David Strong Consulting

Report

The distinctive benefits of glazing

The social and economic contributions of glazed areas to sustainability in the built environment

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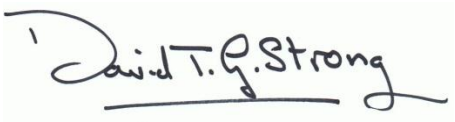
Signature: 

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Front cover photo: Tampines School (United World Colleges South East Asia), Singapore. This ultra-low energy school utilizes an exemplary approach to exploiting daylight and optimising views of the natural world. Daylight penetration into classrooms is further enhanced by the use of light-shelves to reflect natural light deep into the classrooms.

Introduction and Executive summary

We spend over 80% of our lives within buildings and numerous research studies have demonstrated that glazing has profound implications in terms of human health, happiness and productivity, including:

- quality of life, happiness and a sense of wellbeing
- health (and healing)
- ability to learn in educational establishments
- productivity whilst at work
- profitability and shopper-footfall in retail buildings

The non-energy related benefits associated with glazing are primarily linked to the following:

- The provision of daylight within buildings and/or access to sunlight
    - Enabling tasks to be undertaken, whilst also enhancing the spatial environment
- Establishing a link between the internal and external environment, by providing building occupants with a visual connection to the natural world outside the building
- The use of glazing as a structural façade element, aesthetic component and/or cultural art-form

During the history of mankind the importance of sunlight and daylight has been recognised and then forgotten several times. Ancient civilisations understood the critical importance of daylight associated with human health, happiness and wellbeing. Following the fall of the Roman Empire, much of this wisdom was lost during the Dark Ages. It wasn't until the mid-19th century that the healing properties of light started being appreciated again by healthcare pioneers, such as Florence Nightingale. The importance of the beneficial therapeutic effects of daylight and sunlight reached new levels of understanding with the treatment of tuberculosis (TB), rickets and jaundice becoming more widely understood in the early 1900's. This important new branch of medicine was referred to as 'heliotherapy.'

A new architectural language and form of expression centred on exploiting and celebrating the virtues of daylight in buildings was championed by architects such as Le Corbusier in the 1920's and embraced by building developers and designers around the world.

No sooner had solar architecture reached a zenith again, than the benefits were to be forgotten as a result of rapid developments in building technology and medicine. The advent of air-conditioning and the introduction in the 1930's of fluorescent lighting enabled architects to design deep buildings, without the need to exploit daylight. This trend was exacerbated by improved public health and in new treatments for TB, coupled with the introduction of antibiotics. As a result, the healing properties of the sun and the benefits of heliotherapy were soon forgotten again.

We now have a legacy of buildings constructed over the past 70 years which rely on artificial light and energy intensive building services to provide habitable conditions. Many of these buildings have a negative impact on human health, productivity and wellbeing. For many occupants, this implies higher levels of stress and in extreme cases the buildings are responsible for debilitating health problems associated with Sick Building Syndrome (SBS).

The issues associated with SBS and/or daylight deprivation, coupled with a renewed interest in the

use of daylight in the design of low-energy, sustainable buildings is leading many architects and engineers to consider innovative ways of exploiting the benefits of daylight (and views) without the negative impacts associated with solar over-heating. However, there are concerns that current health implications associated with excessive solar exposure (e.g. skin cancer etc.) could inhibit the re-emergence of a renewed interest in solar architecture. It is critically important that the positive benefits of daylight do not become confused with the negative impacts associated with excessive solar radiation, not least because modern glazing can reduce the transmission UVs.

Compelling, objective, independent research evidence regarding human health, happiness and wellbeing associated with glazing is presented in this report. Of particular importance are the findings from the healthcare and education sectors, together with emerging evidence regarding the importance of daylight in retail buildings and in providing a link to the natural world in homes.

- **In healthcare**, research findings demonstrate that access to daylight provides; a reduction in the average length of hospital stay, quicker post-operative recovery, reduced requirements for pain relief, quicker recovery from depressive illness and disinfectant qualities.

- **In educational buildings** access to daylight has been shown to result in a dramatic (and demonstrable) improvement in student academic achievement, behaviour, calmness and focus.

- **In the workplace** numerous studies have identified a preference to work near windows and under conditions which fully utilise natural rather than artificial light.

- **In retail establishments**, research shows that a substantial improvement in sales can be achieved in daylit shops.

- **In buildings of all types, including in the residential sector**, many of the studied benefits associated with daylight and connections to the outside world can be equally realised, thus contributing to sensations of well-being.

This report provides a comprehensive summary of the benefits provided by glazing by enabling daylight penetration into buildings and an ability to establish a visual link with the natural world outside.

The distinctive benefits of glazing

Chapter 1 At the rising of the Sun

1.1 Day 1 "Let there be light ……and it was good" Genesis 1: 3-4

Ancient civilisation understood that daylight and sunlight were inextricably linked to human health, happiness and wellbeing. For millennia the sun was worshipped as the source of all life. Architects and engineers in the ancient world built to exploit sunlight – they understood that sunlit buildings prevented disease and promoted a sense of happiness and health.

1.2 Egyptian Wisdom

Over 5000 years ago, the great Egyptian architect, engineer and doctor (and high priest of an Egyptian solar cult), Imhotep, began work on the first pyramid at Saqqara near Memphis. Imhotep understood and exploited the link between the sun, architecture and medicine. Egyptians worshipped the sun for its healing powers and used light as a medicine[1].

1.3 Greece, Rome and the Arab World

One of the oldest surviving Egyptian medical texts, the Ebers Papyrus, records the therapeutic benefits of exposure to sunlight. The greatest doctors and architects of the Greek, Roman and the Arab world utilised and deployed this ancient wisdom for many thousands of years.

