

# Authentically Green Interiors: Optimizing Nature's Design



*Communicating the aesthetic, environmental, productivity and health benefits of plants in the built environment.*

**January 2015 Edition**

Green Plants for Green Buildings  
720-579-8250  
admin@gpgeb.org  
greenplantsforgreenbuildings.org



# **Authentically Green Interiors: *Optimizing Nature's Design***

Presented by  
Green Plants for Green Buildings

[www.GPGB.org](http://www.GPGB.org)

This White Paper was produced in accompaniment with GPGB's Registered Trainer Program. GPGB is an approved provider of continuing education in the US and across Canada for **AIA, IDCEC, ASID, BOMI, ASLA and USGBC members and Canadian counterparts.**

If you are interested in booking a continuing education presentation, please contact GPGB at 720-579-8250 or at [admin@gpgb.org](mailto:admin@gpgb.org)

Contributors:  
Simon May, GPGB Registered Trainer  
McRae Anderson, ASLA, CLP, GPGB Registered Trainer  
Kathy Fediw, LEED AP ID+C, CLP, CLT

*Copyright 2015, Green Plants for Green Buildings*

*GPGB- Communicating the aesthetic, environmental, productivity and health benefits of plants in the built environment.*

# Authentically Green

## Interiors:

### *Optimizing Nature's Design*

#### **Introduction**

There is growing recognition within the sustainability movement that to be truly effective, a green facility must do more than effectively use natural resources. These facilities need to nurture the health, prosperity and general well being of the inhabitants of its spaces.

The efficient use of our natural resources is vitally important to our futures. Energy and environmental related costs represent only a small portion of the full costs of the facility. The human capital that occupies a facility is, by far and away, the largest cost of any facility. Critical to a building's success is its impact on people, individually and collectively. A number of design factors impact the actions and reactions of people. One of these factors is Biophilia (the human affinity for natural things) that contributes to the well being of humans in the built environment. There are several organizations around the world that are committed to bringing forward, and bringing to the attention of the design community, the most relevant and compelling findings on the environmental contributions of plants to a building's interior.

This article will draw upon several research results from around the world that have sought to identify, assess and value the benefits of interior plantings in buildings. Designers who subscribe to the ideals of Human Centered Sustainable Design (HCS D) believe that such benefits are vital to a building's sustainability and as such should be incorporated into the guidelines such as USGBC's LEED rating system.

Until such time as rating systems such as LEED recognize the contribution and value of interior plantings, designers will need to "do the right thing" when challenged and continue to accommodate human physical and psychological needs by including interior planting in their sustainable designs.



#### **"Do the Right Things"**

Later in this document will be a review of two projects that "Do the Right Thing". The Genzyme Center, the new corporate headquarters for Genzyme Corporation, combines innovative design and cutting-edge technology to achieve two goals: create an exciting new workplace for more than 900 Genzyme employees, and set a new standard in environmentally-responsible architecture. Designed by the award-winning German architectural firm Behnisch, Behnisch and Partner, the new building stands as a reflection of

- 
- 
- 
- 
- 

Genzyme's commitment to innovation, transparency, collaboration and the entrepreneurial spirit.

Our second project will be the new 135,00 square foot Guelph Humber building located on the north campus of Humber College in Toronto. This project accommodates an academic partnership between the University of Guelph and Humber College Institute of Technology and Advanced Learning. In the heart of the building is a four-story sky lit court, which offers an excellent informal gathering area and houses a four story green-wall.



The Integrated Learning Centre (ILC) utilizes "Green" building aspects to address environmental and sustainable technologies. These green design features have been incorporated into the building for both environmental and pedagogical reasons. There are several major categories in building operation that have the potential for utilizing green ideas. The ILC has not only identified these areas, but has also designed green features to address environmental concerns in the different fields.

## What Our Human Behavior Shows

### We love to garden

The National Gardening Association is a well-known and widely recognized authority on the consumer lawn and garden market in the U.S. Since 1973, NGA has worked with the Gallup Organization to provide market research information for the lawn, garden, and nursery industries. The 2003 National Gardening Association's comprehensive study of consumer's gardening practices shows that eight out of ten U.S. households (78%) or 84 million households participated in indoor and outdoor lawn and garden activities. This study also found that total lawn and garden sales have increased at a compound annual growth rate of 5%.

