, does increased personal productivity translate to improved product quality, timeliness of output, increased innovation?

The pre-post study of the Herman Miller building in Holland, Michigan, mentioned earlier, showed modest increases in productivity that could be attributed to the building (Heerwagen, 1998). Using the organization's Total Quality Metrics data, researchers found increases of 0.5 to 2.0% in several of the dimensions. Although the increases were fairly small, they can nonetheless represent a competitive advantage in the market place. The small increases may be due to a ceiling effect: that is, the organization may already be operating so efficiently that it is increasingly difficult to find additional ways to be efficient. Under such circumstances, enhanced strategic performance is likely to come from new products or product innovation, which take time to develop. In the

Herman Miller study, TQM measures were tracked for just the year prior to and the year after the move.

Cost savings. The Herman Miller building performance data show a 7% decrease in natural gas costs, a 65% decrease in water and sewage, and an 18% decrease in electricity costs on a square foot basis (Heerwagen et al, 1997). Similar results have been reported by O'Dell (1999) for a new Johnson Wax building in Wisconsin and for the case study buildings described by Romm (1999).

Marketing and Sales. Although Makower (1992) discusses the importance of organizational sustainability to marketing and sales strategies, data on how many companies use their environmental record as a sales tool are currently not available. However, pilot data from the Herman Miller study show that sales personnel use the new green building and the company's sustainability record in their sales efforts (Heerwagen, 1999). Furthermore, the company has hired a full time guide to conduct tours for both potential customers and the general public as part of its outreach program. Tours highlight both the sustainable features of the building and of the manufacturing process which Herman Miller sees as inextricably linked.

In an article on the competitive advantage of sustainability, Hart (1995) sees sustainable market development as a major driver of economic benefits. He writes: "Market research suggests there is a vast amount of unclaimed reputation 'space' with respect to corporate environmental performance… A sophisticated take-back and remanufacturing process allows these parts and components to be collected, reconditioned, tested, reassembled, and then sold in new 'green' machines." (Hart, p. 996).

Costs of Indoor Air Quality Illnesses from an Insurance Perspective. Many researchers cite reduced costs of building related illnesses as a major benefit of improved interior quality, with cost savings due to both reduced absenteeism and decreased litigation. Although the argument is compelling and logical, there is little actual data on these costs. A recent study by researchers at the Lawrence Berkeley National Laboratory assessed costs to the insurance industry associated with poor indoor air quality and litigation, including health care insurance payments and professional liability claims. Although they turned up little specific information about costs to insurance companies, they conclude that "there is a strong awareness and growing concern over the 'silent crisis' of IAQ and its potential to cause large industry losses , and that a few companies are taking steps to address this issue." (Chen and Vine, 1998, p. i).

They also conclude that energy efficient building improvements have insurance loss reduction implications due to their potential to improve indoor air quality. One company interviewed, a provider of professional liability insurance to architects and consulting engineers, paid out more than $24 million for claims related to heating, ventilating, and air conditioning between 1989 and 1993. The claims involved over or under heated buildings, inadequate ventilation, or inadequate cooling. As noted in the

previous sections on productivity and illness, temperatures and ventilation are prominent contributors to indoor air quality problems.

Summary

This brief overview of business perspectives on facilities conveys several lessons for green buildings:

- *First,* green buildings are relevant to business interests across the full spectrum of concerns, from portfolio issues (e.g., resale value of property) to enhanced quality of individual workspaces (through improved ambient conditions.)
- *Second,* because the potential influence of green buildings is broad, research on green buildings should address a range of outcomes rather than focusing narrowly on just a few. Outcomes of interest to organizations include workforce attraction and retention, quality of work life, work output, and customer relationships.
- *Third,* green buildings can provide both cost reduction benefits and value added benefits. The emphasis to date, however, has been on costs, rather than on benefits. The need for more data on value added benefits underscores the importance of studies that focus on these human and organizational factors.

It is also important to recognize that the benefits of green buildings are more likely to occur when the building and organization are treated as an integrated system from the start. As pointed out by Cole (1999), it is entirely possible to have a "green" building with "gray " occupants due to lack of systems integration and lack of training on how to use the technologies in the most efficient and effective way. Gray occupants are also more likely to be found in buildings that "green" individual systems rather than the environment as a whole or in buildings which focus primarily on technology to the exclusion of building features that wield their effects through social and psychological mechanisms. And finally it is possible for "gray" organizations to exist in green buildings, thereby passing up significant opportunities for high-level benefits resulting from resource efficiency and process innovation throughout the organization.