In Rome, sunlight therapy was widely practised, with the Romans building solaria for sunbathing. Sunlight was regarded as so important to health, the Senate even provided citizens with legislation safeguarding their right to light.

Greek and Roman physicians called the emotion associated with gloom and darkness 'melancholia'. The Roman philosopher and writer Aulus Cornelius Celsus (25 BC – AD 50) advised patients suffering from depression/melancholia to live in rooms `full of light`[2].

1.4 The Dark Ages

The fall of Rome ushered in the Dark Ages, which were dark in every sense, with much of the ancient wisdom associated with the importance of daylight and sunlight being forgotten. Medical texts in the Western world hardly mention the importance of the sun until the end of the 17th century, but even when considered its role in the avoidance and treatment of disease was still not understood or appreciated.

Indeed the importance of a right to light was so poorly understood in England the government introduced a window tax in 1695, which resulted in buildings being constructed with the minimum number of windows. Home-owners even bricked up existing windows to avoid paying the tax. To

[1] Hobday R The Light Revolution, Health Architecture and the Sun Findhorn press 2006 ISBN: 1-84409-087-6
[2] Hobday R.. The Healing Sun, Findhorn Press, 1999. ISBN: 1-99171-97-5.

this-day, as a consequence of the window tax, many historic houses in England retain the legacy of bricked up windows.

1.5 The Industrial Revolution

The English poet William Blake[3] refers to the "dark satanic mills" of the industrial revolution. In the factories and mills, daylight was recognised as important, but only with the objective of ensuring that adequate task lighting was provided. The human health benefits remained ignored and not fully understood and workers homes were built close together, enabling only limited natural light reaching the inhabitants

Although conditions were often poor in factories, they were even worse below ground, where workers, (including children) toiled in mines devoid of any natural light. In less than a generation, millions of people had moved from working on the land in agricultural jobs (with regular exposure to sunlight), to working indoors and underground. The health implications were not recognised but were devastating, with rickets, jaundice, tuberculosis and other diseases becoming endemic.

1.6 A new dawn

It was the pioneer of modern nursing, Florence Nightingale, who recognised the importance of natural light and access to sunlight, in providing a healthy environment for curing the sick. Her 1859 Notes on Hospitals[4] states;

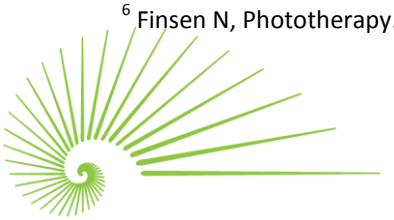
> *'Direct sunlight, not only daylight, is necessary for speedy recovery …….while we can generate warmth, we cannot generate daylight or the purifying and curative effect of the sun`s rays'.*

Over the next 50 years doctors and scientists investigated the therapeutic and sanitary benefits of the sun's rays with the bactericidal properties of sunlight being reported to The Royal Society in 1877 by Downes & Blunt[5].

In 1903 Neils Finsen[6] was awarded the Nobel Prize for treating tuberculosis (TB) with ultra-violet light and in the same year, Dr Auguste Rollie began to treat both TB and rickets at his clinic in Switzerland. This stimulated a renewed interest by physicians around the world in the healing power of the sun.

The 1st World War resulted in a growing recognition in the importance of sunlight and daylight. Doctors found that exposure to daylight reduced injury recovery time and it was very effective in pain relief.

[3] Blake William "Milton" 1804
[4] Nightingale F. Notes on Hospitals. London, Parker & Son 1859
[5] Downes A, Blunt TP. Researches on the effect of light upon bacteria and other organisms. Proc. Rotaly Soc. 1877;26:488-500
[6] Finsen N, Phototherapy. London Edward Arnold 1901



During the first 20 years of the 20th century the importance of daylight was increasingly recognised and incorporated in the design of hospitals and sanatoria, with doctors and some architects recognising the importance of what was now becoming called “heliotherapy”.

From the late 1920’s, the great French architect Le Corbusier developed a new language and form of architectural expression, which exemplified his belief that the sun conferred physical and moral regeneration on those who exposed themselves to its rays. The Le Corbusier movement influenced architects the world-over, but no sooner had the importance of daylight and sunlight been recognised again, than it started to be supplanted by the impact of new technology.

In particular, the advent of cheap low Wattage fluorescent tubes in the mid 1930’s allowed architects to ignore the need to fully exploit daylight. This situation was exacerbated by a growing reliance on air conditioning and the introduction of antibiotics and a reduction in TB and rickets (as a consequence of improved public health and diet).

The sun was waning again – old wisdom was being lost and replaced by technology and modern medical treatments. Architects were now free to design climate-excluding buildings (i.e. reliant upon mechanical, rather than natural systems to enable comfortable conditions and illumination to be maintained). Designers no longer considered it necessary to work in harmony with nature or natural systems, or to design for daylight/sunlight.

The last 50 years has resulted in most buildings being designed to be reliant on energy intensive building services and artificial lighting. Many of these buildings proved to be uncomfortable and unhealthy for occupants, resulting in high levels of sickness, absenteeism and poor productivity – the term Sick Building Syndrome (SBS) was coined in the 1970’s. Many architects and engineers were slow to recognise or respond to the issues associated with SBS and as a consequence the symptoms associated with SBS became even more prevalent in buildings constructed in the 1980’s and ‘90’s.

Many commercial and retail buildings have been constructed with deep floor-plates which require artificial lighting whenever they are occupied, thus denying the visitors and workers within the buildings access to the beneficial and healing qualities of daylight. We now have a legacy of buildings which are reliant upon air-conditioning and other energy intensive building services. The following Chapters present compelling evidence why we urgently need to reconsider the role of daylight in providing buildings which are healthy, comfortable, productive and truly sustainable.