Our behavior also demonstrates that we love indoor gardening in that 58 million household purchased indoor plants and supplies. This was the largest of all categories of purchase. What we do says a lot about what we want to see in our workplace. Surveys also conducted by Unifi Network, Westport, Conn. indicate in order to attract and retain top employees, the workplace must include aspects of what inspires employees during "off" time. Perhaps the "green thumb" passion explains why humanizing the workplace with green plants is a highly effective method to promote employee satisfaction. Copious studies such as those conducted by Dr. Ulrich and Dr. David Uzzell from Oxford University verify the positive effect plants have on employee perception and disposition. In the final analysis, marketing research (Krome Communications, 2000) confirms that employee attitude and retention is a top incentive for corporations to use plants in their facilities.

### We personalize our offices with plants

Humans are notorious for using material goods to show their individuality. We use "things" to customize our homes, yards and cars to make them feel like our own. So why not do the same with our offices! In fact, eighty-five percent of office workers do just that -- they decorate their workspace with personal belongings, according to a recent Steelcase Workplace Index.

**42 percent personalize their offices with flowers and plants**

"People like to make the places they spend time in a reflection of who they are," said Pam Brenner, Manager of Workplace Issues, Steelcase Inc. "People take this to different degrees of personalization. The objects are an expression of the person, their interests and personality." Sixty-nine percent of those surveyed said they used photographs to personalize or decorate their workspace, making it the most popular technique. Respondents also said they personalize

with flowers or plants (42 percent). "People want to have ownership over their space and feel good about where they spend the majority of their time," Brenner explained. "Given the changes taking place in today's workplace -- telecommuting, downsizing, hoteling -- office workers want to create their own sense of security and stability. Surrounding themselves with personal effects is one way to do that. Attitude and psychological well-being can have a major impact on productivity and job satisfaction."

### **We are less stressed and more productive around plants**

Human assets are the most valuable and expensive assets of any business. In terms of cost per square foot, the human asset is approximately 10 times the total building operating cost and nearly 100 times the energy cost. No matter how it is expressed, when a business can give rise to personal productivity, the business wins.

It is widely known through the respected research done by Dr. Roger S. Ulrich of Texas A&M University, Helen Russell, Surrey University, England as well as the recent studies conducted by Dr. Virginia Lohr of Washington State University that plants significantly lower workplace stress and enhance worker productivity.

In Dr. Lohr's study, participants were 12 percent more productive and less stressed than those who worked in an environment without plants. The study took place in a simulated office setting. Common interior plants were used in a computer laboratory with 27 computer workstations. A computer program to test productivity and induce stress was specifically designed for these experiments. These experiments incorporated one hundred symbols and time-measured readings of participants' reactions. They were presented in the same randomized sequence to each subject. Blood pressure readings recorded, while using the program, confirmed the program was effective in inducing stress.



Emotional states and pulses were also measured during the experiment. Plants present and plants not present were the only variables that participants experienced. When plants were present, they were positioned so that a cluster would be in the peripheral view of each subject sitting at a computer terminal, but would not interfere with the subject's activity. In addition to demonstrating significant increases in their post-task attentiveness, subject reaction time in the presence of plants was 12 percent faster than those in the absence of plants.

The results, indicating an influence of plants on blood pressure, are consistent with research conducted by Dr. Ulrich. Visual exposure to plant settings has produced significant recovery from stress within five minutes.

Several performance-based incentives to enhance employee productivity also give rise to stress, so the rare capability of plants to raise productivity while lowering stress is extremely valuable. Design professionals cannot afford to ignore such an efficient method to improve human asset performance.



•  
•  
•  
•  
•

### **We are willing to pay more in retail areas that include trees**

Retailers have long understood the importance of store environments in enhancing the shopping experience. Marketers have studied the situational influences of product packaging and store layout on the behavior of shoppers (Engel et al. 1990). While business people are keenly interested in the presentation of their product and store they often overlook "macro" level settings - the district that surrounds their shop or office. Mattila and Wirtz (2002) extend the notion of Gestalt to consumers' perceptions of retail environments and demonstrated that consumers perceive the service-landscape holistically.

Interior plants and landscapes create situations more favorable for retail activity. When we shop in retail areas with "tree" versus "non-tree" environments we visit more frequently, stay longer, rate the quality of the products 30% higher and are willing to pay about 12% more for goods.