References

Baier, R.D. (1999) Customer service made easy: deliver what office tenants want. *HPAC Engineering*. September: 41-45.

Becker, F. and M. Lynn (1986). The importance of office closure versus quality in job selection. In Proceedings of the Environmental Design Research Association, *The Costs of Not Knowing*. Eds. J. Wineman, R. Barnes, and C. Zimring. EDRA, Atlanta, GA.

Berkebile, B. and K. Williams(1998). The Montana State University EPI Center, EnvironDesign 3, Baltimore, Maryland, May 1-3.

Boubekri, M., R.B. Hulliv, and L.L. Boyer (1991). Impact of window size and sunlight penetration on office workers' mood and satisfaction: A novel way of assessing sunlight. *Environment and Behavior*, 23(4): 474-493.

Boyce, P. (1998). Lighting Quality: The Unanswered Questions. Keynote Address presented at the CIE Symposium on Lighting Quality, Ottawa, Canada, May 9-10.

Brager, G.S. and deDear, R.J. (1998). Thermal adaptation in the built environment: a literature review. *Energy and Buildings* 27: 83-96.

Browning, W. and Romm, J. (1995). Greening and the Bottom Line: Increasing Productivity through Energy Efficient Design. In *Proceedings of the Second International Green Buildings Conference and Exposition*, Eds. K.M.Whitter andT.B. Cohn, National Institute of Standards and Technology (NIST), Special Publications 888, Gaithersburg, MD.

Chen, A. and E.L. Vine (1998). A scooping study on the costs of indoor air quality illnesses: an insurance loss reduction perspective. Ernest Orlando Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division, Berkeley, CA.

Cole, R. (1999) Green buildings and gray occupants. Paper presented at the AIA-USGBC Conference on Mainstreaming Green, Chattanooga, TN, October 14-16, 1999.

Collins, B.L. (1993). Evaluation of Subjective Response to Lighting Distributions: A Literature Review. Washington, DC: United States Department of Commerce, National Institutes of Standards and Technolgoy, NISTIR 5119.

Collins, B.L. (1975) Windows and People. Washington, DC.: NBS BSS 70.

Fisk, W.J. and A. H. Rosenfeld (1997) Estimates of Improved Productivity and Health from Better Indoor Environments. *Indoor Air*. 7:158-172.

Gladwin, T.N. , J.J. Kennelly, and T.S. Krause (1995). Shifting paradigms for sustainable development: Implications for management theory and research. *Academy of Management Review* 20: 874-907.

Hart, S.L. (1995) A natural-resource-based view of the firm. *Academy of Management Review*, 20(4): 996-1014.

Hedge, A., W.R. Sims, and F.D. Becker (1995) Effects of lensed-indirect and parabolic lighting on the satisfaction, visual health, and productivity of office workers. *Ergonomics* 38: 260-280.

Heerwagen, J. (1998) Of light, time and space: lighting quality and green building Design. Paper presented at the CIE Symposium on Lighting Quality, Ottawa, Canada, May 9-10, 1998.

Heerwagen, J. (1990). Affective functioning, light hunger, and room brightness preferences. *Environment and Behavior*, 22(5): 608-635.

Heerwagen, J. and J. Wise (1998). Green Buildings: Differences in Perceptions and Experiences Across Manufacturing Shifts. *HPAC Engineering*, February: 57-63.

Heerwagen, J., N. Durbin, and J. Macaulay (1997). Do Energy Efficient, Green Buildings Spell Profits? *Energy and Environmental Management*, Spring issue, 29-34.

Heerwagen, J., J. Heubach, J. Montgomery, and W. Weimer (1995). Environmental design, work and well being: managing occupational stress through changes in the workplace environment. *American Association of Occupational Health Nurses Journal*. 43(9): 458-468.

Heerwagen, J. and R. Diamond (1992). Adaptations and coping. Occupant response to discomfort in energy efficient buildings. Paper presented at the American Council for an Energy Efficient Economy, Alsilomar, CA, August, 1992.