Chapter 2 Daylight and our quality of life

2.1 Happiness and wellbeing

Numerous studies have demonstrated that human health, happiness and wellbeing are inextricably linked to daylight. Humans are outdoor animals and an absence of daylight has a profound impact on our quality of life.

Of particular relevance is our reliance on daylight to synchronise our body-clock and establish a circadian rhythm. As discovered by ancient civilisations the influence of daylight on the avoidance or treatment of depression and lethargy is also vitally important. These two issues are considered in the following sections.

2.2 The Circadian rhythm of life

Each of us has a body-clock located in our brain (within the hypothalamus). Our main body clock requires daily recalibration -it needs to know when dawn and dusk are to do this. In simple terms, we need access to daylight, so chemical messengers within the body can be produced, such as the hormone melatonin, which during darkness, helps to induce sleep. Similarly, the suppression of melatonin during the day keeps us awake and alert. For the body to produce melatonin, we also need to make the neurotransmitter serotonin. Medical research has found that mood and other bodily functions are severely disturbed and disrupted without melatonin and/or serotonin being produced during a 24 hour cycle.

2.3 Seasonal Affective Disorder (SAD)

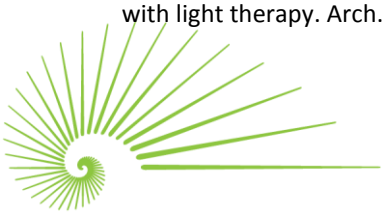
Prior to the 1970`s very little research was undertaken to determine if levels of natural light had any influence upon human health or happiness. A breakthrough came in 1987 with the publication in Science of research findings by a team led by Dr Alfred Lewy at the US National Institute of Health. The team found that they could suppress the production of melatonin by exposing trial participants to bright light[7].

A further ground breaking paper was published in 1984 by Dr Norman Rosenthal[8] in the Archives of General Psychiatry, regarding a seasonal pattern of depression. Dr Rosenthal coined the term Seasonal Affective Disorder (SAD) to describe the symptoms of lethargy, drowsiness, and low levels of concentration, which are experienced by some individuals during the winter months. These findings led to new forms of treatment for SAD sufferers, using light therapy.

SAD is likely to affect us all. The severity of symptoms will vary from individual to individual, but the research associated with SAD provides further evidence regarding the impact of adequate access to sunlight and daylight to our happiness and wellbeing.

[7] Lewy A, Sack RL, Miller LS, Hoban TM, Antidepressant and circadian phase-shifting effects of light. Science 1987; 235:352-354

[8] Rosenthal NE, et al. Seasonal affective disorder: a description of the symptoms and preliminary findings with light therapy. Arch. Gen. Psychiatry 1984 41:72-80



2.4 Windows, daylight and view in the home environment.

Veitch[9] published a review in 2011 of the physiological and psychological effects of windows, daylight and views at home. The review provides compelling evidence that residential buildings with a view of nature contribute significantly to the inhabitants' sense of wellbeing. The key conclusions are:

> *"Following the discovery that intrinsically photoreceptive retinal ganglion cells are responsible for entraining circadian rhythms to patterns of light and dark, and furthermore that those cells are most sensitive to short-wavelength optical radiation, considerable attention has focused on the possibility of using daylight to achieve a healthy lit environment. Daylight is rich in that area of the spectrum, and bright at the times of day that seem most important to these processes. …….. It may be that increasing our use of daylight as a light source in all settings is an important means to contribute to our own well-being while reducing our dependency on electric lighting. Residential daylighting strategies may need to be modified, or new strategies developed, to enable our homes to make their fair contributions to this endeavour."*

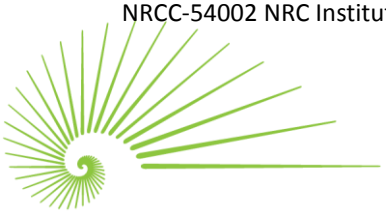
2.5 Glass Properties impacting on quality of life

The use of glass in our buildings is so ubiquitous, that it would be easy to take the benefits it brings to our quality of life for granted. Glass is a remarkable material with extraordinary properties - transparent to light and yet it prevents the ingress of water. You can look through it and establish a connection with the natural world –but without being subjected to the outdoor climate or weather. Glass is phenomenally strong and as a consequence is used as a structural component in many buildings.

The role of glass in improving the thermal performance of the built environment is self- evident and architects and engineers are constantly discovering new ways of exploiting glass's unique properties, to ensure that buildings optimise the use of daylight, whilst minimising the energy requirements for heating and cooling. N.B. The contribution glass makes to the thermal performance of buildings is outside the scope of this report.

Glass partitioning allows daylight penetration into the building, but enables the occupant to maintain the vital connection with the natural world. This important issue is addressed in greater detail in the following Chapters. In addition, glass provides quality of life benefits by providing an acoustic barrier between the occupied space within buildings and the external environment. This is of particular importance in urban environments, or where buildings are located near noisy sites, such as airports or motorways. Within buildings, glass partitioning also provides a valuable way of reducing noise in the workplace whilst maintaining access to daylight and views.

[9] Veitch JA, The physiological and psychological effects of windows, daylight, and view at home May 2011 NRCC-54002 NRC Institute for Research in Construction, Canada



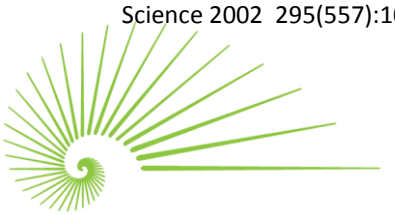
Urban noise is a major source of neighbour dispute, resulting in extreme cases in murder. Glass has a unique and vital role in addressing the nuisance and distress caused by neighbourhood noise.