### **Flowers and plants promote innovation and ideas**

In an eight-month study, the Texas A&M University research team explored the link between flowers and plants and workplace productivity. Participants performed creative problem solving tasks in a variety of common office environments or conditions. The conditions included a workplace with flowers and plants, a setting with sculpture and an environment with no decorative embellishments.



During the study, both women and men demonstrated more innovative thinking, generating more ideas and original solutions to problems in the office environment that included flowers and plants. In these surroundings, men who participated in the study generated 15% more ideas. And while males generated a greater abundance of ideas, females generated more creative, flexible solutions to problems when flowers and plants were present.

“We know the importance of learning, for example, how natural surroundings affect drivers, school children and hospital patients,” said Ulrich, who has conducted extensive research on the effects of environments on psychological well-being, stress and health. “To businesses, it should be equally as important to understand what features can improve performance at work and make employees more productive.”

---

*An increasing number of companies are focusing on the physical workplace as a key component of their corporate strategy to improve productivity. And today, corporations are investing in people and what makes them more productive.*

*People have a positive response to plants and planted environments. We inherently know a walk in the woods amidst nature refreshes our soul and revitalizes our spirit. Plants in our work environment connect with those same factors and make us more creative and more productive*

---

## What scientific research has shown

### Plant improve our health

Real life office studies have proven the direct relationship between clinical health complaints and plant installations. Sick Building Syndrome is a serious and expensive issue, and the degree to which interior plants can positively affect employees' health is an important issue in today's workplace.

Professor Tove Fjeld of the Agricultural University in Oslo, Norway carried out several conclusive studies regarding health claims relating to Sick Building Syndrome among workers. This crossover study was conducted among 51 offices. During one period, plants were included in the offices. And during another, plants were not included. All participants worked in identical, single offices, with a floor area of ten square meters and a window covering most of the outer wall. When plants were included, the participants were exposed to 13 commonly used foliage plants placed in three containers on a window bench, and a terracotta container with plants in the back corner of the office. Data from the study can be found in the table below.

**Recorded Health Improvements after the Introduction of Interior Plants**

AILMENT	% REDUCTION
Fatigue	20%
Headache	30%
Sore/dry throats	30%
Coughs	40%
Dry facial skin	25%

It was found that the score sum, as a mean of 12 symptoms, was 23% lower during the period when the participants had plants in their offices (mean score sum was 7.1 during the period without plants, vs. 5.6 during the period with plants (P=0.002)). If the symptoms were clustered, a significant reduction was obtained in neuro-psychological symptoms and in mucous membrane symptoms, while skin symptoms seemed to be unaffected by the plant intervention (Fjeld et al. 1998).

### Plant improve indoor air quality

Plant leaves can absorb certain organic chemicals and destroy them through a process called "metabolic breakdown". A group of German scientists proved this when they labeled formaldehyde with a radioactive carbon 14 tag and followed its absorption and metabolic destruction inside a spider plant (*Chlorophytum comosum*). The formaldehyde was metabolized and converted into tissue products such as organic acids, sugars and amino acids as demonstrated by the radioactive carbon 14 tag. This information was published in the *Plant Physiology Journal* in 1994. Martina Giese, Ulrike Bauer-Doranth, C. Langebartels, and Henrich Sanderman, Jr. "Detoxification of formaldehyde by the spider plant (*Chlorophytum comosum*)."  
*Plant Physiology*, 1994, 104: 1301-1309.

- 
- 
- 
- 
- 

When plants transpire water vapor from their leaves, they pull air down around their roots. This supplies their root microbes with oxygen. The root microbes also convert other substances in the air, such as toxic chemicals, into a source of food and energy. Microbes, such as bacteria, can rapidly adapt to a chemical contaminant by producing new colonies that are resistant to the chemical. As a result, they become more effective at converting toxic chemicals into food the longer they are exposed to the chemicals. It is also important to remember that the efficiency of plants as a filtering device decreases as the concentration of chemicals in the air decreases. For example, the removal rate of a chemical is much higher at 7 parts per million (ppm) exposure than at 2 ppm. (Information taken from study listed above.)