Heerwagen, J. and G.H. Orians (1986). Adaptations to windowlessness: a study of the use of visual décor in windowed and windowless offices. *Environment and Behavior* 18(5):: 623-630.

Heerwagen, J., J. Loveland, and R. Diamond (1992) Post occupancy evaluation of Energy Edge buildings. Center for Planning and Design, University of Washington.

Hodgkinson, S. (1993). Environmental Issues and the Workplace. In F. Duffy, A. Laing, and V. Crisp (Eds.) *The Responsible Workplace*. London: DEGW Ltd.

Holcomb, L.C. and J. F. Pedelty (1994) Comparison of employee upper respiratory absenteeism costs with costs associated with improved ventilation. ASHRAE Transactions, V. 100, Pt. 2.

Horgen, T.H., M.J. Joroff, W.L. Porter and D.A. Schon (1999) *Excellence by Design: Transforming Workplace and Work Practice*. New York: John Wiley.

Johnson, D.B. (1996) Green businesses: perspectives from management and business ethics. *Society and Natural Resources*, 11:259-266.

Kaplan, R. (1992). Urban forestry and the workplace. In P.H. Gobster (Ed) Managing Urban and High-Use Recreation Settings. USDA Forest Service, General Technical Report NC-163. Chicago, IL: North Central Forest Experiment Station.

Kaplan, R.S. and D.P. Norton (1996) *The Balanced Scorecard*. Boston, MA: Harvard Business School Press.

Karasek, R. and T. Theorell (1990). *Healthy Work: Stress, Productivity and the Reconstruction of Working Life.* New York: Basic Books.

Krogstad, A.L., G. Swanbeck, L. Barregard, S. Haagberg, K.B. Rynell, A. Ran, and L. Jorulf (1991). A prospective study of indoor climate problems at different temperatures in offices, in Swedish). Goteborg, Sweden, Volvo Truck Corp.

Kroner, W. , J.A. Stark-Martin, T. Willemain (1992). Using Advanced Office Technology to Increase Productivity. Rensselaer Polytechnic Institute: Center for Architectural Research.

Leaman, A. (1999). UK study links productivity to ventilation systems. *HPAC Magazine*, 71(11): 14.

Leather, P., M. Pyrgas, D. Beale, and C. Lawrence. (1998). Windows in the workplace: sunlight, view, and occupational stress. *Environment and Behavior*. 30(6): 739-762.

Leiber, R.B. (1998). Why employees love these companies. *Fortune*, Jan. 12.

Magretta, J. (1997). Growth through global sustainability: an interview with Monsanto's Robert Shapiro. *Harvard Business Review*, Jan-Feb: 79-88.

Makower, J. (1994). *The E Factor: The Bottom Line Approach to Environmentally Responsible Business*. New York: Penguin Books.

Melnechuk, T. (1988). Emotions, Brain, Immunity, and Health: A Review. In M. Clynes and J. Panksepp (Eds.), *Emotions and Psychopathology*. New York and London: Plenum Press.

Menzies, D., J. Pasztor, F. Nunes, J. Leduc, and C-H Chan (1997). Effect of a new ventilation system on health and well-being of office workers. *Archives of Environmental Health,* 52(5): 360-368.

Montgomery, J., J. Heubach, W. Weimer, and J. Heerwagen (1994) Internal report, Impacts on satisfaction and productivity in a laboratory renovation. Pacific Northwest National Laboratory.

National Summit on Building Performance (1999) Washington, DC. October 29. Sponsored by Johnson Controls, Inc.

Nunes, F., R. Menzies, R.M. Tamblyn, E. Boehm, and R. Letz. (1993) The effect of varying level of outdoor air supply on neurobehavioral performance function during a study of sick building syndrome (SBS), *Indoor Air'93,* Helsinki, Vol. 1, 53-58.

O'Dell, W. (1999). Presentation at the National Summit on Building Performance, Panel on the Eco-Sensitive Office, Washington, DC. , Oct. 28, 1999.

Pepler, R.D. and Warner, R.E. (1968) Temperature and learning: an experimental study. ASHRAE Transactions, 74, Pt.2, 211-210.

Petzinger, T. (1997). Business achieves greatest efficiencies when its at its greenest. *Wall Street Journal*. July 15.