Further evidence regarding the importance of daylight to our wellbeing, was reported in a paper by Berson et al. at Brown University in 2002[10]. The research team discovered light sensing cells in the eye which are critical to the circadian system. The cells are also sensitive to different wavelengths of light with maximum sensitivity in the blue part of the spectrum – precisely the wave length of blue sky.

Further research is required but observers suggest that access to natural light rich in the spectral qualities of daylight, may be essential in stimulating the production of serotonin – without which humans can suffer; depression, anxiety, pain perception and aggressive behaviour.

Daylight is also vital in enabling effective colour rendering in the workplace, this issue is considered further in Chapter 5.

[10] Berson DM, Dunn FA, Takao M. Phototransduction by retinal ganglion cells that set the circadian clock. Science 2002 295(557):1070-1073



3.0 Benefits in Healthcare buildings

3.1 Impact of daylight on average length of in-patient stay

A number of peer-reviewed independent studies provide compelling evidence that access to daylight enables patients to be discharged from hospital sooner than patients without daylight access.

A study by Choi et al[11]. published in 2012, found that;

> *'A significant relationship appears to exist between indoor daylight environments and a patient's average length of stay (ALOS) in a hospital. 25% of the comparison sets showed that, in the brighter orientations, as in rooms located in the SE area, the ALOS by patients was shorter than that in the NW area by 16%-41%. Further, no dataset showed a shorter patient ALOS in the NW area than in the SE.'*

Furthermore, the study concluded that;

> 'T*he high illuminance in the morning seemed to be more beneficial than in the afternoon. Patient rooms are oriented to the southeast (SE) and northwest (NW), and admitted daylight was found to be more intense in the SE in the morning and in the NW in the afternoon. However, since short ALOS cases were more consistently found in the SE, it would appear that morning light has a more positive effect than light in the afternoon does, and provides physiological benefits for humans.'*

In 2006 a comprehensive review of the impact of light on outcomes in healthcare settings by Anjali Joseph[12] found that;

> *'A retrospective study of myocardial infarction patients in a cardiac intensive-care unit treated in either sunny rooms or dull rooms found that female patients stayed a shorter time in sunny rooms (2.3 days in sunny rooms, 3.3 days in dull rooms) [13]. Mortality in both sexes was consistently higher in dull rooms (39/335 dull, 21/293 sunny).*

Another study found that Veterans Health Administration medical centres located in sunnier, warmer and drier climates had shorter length of stay of patients[14].

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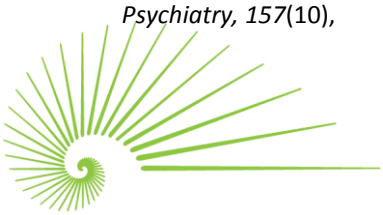
[11] Choi JH, Beltran L and Kim H. Impacts of indoor daylight environments on patient average length of stay (ALOS) in a healthcare facility. *Building and Environment* 2012; 50: 65-75

[12] Joseph A The Impact of Light on Outcomes in Healthcare settings. Issue Paper 2 The Centre for Health Design 2006

[13] Beauchemin, K. M., & Hays, P. (1998). Dying in the dark: Sunshine, gender and outcomes in myocardial infarction. *Journal of the Royal Society of Medicine, 91*(7), 352–354.

[14] Federman, E. J., Drebing, C. E., Boisvert, C., & Penk, W. (2000). Relationship between climate and psychiatric inpatient length of stay in Veterans Health Administration hospitals. *American Journal of Psychiatry, 157*(10),



3.2 Post-operative recovery

A literature review of the effects of natural light on building occupants undertaken by Edwards and Torcellini[15] states;

> '*Improving the mental well-being of patients improves their recovery rates. Recent studies show that daylit post-surgical facilities improve this mental well-being. Intensive Care Unit (ICU) areas in hospitals can be very stressful for patients and workers[16]). Some patients can develop "post-operative delirium" in a stressful environment, which affects the intellectual ability of the patient. Many factors affect the development of the delirium: age, alcoholism, drug abuse, sex, preoperative anxiety, sleep deprivation, and perceptual distortion). Daylight helps reduce the stress associated with this environment'.*

Wilson[17] conducted a study to see whether windows had an effect on the postoperative delirium rates in hospital units. He found that;

> *' the windowless ICU had twice as many patients developing post-operative delirium and depression. Windows provided a psychological escape that decreased the stress level for patients. This environment provides a necessary mental balance for patients and reduces the tendency toward brief psychotic episodes. Windows are important in the medical field because they can reduce the stress and depression in patient units.'*

3.3 Daylight and pain relief

Research has demonstrated a clear link between daylight/sunlight and a reduced requirement for pain relief medication in hospitals. The use of analgesic medication can result in side-effects and for this reason any strategy which reduces the requirement for pain-relief medication is desirable.

A study published in the Journal of Psychosomatic Medicine[18] in 1995 concluded;

> *'Consecutive patients undergoing elective spinal surgery who were assigned postoperatively to rooms on either the bright or dim side of the hospital unit. The patients staying on the bright side received 46% more natural sunlight and required 22% less opioid equivalent analgesic medications during their hospitalization. The patients staying on the bright side*

[15] L. Edwards & P. Torcellini, 'A Literature Review of the Effects of Natural Light on Building Occupants' –NREL - July 2002 - http://www.nrel.gov/docs/fy02osti/30769.pdf

[16] Collins, B. "The Psychological Aspects of Lighting: A Review of the Work of CIE TC3.16."Gaithersburg, MD: National Institute of Standards and Technology; 1990.

[17] Wilson L. Intensive care delirium: The effect of outside deprivation in a windowless unit. Archives of Internal Medicine 1972; 130:225-226.