### Plants reduce IAQ related absenteeism

According to studies done by JCAHO, IAQ (indoor air quality) related absenteeism has been on an alarming upswing. In recent studies 40% of absenteeism was attributed to IAQ related illnesses. Similarly, the same report demonstrates an increase of Worker Compensation Claims from 1980 to 1994 for IAQ related issues. The number of such cases rose by almost 5000 claims within that period and has continued to rise over the last five years. Data from Bio-Safe Incorporated confirms that without the air filtering provided by live plants, energy efficient, sealed office structures are often 10 times more polluted than the air outside!

Common Name	Botanical Name	Removal Rate* (Micrograms/Hour)
Boston fern	Nephrolepis exaltata "Bostoniensis"	1863
Dwarf date palm	Phoenix roebelenii	1385
Bamboo palm	Chamaedorea seifrizii	1350
Janet Craig	Dracaena deremensis "Janet Craig"	1328
English Ivy	Hedera helix	1120
Weeping fig	Ficus benjamina	940
Peace lily	Spathiphyllum "Clevelandii"	939
Areca palm	Chrysalidocarpus lutescens	938
Corn plant	Dracaena fragrans "Massangeana"	938
Lady palm	Rhapis excelsa	876

Research shows that plant-filled rooms contain 50-60 percent fewer disease causing airborne molds and bacteria than rooms without plants. For almost twenty years Dr. William C. Wolverton and his aids in the Environmental Research Laboratory of John C. Stennis Space Center have been conducting innovative research employing natural biological processes for air purification. "We've found that plants have been found to suck these chemicals out of the air," he says. "After some study, we've unraveled the mystery of how plants can act as the lungs and kidneys of these buildings." The plants clean contaminated office air in two ways. They absorb office pollutants into their leaves and transmit the toxins to their roots, where they are transformed into a source of food for the plant.

Wolverton has found that plants are especially needed in office buildings in which sick building syndrome is common. He goes so far as to suggest that everyone have a plant on his or her desk, within what he calls the "personal breathing zone". This is an area of six to eight cubic feet where you spend most of your working day. Jay Naar, author of *Design for A Livable Planet*, suggests 15 to 20 plants are enough to clean the air in a 1,500 square foot area.



## Productivity and Plants

The direct relationship between office workers' productivity and the presence of plants was, until several years ago, somewhat speculative and had not been demonstrated in scientific research.



Fortunately, in recent years, research results have become available that throw some light on the effects of plants on the wellbeing of people in offices and schools (Fjeld, 1999). A similar study was carried out in the Netherlands, at the Winterswijk Tax Office, where the influence of plants on productivity was closely monitored (Van Dortmund, 2001).

The study was carried out using a control group (without plants) and a test group (with plants) in comparable areas of the building. Before and after measurements were taken with the help of a questionnaire. Physical measurements were also taken. 250 employees were involved in the test.

The before measurements showed the building scored lower than standard for air quality and equipment. This led to a higher than standard rate of health problems in terms of eye, throat and nose complaints.

The most significant findings of the study are:

- the test group (with plants) rated the factor wellbeing more favorably than the control group (the factor is created up by giving ratings to feelings such as calm, harassed, relaxed, cheerful, depressed, self-assured, stressed)
- the same applied to the ratings for the quality of the working area - the differences that were found are more explicit for the group of employees who work for more than 4 hours a day in front of a computer screen
- with plants their productivity improved, especially in terms of efficiency; the strongest links were found in the context of functional equipment and privacy
- the strongest link was found with experimental group ( $R^2 = 0,65$ ) those working at computer terminals. The most explicit variables are the ratings assigned for quality of the working environment and wellbeing
- loss of concentration dropped, i.e. concentration improved, in the test group (with plants)
- other environmental factors: static electricity and daylight were rated better (with plants)

Results of studies into perception of the work environment, with negative complaints being expressed about health, comfort, well-being, sick leave, productivity loss and less studied aspects such as reduced motivation, creativity, etc. do not usually make their way to facility managers. It should come as no surprise that a poor quality workplace, causing health and comfort complaints, reduce productivity.

## Humidity Levels... Another Important Factor in Health

Plants not only control the toxin levels in the air, but also humidity. Interior plants are vital to maintaining the approved human comfort range for relative humidity in offices. A study conducted by Virginia Lohr, Ph.D., at Washington State University determined that when plants were placed in offices, the relative humidity increased significantly and actually

•  
•  
•  
•  
•

stabilized at the recommended range of 30 to 60 percent. In the absence of plants, the relative humidity in offices was slightly below the recommended range for human comfort levels.