Preller, L. , T. Sweers, B. Brunekreef, and J.S. M. Bolej. (1990) Sick leave due to work related health complaints among office workers in the Netherlands. Indoor Air '90, Toronto, Vol 1, 227-230.

Phillips, J.D. (1990). The Price Tag of Turnover. *Personnel Journal,* 69(12): 58-62.

Preller, L., T. Zweers, B. Brunekreef, and J.S. M. Bolej (1990) Sick leave due to work related health complaints among office workers in the Netherlands. *Indoor Air '90,* Toronto, Vol. 1, 227-230.

Raw, G. (1998a). Office hygiene and sick building syndrome: a demonstration of the power of intervention studies.

Raw, G. (1998b). Tackling sick building syndrome. British Research Establishment, Ltd.

Raw, G, M.S. Roy, and A. Leaman, (1990). Further finding from the office environment survey: productivity. In Walkinshaw, D.S. (Ed). Proceedings of Indoor Air '90, Ottawa, Canada Mortgage and Housing Corporation, Vol. 1, 231-236.

Romm, J. (1999). *Cool Companies*. Covelo, CA and Washington, DC: Island Press.

Russo, M.V. and P.A. Fouts (1997). A resource based perspective on corporate environmental performance and profitability. *Academy of Management Journal*, 40(3): 534-559.

Sensharma, N.P., J.E. Woods, and A.K. Goodwin (1998). Relationship between the indoor environment and productivity: a literature review. *ASHRAE Transactions,* V. 104, Part 2

Sink, D.S. (1985). *Productivity Management: Planning, Measurement and Evaluation, Control and Improvement*. New York: Wiley.

Sims, W.R., M. Joroff, and F.D. Becker (1998). *Teamspace Strategies*. Atlanta, GA: IDRC Foundation.

Turban.D.B. and D.W. Greening (1996). Corporate social performance and organizational attractiveness to prospective employees. *Academy of Management Journal*. 40(3): 658-672.

Ulrich, R.S. (1993). Biophilia, Biophobia, and Natural Landscapes. In S.K. Kellert and E.O.Wilson (Eds). *The Biophilia Hypothesis*. Washington DC: Island Press, Shearwater Books.

Ulrich, R.S., R.F. Simons, B.D. Losito, E. Fiorito, M.A. Miles, and M. Zelson. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology* 11: 201-230.

USGBC (1999). Membership survey, on the USGBC Home Page, www.usgbc.org.

Valbjorn, O. L. Valbjorn, J. M. Pedersen, B.V. Pedersen, P. Skov and the Working Conditions Study Group. (1995). A multi-disciplinary study of working conditions in 3 European office buildings. Healthy Buildings, Milano, Italy, September 1995.

Veitch, J.A. and G.R. Newsham (1997). Determinants of lighting quality II: Research and recommendations. Paper presented at the 104th Annual Convention of the American Psychological Association, Toronto, Canada, August 12, 1996.

Veitch, J.A. and McColl (1994). Full-spectrum fluorescent lighting effects on people: a critical review. In J.A. Veitch (Ed.) *Full-spectrum lighting effects on performance, mood, and health.* (IRC-IR-659, pp 53-11). Ottawa, ON: National Research Council of Canada, Institute for Research in Construction.

Vischer, J.C. (1996) *Workspace Strategies: Environment as a Tool for Work*. New York: Chapman and Hall.

Wargocki, P. , D.P. Wyon, Y.K. Baik, G. Clausen, P.O.Fanger (1999). Perceived air quality, SBS symptoms, and productivity in an office at two pollution loads. Indoor Air'99, Edinburgh, Scotland, Vol.2: 131-136.

Weinberg, A.S. (1998). Distinguishing among green businesses: growth, green, and anomie. *Society and Natural Resources,* 11:241-250.

Wheeler, G. (1998).Presentation of ASID survey findings, AIA Conference on Highly Effective Buildings, Cincinnati, OH, March 12-14.

Wyon, D.P. (1993) Healthy buildings and their impact on productivity. *Indoor Air '93*, Helsinki, Vol 6, 3-13.

Wyon, D.P.(1996). Indoor environmental effects on productivity. In Proceedings of *IAQ '96, Paths to Better Building Environments*, October 6-8, Baltimore, MD.