[18] Walch JM, Rabin BS, Day R, Williams JN, Choi K and Kang JD. The effect of sunlight on postoperative analgesic medication usage: A prospective study of spinal surgery patients. *Psychosomatic Medicine* 2005; 67(1): 156-163.

also experienced a 21% reduction in analgesic medication cost compared with patients on the dim side.'

This is a remarkable finding with significant implications in terms of hospital design, patient care and benefits in terms of reduced medication side-effects treatment cost.

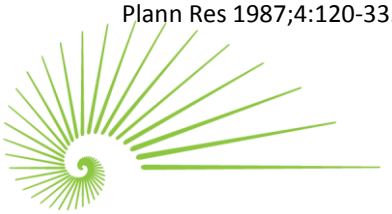
3.4 The importance of views from healthcare buildings

Numerous qualitative and quantitative studies have identified and reported the importance of establishing a visual connection with the natural world outside the building. Demonstrable benefits have been found associated with faster post-operative recovery and improved treatment.

In 1995 The New England Journal of Medicine[19] published a review regarding the importance of patient views. The review concluded that;

- *Connection with nature is highly valued; we prefer views of nature to those of the built environment.*[20]
- *In a hospital study, views of nature were associated with reduced stress and fewer health-related complaints among employees.*[21]
- *Students under the stress of examinations felt better after viewing nature scenes,*[22] *and prisoners with a view of nature from their cells were less likely to attend sick call than those whose cells did not have such a view.*
- *In a retrospective study of patients who had undergone cholecystectomy, those assigned to rooms with a view of a natural setting had shorter postoperative stays and took fewer analgesic drugs than those whose rooms looked onto a brick wall.*[23]
- *Taken together, these results suggest that views of nature provide therapeutic benefit. Obtaining views of nature requires both the appropriate placement of windows and the availability of natural views. The tendency to eliminate windows from hallways, intensive care units, and other hospital areas must be resisted. Poorly fenestrated rooms have deleterious effects on both patients and staff members, but patients are more severely affected.*[24] *The window sills should be lower in patient rooms so that the landscape outside can be seen by a patient lying in bed. In addition to providing views, windows admit natural light, which is more changeable, interesting, and informative than artificial illumination.*

[19] Horsburgh, R Healing by Design.. New England Journal of Medicine, 333, September 1995.
[20] Kaplan R, Kaplan S. The experience of nature: a psychological perspective. New York: Cambridge University Press, 1989.
[21] Verderber S. Dimensions of person-window transactions in the hospital environment. Environ Behav 1986;18:450-66.
[22] Ulrich RS. Visual landscapes and psychological wellbeing. Landscape Res 1979;4:17-23.
[23] Ulrich RS. View through a window may influence recovery from surgery. Science 1984;224:420-1.
[24] Verderber S, Reuman D. Windows, views, and health status in hospital therapeutic environments. J Archit Plann Res 1987;4:120-33.



In Keep's research (1980)[25] of windowed vs. windowless intensive care units, the windows were translucent thus eliminating view as a variable. He nonetheless discovered that disorientation, hallucinations, loss of memory, and delusions were still significantly less common in the windowed but viewless ICU. The implication is that daylight alone provided critical information, perhaps about time and weather patterns, to the patients which in turn led to stress reduction.

A review of research associated with the impact of daylight and windows on Intensive Care Unit patients and staff by Shepley et al[26] reported that;

> *'In 1972 Wilson[27] compared the incidence of postoperative delirium in patients located in windowed and windowless ICUs. Twice as many windowless patients demonstrated delirium and, among patients with abnormal haemoglobin or blood urea, the incidence was threefold. Hallucinations were more than twice as high in a new windowless unit than in the old unit.'*

Empirical and objective research data is now providing support for the considerable body of anecdotal evidence that the benefits are greatly enhanced if the views from windows enable a connection with the natural world to be established (e.g. trees, vegetation, water, and the sky). In particular;

- *Ulrich[28] noted that gall bladder surgery patients who had nature views had a shorter length of stay, took less pain medication and made fewer negative comments than those who had views of a building wall.*
- *Verderber[29] found that windows with high sills, distant from the viewer or obscured by walls and furnishing, were ranked as poorly as having no windows at all.*

It is important to recognise that the benefits associated with views extend to healthcare staff, with doctors and nursing staff displaying lower levels of stress and higher performance in daylit spaces and with views from windows.

3.5 Optimum window design and size in healthcare buildings

In her review of patient and staff environments, Shepley summarises the findings from a number of studies associated with window size and design;

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[25] Keep, P., James, J., Inman, M., "Windows in the Intensive Therapy Unit", Anathesia, Vol 35, 257-262, 1980
[26] Dr Mardelle Shepley AIA, ACHA, LEED AP, Raymond Gerbi, Angela Watson AIA, Stephen Imgrund MD Patient and staff environments: The impact of daylight and windows on ICU patients and staff http://www.worldhealthdesign.com/Patient-and-staff-environments.aspx
[27] Wilson L. Intensive care delirium: The effect of outside deprivation in a windowless unit. Archives of Internal Medicine 1972; 130:225-226.
[28] Ulrich R. View through a window may influence recovery from surgery. Science 1984; 224:420-421.
[29] Verderber S. Dimensions of person-window transactions in the hospital environment. Environment and Behavior 1986; 18(4):450-466.