Humidity levels play an important role in employee health. When humidity levels are too low you are more likely to develop a cold or catch the flu. And, when levels are too high you are more vulnerable to disease and illness.

Plants contribute to interior humidity by adding moisture to the air through transpiration and secondarily through evaporation from growing media and drainage dish surfaces. The relative humidity in the studied offices stabilized because the plants either naturally reduced their levels of transpiration when relative humidity was high or increase the rate of transpiration, thus adding humidity, when relative humidity was lower. The study documented that plants did not contribute excessive amounts of moisture to any of the interior spaces studied.



Researchers recorded the relative humidity of office space in a building with a central, forced air system in the presence and absence of plants. Measurements were taken during four consecutive winter months. Once each week, plants were added or removed as required. Humidity and temperature were recorded every six hours. A variety of plant species were used. Air exchange rates were estimated to average one to two air changes per hour.

Most buildings do not have systems to maintain humidity within desirable ranges. Those with systems often have problems with humidifiers that become contaminated by microorganisms, which can cause human disease. When the relative humidity of interior air is too low, workers develop colds and virus infections more frequently.

These statistics have become an important tool for today's environmentally efficient corporate designers and facility managers. U.S. Energy Systems Inc. a growing energy company, is enthusiastically endorsing the use of indoor plants. Susan Odiseos, V.P. of Corporate Communications states "We practice what we preach and find that our investment in interior plant services has had the expected outcome of improving indoor air quality, supporting a positive outlook in the workplace and increasing employee productivity." She continued "interior plants are a solid return on investment and a MUST for any corporation concerned with sustainable, 'green building' solution".

---

*Plants provide a physical surrounding, that is more comfortable to live and work in, by purifying the air, moderating temperatures, removing pollutants from the air and increasing relative humidity.*

*When asked specifically if the physical workplace would have an influence on their decision to accept a position, two out of five employees said it would. Half said the physical workplace would impact their decision to leave a position.*

*Buildings are habitats for people; being in "the right place" is an important determinant of survival and well being. Given our affinity for nature, it is hardly surprising that many large building complexes create indoor parks with large trees and plants, water features, daylight, multiple view corridors, an interior "big sky," and comfortable retreats. Builders and developers would not be likely to invest in such costly aesthetic touches if they didn't believe such "amenities" had positive payoffs.*

*People have a positive response to plants and planted environments and they produce a positive economic return.*

---

## What good examples show

### The Genzyme Center

Winning companies show a consistent attitude about creating a positive workplace for interaction among employees. The Genzyme Center is an example of a company doing the right things and this building was chosen as an AIA Top Ten Green Project for 2004.

Genzyme Center's corporate headquarters offices 900 employees and includes an employee cafeteria, a library, eighteen indoor gardens, training rooms, a conference center, cafes, and public retail space. Genzyme Center was created as a symbol of progress to represent a point of identification for the company, its employees, and visitors. The goal of the design was to develop a building from the inside out, from the individual working environment to the overall complex structure of the building. Largely due to the collaboration of the design team, developer, client, and construction team, this led to an environmentally friendly, highly communicative, and innovative signature building.



Did project architects Behnisch, Behnisch & Partner of Venice, CA set out to make Genzyme Center a Green Building? No, Genzyme Center was designed from the inside out according to Architect Stephan Behnisch.

*The design of this building has been focused from the outset on the people who work and live in this building. It is our conviction that since people spend a significant portion of their lives working, that their working place should be as friendly, as human as possible. As we know humans are not normative — they are individuals, and we should help create an appropriate environment. An environment that they can influence, that they can adapt, that allows them to connect to the real world and the natural world. Together with the client (and it takes a great client to build a great building) we discussed the possibility of creating a place for the responsible human to live and work.*

Genzyme CEO Henri Termeer, who was as instrumental in the design and direction of the project as the project architects, had a strong position on the direction and the process they used to create their headquarters:

*“We needed to do the right things. This project needed to be consistent with our purpose to innovate, to create new standards and to go beyond the norm. When you build a plant you build an engineering marvel. When you build an office you need to think about it, how to make it an interesting experience, an important experience, an innovative experience, a learning experience.*