- *Markus[30] emphasised four factors which influence window design: sunshine, awareness, view and lack of privacy. In his study he noted that being close to a window was highly desirable regardless of the size of the visual field. Keighley[7] found that satisfaction regarding windows was influenced by area and proportion and the number and width of mullions. The most preferred windows were horizontal apertures occupying 25-30% of the exterior wall.*
- *Roessler[31] found that unpleasant feelings of enclosure were minimal with a window width of at least 1.5 metres. The ideal was two lateral windows with a total width of 3-4 metres in a six-metre-wide room.*
- *Finnegan and Solomon[32] found differences regarding job satisfaction, how interesting the job was perceived to be, physical working conditions and overall experience in favour of windowed spaces.*
- *Ne'eman[33] noted the following positive contributions of sunshine: warmth, functional lighting, contact with the outside and biological effects of solar radiation. He found that 2% of patients and 62% of staff considered sunlight to be a nuisance, while 91% of patients and 31% of staff considered sunlight to be pleasurable. In hospitals, when forced to choose between good views without indoor sunshine and unpleasant views with indoor sunshine, 50% preferred the former while 31% preferred the latter.*

3.6 Treatment of depression and depressive illness

In the review of the Impact of Light on Outcomes in Healthcare settings Joseph reports that;

- A*t least 11 strong studies suggest that bright light is effective in reducing depression among patients with bipolar disorder or seasonal affective disorder (SAD). A majority of the studies have examined the impact of artificial bright light on reducing depression. Artificial light treatments usually range between 2,500 lux and 10,000 lux[34] . The treatment is believed to be effective by suppressing the onset of melatonin.*
- *Two studies have shown that exposure to natural bright light is similarly effective in reducing depression [35]/[36].*

[30] Markus T. The function of windows. Building Science 1967; 2:97-121
[31] Roessler G. The psychological function of windows for the visual communication between the interior of rooms with permanent supplementary artificial lighting and the exterior. Lighting Research & Technology 1980; 12 (3):160-168
[32] Finnegan M, Solomon L. Work attitudes in windowed vs windowless environments. Journal of Social Psychology 1981; 115:291-292.
[33] Ne'eman E. Visual aspects of sunlight in buildings. Lighting Research and Technology 1974; 6 (3):159-164.
[34]. Terman, J. S., Terman, M., Lo, E.-S., & Cooper, T. B. (2001). Circadian time of morning light administration and therapeutic response in winter depression. *Archives of General Psychiatry, 58*(1), 69–75.
[35] Eastman, C. I., Young, M. A., Fogg, L. F., Liu, L., & Meaden, P. M. (1998). Bright light treatment of winter depression. *Archives of General Psychiatry, 55*(10), 883.
[36] Lovell, B. B., Ancoli-Israel, S., & Gevirtz, R. (1995). Effect of bright light treatment on agitated behavior in institutionalized elderly subjects. *Psychiatry Research, 57*(1), 7–12.

Benedetti and colleague[37] found that bipolar depressed inpatients in east-facing rooms (exposed to bright light in the morning) stayed an average of 3.67 days less in the hospital compared with similar patients who stayed in west-facing rooms.

There is strong evidence that exposure to bright light in the morning is more effective than exposure to bright light in the evening in reducing depression[38]. An experimental study that compared the effect of morning and evening light on patients with winter depression found that morning light was twice as effective as evening light in treating SAD[39]

3.7 Reducing patient stress and agitation.

Sloane and colleagues[40] found that residents in facilities with low light levels displayed higher agitation levels.

Exposure to bright morning light has been shown to reduce agitation among elderly patients with dementia. When elderly patients with dementia were exposed to 2,500 lux for 2 hours in the morning for two 10-day periods, their agitation reduced. Patients were significantly more agitated on non-treatment days[41].

3.8 Sunlight –nature's disinfectant

Experiments undertaken in the USA and the UK between 1941 and 1944 demonstrated the extraordinary and remarkable effectiveness of daylight in killing the bacteria streptococci[42]. The blue light in skylight was found to be particularly potent. The trials also examined the bactericidal effects of artificial light, which was found to have little value as a disinfecting agent.

Even diffuse daylight passing through two layers of glass from a north window was found to be highly effective in killing haemolytic streptococci within 13 days, with the same strain surviving in the dark, at room temperature, for 195 days.

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[37] Benedetti, F., Colombo, C., Barbini, B., Campori, E., & Smeraldi, E. (2001). Morning sunlight reduces length of hospitalization in bipolar depression. *Journal of Affective Disorders, 62*(3), 221–223.

[38] Oren, D. A., Wisner, K. L., Spinelli, M., & Epperson, N. (2002). An open trial of morning light therapy for treatment of antepartum depression. *American Journal of Psychiatry, 159*(4), 666.

[39] Lewy, A. J., Bauer, V. K., Cutler, N. L., Sack, R. L., Ahmed, S., Thomas, K. H., et al. (1998). Morning vs. evening
light treatment of patients with winter depression. *Archives of General Psychiatry, 55*(10), 890–896.

[40] Sloane, P. D., Mitchell, C. M., Preisser, J., Phillips, C., Commander, C., & Burker, E. (1998). Environmental correlates of resident agitation in Alzheimer's disease special care units. *Journal of the American Geriatrics Society, 46*, 862-869.

[41] Lovell, B. B., Ancoli-Israel, S., & Gevirtz, R. (1995). Effect of bright light treatment on agitated behavior in institutionalizedelderly subjects. *Psychiatry Research, 57*(1), 7–12.

[42] Buchbinder L. et al. Studies on microorganisms in simulated room environments. The Survival rates of streptococci in the presence of natural daylight and artificial illumination. J Bacteriol 1942;42(5):545-555

Hobday, who has researched this issue extensively, reports that no significant further work on this issue has been undertaken since the mid-1940's. This is surprising given the current concerns regarding methicillin-resistant *staphylococcus aureus* MSRA and other other highly infectious bacteria prevalent in many hospitals, which are becoming increasingly resistant to treatment with commonly prescribed antibiotics. It is interesting to reflect that if daylight has such a dramatic and potent impact on killing streptococci, it's surprising that its potential for reducing super-bug infections in hospitals, has not been fully investigated.