*This project needed to be consistent with our values and our purpose. It needs to be transparent, needs to be open, needs to be inviting and all of this, of course, happens through the people ... so the building has to work, as to be inviting for the employees to work together with regard to their privacy as well.*

Genzyme used an initial competition to select their architect. Henri Termeer explained the selection process and how he responded:

*The first four architects presented beautiful buildings, beautiful glass buildings, beautiful models. It's unbelievable how beautiful this can look. Statues ...Sculptures but they didn't really quite make the connection. You really need to think about other stuff... then the fifth architect came in empty handed.... nothing, no building, no drawing, no model*

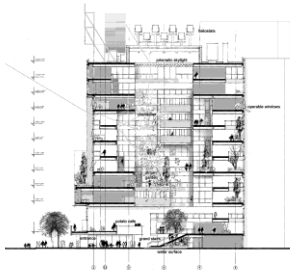


*and he said, let me talk about what I think a building should look like and he spoke to us about a building from the inside out not from the outside in... and it was a magnificent experience to think through what it means when you're in a building ... how it comes to life for you ... it doesn't take an outside shell, it takes words, the concept and the sensitivity of the building to make the experience in which to begin with. The architect spoke of how innovation and technology truly can deliver a green building, an environmentally friendly building is a life science. Innovation that comes from the possibilities of making a building green, make a building friendly in that way, it makes a building a new standard in that way. It is consistent with our purpose, what we do every day.*

He went on further in our discussions to speak to the desired results of building, a user friendly building, a building where collaboration is the key result:

*We are in a facility together, in an environment where you can become creative and where creativity must lead to innovation. And this facility can provide additional energy at least for one group of people to make an important contribution. If we are successful together we will make a difference in the lives of many people.*

Further discussions with the project team reveal important facets of the project. Why were the eighteen gardens such an important part of the design? Was it because they contributed to the green building concept and how was it that they decided to use the LEED standards? Gordon Brailsford, Project Manager and Richard Mattila, Director of Environmental Affairs explained their process:



*We looked at several rating systems and in the end decided to use the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. While the LEED system provides standards for decision-making, it was not the only criteria we used for making decisions. It did however provide a framework and once we looked at it we decided we had a good chance to make and to apply for the highest possible ("platinum") rating under the LEED 2.0 standard. If we are successful, Genzyme Center will become one of the first large-scale commercial office buildings to reach this standard in the United States.*

Talking further about the building and the process:

*We have always viewed the building as a living organism that would provide a connection to the outside through a visual connection with the outside, to look outside at the green and to bring that green into the building through the gardens. The gardens were always a part of the concept from the beginning and even though we didn't apply for any LEED points for the gardens, it was always a high level of commitment to include the interior plants.*

*Even when we went through value engineering, the gardens were considered. However in all our discussions, we understood they were a vital part of our green building concept. And while other elements of the project were cut (even though they would have gotten us LEED points) we chose to keep the interior gardens because it was the right thing to do for our green building.*

The Genzyme Center is a symbol of progress representing a point of identification for the company, its employees and its visitors. They built the project from the inside out, from the individual working environment to the overall complex structure of the building. Largely due to the collaboration of the design team, developer, client and construction team, this led to an environmentally friendly, highly communicative, and innovative signature building.





## What good examples show

### The Guelph Humber Building

Since the early nineties, researchers at the University of Guelph have been investigating the use of biofilters as an alternative means of removing VOCs from the indoor environment. The new 135,000 sq ft Guelph Humber building, located on the north campus of Humber College in Toronto, is a working example of this research. In the heart of the building is a four-story sky lit court that offers an excellent informal gathering area and houses a four-story green-wall.

The Integrated Learning Centre utilizes "Green" building aspects to address environmental and sustainable technologies. These green design features have been incorporated into the building for both environmental and pedagogical reasons. There are several major categories in building operation that have the potential for utilizing green ideas; the ILC has not only identified these areas, but has also designed green features to address environmental concerns in the different fields.