3.9 Daylight, obesity and heart disease

Obesity is reaching epidemic proportions in many developed countries. Considerable research evidence links obesity to depressive illness. Morbidly obese individuals seldom leave home and it is self-evident that their exposure to daylight and sunlight is likely to be severely restricted. Sunlight is essential for the production of Vitamin D. Experiments have shown that obesity is associated with Vitamin D deficiency with the human body accumulating fat as Vitamin D levels fall. The strong causal link between depression and inadequate access to daylight and sunlight has been demonstrated repeatedly –more research is required, but access to adequate levels of daylight and sunlight may prove to be useful in the treatment of obesity.

Sunlight and/or daylight may also have an important role to play in the prevention and treatment of heart disease. In his book The Light Revolution, Health, Architecture and the Sun, Hobday speculates that;

> *'Sunlight may prevent heart attacks in a similar manner to antidepressants by alleviating depressive symptoms ……..Regardless of the exact mechanisms involved the fact that being in a sunlit ward may have health benefits is a significant finding, which has profound implications not the least of which is the patients' survival from life-threatening conditions'.*

4.0 Benefits in Education

Lisa Heschong is an internationally recognised expert on the effects of light on learning. She has undertaken or reviewed studies on thousands of students examining the effects of spatial qualities such as; classroom size, orientation, daylight and views on learning performance were assessed.

Almost every study undertaken in educational establishments has produced the same result – daylight and views out of windows were among the most consistent factor associated with student learning. Heschong's conclusion is that;

> *'Daylight is a drug that stimulates the production of serotonin, dopamine and gamma-aminobutyric acids in the human body, enhancing muscle coordination, calmness and focus'.*

4.1 Lighting type and quality in schools

Studies undertaken by Ott [43]/[44]and published in 1973 and 1976 found that in windowless classrooms the students exposed to standard cool-white fluorescent lighting exhibited decreased attention and greater hyperactivity, fatigue and irritability than students under full spectrum lighting.

In his book Daylighting, Architecture and Health[45], Mohamed Boubekri makes reference to a study published by Kuller and Lindsten[46] who undertook a study of 90 Swedish elementary school students with the level of the hormone cortisol being measured over the course of a year in four classrooms exposed to different daylight levels. The results indicate;

> *'That classrooms without daylight tend to disturb the basic hormone pattern and this in turn influences student concentration. Researchers concluded that this hormone disturbance could eventually have an impact on annual body growth and absenteeism.'*

Edwards and Torcellini make reference to a Daystar article, "Benefits of Natural Daylighting" (1998);

> '*There is increased student and teacher attendance, increased achievement rates, reduced fatigue factors, improved student health, and enhancement of general development. Furthermore, natural lighting eliminates noise and flickering from electric light sources and provides the best quality of light available in classrooms, gymnasiums, and corridors. Other*

[43] Ott JN. Health & light 1973 Old Greenwich CN: Devin-Adair
[44] Ott JN Influence of fluorescent lights on hyperactivity and learning disabilities. 1976 Journal of Learning Disabilities 9, 417-22
[45] Boubekri M Daylighting, Architecture and Health 2008 Elsevier ISBN: 978-0-7506-6724-1
[46] Kuller R, . Lindsten C Heralth & behaviour of children in classrooms with and without windows. 1992 Journal of Environmental Psychology 12, 305-17

research has shown that students in windowless classrooms are more hostile, hesitant, and maladjusted. Also, students in windowless classrooms tend to be less interested in their work and complain more'.

4.2 Daylight and enhanced student performance

In her investigation into the relationship between daylight and human performance in schools Heschong[47] (Ref Daylight in schools) found a statistically compelling connection between daylighting and student performance. Test score results were analysed from over 21,000 students from three separate school districts in California, Washington State and Colorado.

The Orange County results demonstrated;

'*That students with the most daylighting in their classrooms progressed 20% faster on math tests and 26% on reading tests in one year than those with the least. Similarly, students in classrooms with the largest window areas were found to progress 15% faster in math and 23% faster in reading than those with the least. And students that had a well-designed skylight in their room, one that diffused the daylight throughout the room and which allowed teachers to control the amount of daylight entering the room, also improved 19-20% faster than those students without a skylight*.'

In the studies undertaken in Washington State and Colorado the results found;

'……positive, and highly significant, effects for daylighting. Students in classrooms with the most daylighting were found to have 7% to 18% higher scores than those in rooms with the least.

It is important to note that the three school districts included in the study have;

'different curricula and teaching styles, different school building designs and very different climates. Yet the results of the studies show consistently positive and highly significant effects. This consistency supports the proposition that there is a valid and predictable effect of daylighting on student performance.'

A study undertaken by Niklas and Bailey[48] in 1996 reached very similar conclusions to the Heschong study;

'students in the new daylit schools had a higher reading and mathematics achievement score that students in schools which relied heavily on electric lighting.'

[47] Heschong Mahone GroupDaylighting in Schools An Investigation into the Relationship Between Daylighting and Human Performance Condensed Report August 20, 1999 http://www.h-m-g.com/downloads/Daylighting/schoolc.pdf

[48] Nicklas MH and Bailey GB. 1996 Daylighting in Schools, Energy Costs Reduced …Student Performance Improved Raleigh NC: Innovative Design.