#### GREEN PLANTS IN A BIOFILTER?

This prototype was designed as a complex ecosystem which infers operational stability and, contrary to conventional biofiltration an ecosystem diversity which promotes the degradation of a broader range of VOC contaminants. Not only were green plants the basis of the system, they also acted as the packing medium on the bioscrubber. Living mosses are an ideal media for an indoor biofilter:



1. Moss colony architecture and high surface area to volume ratios provides excellent bed characteristics. The high porosity allows for even air flow while high surface area provides for good biofilm contact even with very shallow bed depths (ie < 0.05m).
2. The rhizosphere contains higher microbial populations than bare soil. Hence, plants may be able to enhance the degrader populations. Plant transpiration also draws air onto the rootzone (to displace water uptake), thus directly exposing rhizosphere microbes to contaminants.
3. Plants are able to break down VOC contaminants. Plants grown in cell culture could metabolize formaldehyde into cellular components. However, houseplants have limited impact on indoor VOCs due to boundary layer resistance. The incorporation of a biofilter into the air handling system greatly reduced this resistance.
4. Plants also accumulate airborne contaminants. Organics can either absorb to plant cuticle or be accumulated internally. Hence, plants act as a contaminant sink and they may impart some buffering capacity to the biofilter for fluctuating pollutant concentrations.
5. Green plants are a sink for CO<sub>2</sub>, which is considered an indoor pollutant. Through photosynthesis they combine carbon dioxide and water into biomass and produce oxygen, that humans need in order to survive.
6. Green plants have also been included for aesthetic purposes. Maintaining an indoor 'green' area increases employee productivity and lowers absenteeism





## What does this mean for Green Buildings

Current LEED standards do not include points for the inclusion of green plants into the interior environments. So why should designers and builders include interior plantings in their facilities? Why should LEED include points for interior plantings? What are the economic gains of including interior plantings in green buildings? All these are good questions, questions which should be answered in the reader's mind. However, if you are not yet convinced consider the following reminders.

- The average American spends a third of their life in the office. At home, two-thirds of Americans cite gardening as their favorite hobby.<sup>1</sup>
- Once exposed to plant settings, people demonstrated more positive emotions such as happiness, friendliness and assertiveness and less negative emotions such as sadness, anger and fear.
- In a planted office, we recover from stress more quickly than when in an unplanted office.
- When plants are added to an office, we are more productive (test results indicate 12% quicker reactions on computer tasks) and less stressed (systolic blood pressure lowers). We also report feeling more attentive when plants are present.
- When we shop in retail areas with “trees” versus a “no-tree” environment we visit more frequently, stay longer, rate the quality of the products 30% higher and are willing to pay about 12% more for goods.

### People have a positive response to plants

- When plants were included in offices, there was an average 23% lower score of 12 negative health symptoms.
- Commonly used office plants remove the number one office toxin, formaldehyde, as rapidly as 1,800 micrograms per hour.
- Studies showing the effects of healthy workplaces on well being and productivity indicate that in offices without plants, workers stayed home a minimum of 3.6 days per employee per year due to poor indoor air quality (causing a 12% reduction in productivity).
- With workers who spent at least 4 hours a day in front of a computer screen, the introduction of plants made a significant improvement to their efficiency, concentration and well being.
- Plants in an office environment create a humidity level exactly matching the recommended human comfort range of 30% to 60%. Similarly, in an absence of plants, the relative humidity in offices runs below this recommended range.

### Plants improve our environment and our well-being

The built environment has a profound impact on our natural environment, economy, health and productivity.

IF Green Buildings INCLUDED PLANTS as a part of LEED Certified criteria it would increase productivity and health gains won by certified green buildings by a “conservative” 12%. This is equal to \$744 per employee per year for Certified Silver level buildings and \$1,117 per employee per year for Gold and Platinum level buildings.

### **Authentically Green Interiors: Include Interior Plants**

We can safely draw the following conclusions: Plants in offices improve workers sense of wellbeing and health. Health problems caused by the indoor atmosphere, occur less frequently and employees feel plants are a positive element. It is consequently obvious to assume that plants can help reduce the costs resulting from short-term absence due to illness. Effectiveness at work can be improved both through the reduction in health problems and an increased sense of wellbeing. This is interesting from an economic perspective, not least because the individual planting can easily be adapted to the workplace in question. Finally, it should not be forgotten that the individual employee's sense of well-being is clearly promoted, and that plants in the workplace can therefore also help improve quality of life overall.

We therefore dare to draw the conclusion that plants in offices have a positive effect on individuals' health and sense of wellbeing. We hope our promotions of studies and research can prompt designers, developers and builders of our future buildings to simply:

**Do the right things!**





## References

- Fjeld, T., et al. "Effect of Indoor Foliage Plants on Health and Discomfort Symptoms Among Office Workers," *Indoors + Built Environment*, 1998, 7:204-206. (Norway).
- Giese, M., U. Bauer-Doranth, C. Langebartels and H. Sandermann, Jr., "Detoxification of Formaldehyde by the Spider Plant (*Chlorophytum comosum* L.) and by Soybean (*Glycine max* L.) Cell Suspension Cultures," *Plant Physiology*, 1994, 104:1301-1309. (Germany).
- Lohr, V. I. "Particulate Matter Accumulation on Horizontal Surfaces in Interiors: Influence of Foliage Plants," *Atmospheric Environment*, 1996, 30:2565-2568. (U.S.).
- Lohr, V. I., et al. "Interior Plants May Improve Worker Productivity and Reduce Stress in a Windowless Environment," *J. Environ. Hort.*, 1996, 14:97-100. (U.S.).
- Nakamura, R. and E. Fujii. "Studies of the Characteristics of the Electroencephalogram When Observing Potted Plants: *Pelargonium hortorum* 'Sprinter Red' and *Begonia evansiana*," *Technical Bulletin of the Faculty of Horticulture of Chiba University, Japan*, 1990, 43:177-183. (Japan).
- Oyabu, T., T. Onodera, H. Kimura, et al. "Purification Ability of Interior Plants for Removing of Indoor Air Polluting Chemicals Using a Tin Oxide Gas Sensor," *J. of Japan Society for Atmospheric Environ.*, 2001, Vol. 34(6):319-325. (Japan).
- Oyabu, T., et al. "Purification Effect of Interior Plants for Indoor Air Polluting Chemicals and Environmental Preservation," 4th Intl. Conf. on Eng. Design and Automation, 2000, (Orlando, FL, July 30-Aug 2) pp. 876-881. (Japan).
- Stiles J. 1995. PhD thesis at Oxford Brookes University, Oxford, England.
- Ulrich, Roger S. "Health Benefits of Gardens in Hospitals," *Plants for People Conference, Intl. Exhibition Floriade 2002, The Netherlands*. (U.S.).
- Ulrich, Roger S., et al. "Stress Recovery During Exposure to Natural and Urban Environments," *J. of Environ. Psychology*, 1991, 11:201-230. (U.S.).
- Ulrich Roger S. "View through a window may influence recovery from surgery." *Science* 1984; 224:420-421.
- Ulrich Roger S., Simons RF. "Recovery from Stress During Exposure to Everyday Outdoor Environments." 1986. In: Wineman J, Barnes R, Zimring C (eds.). "The cost of Not Knowing: Proceedings of the Seventeenth Annual Conference of the Environmental Design Research Association." Environmental Design Research Association, Washington, D.C.
- Wolverton, B. C. "Eco-Friendly Houseplants," Weidenfeld & Nicolson, London, 1996. Released in U.S. as "How To Grow Fresh Air," Penguin Books, New York, 1997. (U.S.).
- Wolverton, B. C. and J. D. Wolverton, "Interior Plants: Their Influence on Airborne Microbes Inside Energy-Efficient Buildings," *Journal of the Mississippi Academy of Sciences*, 1996, 41(2): 99-105. (U.S.).
- Wolverton, B. C. and J. D. Wolverton, "Plants and Soil Microorganisms - Removal of Formaldehyde, Xylene and Ammonia from the Indoor Environment," *Journal of the Mississippi Academy of Sciences*, 1993, 38(2): 11-15. (U.S.).
- Wolverton, B. C., A. Johnson and K. Bounds, "Interior Landscape Plants for Indoor Air Pollution Abatement," *NASA/ALCA Final Report, Plants for Clean Air Council, Davidsonville, Maryland*, 1989. (U.S.).
- Wolverton, B. C., R. C. McDonald and E. A. Watkins, Jr., "Foliage Plants for Removing Indoor Air Pollution from Energy-Efficient Homes," *Economic Botany*, 1984, 38(2):224-228. (U.S.).
- Wood, R. A., et al. "Study of Absorption of VOCs by Commonly Used Indoor Plants," *Proceedings: Indoor Air '99*, 1999, Vol. 2:690-694. (Australia).