A further study undertaken for the California Energy Commission by the Heschong Mahone Group (HMG)[49] and published in 2003, analysed the performance of 8000 students in 450 classrooms in Frenso, California. This study identified that the overall visual environment (i.e. not just daylight access) was important for learning. The report provides the following summary of key findings;

- ***An ample and pleasant view*** *out of a window, that includes vegetation or human activity and objects in the far distance, supports better outcomes of student learning.*
- ***Sources of glare*** *negatively impact student learning. This is especially true for math learning, where instruction is often visually demonstrated on the front teaching wall. Per our observations, when teachers have white marker boards, rather than black or green chalk boards, they are more likely to use them and children perform better in math.*
- ***Direct sun penetration*** *into classrooms, especially through unshaded east or south facing windows, is associated with negative student performance, likely causing both glare and thermal discomfort.*
- ***Blinds or curtains*** *allow teachers to control the intermittent sources of glare or visual distraction through their windows. When teachers do not have control of their windows, student performance is negatively affected.*

4.3 Daylight and Health in schools

Edwards and Tortellini conclude that;

> '*Daylight has physiological and psychological benefits for teachers and students. Thomas Benton, principal of the daylit Durant Road Middle School in Wake County, North Carolina, claims that teachers who have been at his school for more than a year mentioned that they feel better mentally and physically. Physiological benefits due to daylight on school children are less dental decay (cavities), improved eyesight, increased growth, and improved immune system.*
>
> *The sun is a primary source of vitamin D, and increasing vitamin D intake stimulates calcium metabolism. There is a strong correlation between the amount of sunlight a child is exposed to and the level of dental decay, making daylighting a very important element for cavity prevention in children. Reports show that students' rates of dental decay have decreased in fluorescent full-spectrum and daylit schools.*
>
> *Research in the 1930's provided evidence of the effects daylighting in school buildings has on students. McBeath and Zuker (Liberman[50]) conducted a study showing children are more prone to dental cavities in the winter and spring when they spend more time inside a school and less prone during the summer months when they are outside in the sun. These results are supported by a study that compared full-spectrum lit schools in Canada to traditional*

[49] California Energy Commission 2003 P500-03-082-A-7 http://www.h-m-g.com/downloads/Daylighting/A-7_Windows_Classrooms_2.4.10.pdf

[50] Liberman, J. (1991). *Light Medicine of the Future*. New Mexico: Bear & Company Publishing.

schools with fluorescent lighting[51]. Full-spectrum fluorescent light closely resembles daylight, but it does not provide the same spectral content. The full-spectrum fluorescent schools reported that student dental decay decreased nine times [compared to schools with fluorescent lights] as a result of the increase in vitamin D.

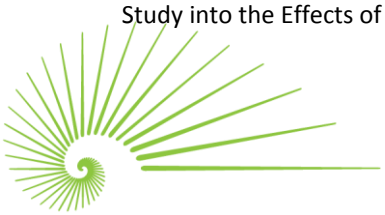
A school with insufficient light can also reduce a student's ability to learn due to the effect lighting has on physiology. Poor spectral light can create strain on students' eyes, leading to a decrease in information processing and learning ability, causing higher stress levels (Liberman 1991). Dr. Walker (1998) found that stress impacts certain growth hormones. He determined that "persistent stress stunts bodily growth in children" because the activity of the growth-inhibiting hormones cortisol and ACTH increase under stress. Students in the Canadian full-spectrum fluorescent schools grew 2.1 cm more in two years (Hathaway, et al. 1992) compared to students who attended traditional fluorescent-lit schools. The increased activity of these hormones supports researchers' observations that children under electric lights all day have decreased mental capabilities, agitated physical behaviour, and fatigue. Daylight also produces ultraviolet radiation. Dr. Ott claims, "trace amounts of certain wavelengths of light…can have a staggering effect on your health" (Liberman 1991). Ott also said that the trace amounts of UV light, measured as parts per trillion, are important because "we need a basic amount [of UV light] to support life and maintain a healthy immune system" (Liberman 1991). Faber Birren states that this basic amount of UV light needed has been demonstrated to "intensify the enzymatic process of metabolism, increase hormone system activity, and improve the tone of the central nervous and muscular systems" (A Summary of Light-Related Studies 1992).'

4.4 School Attendance and Absenteeism

Edwards and Tortellini report that;

'Schools that have integrated full-spectrum fluorescent or natural light show an increase in student and teacher attendance when compared to traditionally lit schools. A study of the full spectrum fluorescent Canadian schools reported that students had an attendance increase of 3.2 to 3.8 more days per year than the students in traditional fluorescent lighting schools (Hathaway, et al. 1992). Durant Road Middle School is a daylit school in the Wake County, North Carolina, school system. Durant reported the best health and attendance in the entire school system, an attendance rate above 98%. Teachers also have lower absenteeism rates, claiming the lowest number of faculty health absences in the area'.

[51] Hathaway, W.E.; Hargreaves, J.A.; Thompson, G.W.; Novitsky, D.; "A Summary of Light-Related Studies." A Study into the Effects of Light on Children of Elementary School Age



5.0 Workplace Benefits

Windows are highly valued in the workplace and a growing body of evidence suggests that the absence of windows is a major determinant of worker stress. A study by Collins[52] reported that 35% of employees when questioned "instantly" identified the absence of a window to be their major concern associated with their office. The specific reasons given for the dislike of the windowless offices were:

- *No daylight,*
- *poor ventilation,*
- *inability to know about the weather,*
- *inability to see out and have a view,*
- *feelings of being cooped-up,*
- *feelings of isolation and claustrophobia,*
- *feelings of depression and tension."*

Finnegan and Soloman[53] published similar results to the Collins study in 1981. This study established that employees in windowless buildings;

> *' have much less job satisfaction and were substantially less productive'.*

In their study "Daylighting and Productivity: Is there a causal link?" Norris and Tillett[54] conclude that;

> *"Workers and researchers alike confirm daylight as the preferred source of light in the workplace. This daylighting predisposition does not appear to derive from people's perception or researcher's proof regarding its potential to increase performance and productivity. It rather derives from daylight's capacity to create psychological comfort. Psychological comfort can be expressed as the absence of stress, a powerful protective reaction deployed by the human organism when confronted by conditions - like windowlessness - that it perceives as harmful to its well-being. In the workplace, the stressed employee can adopt attitudes and behaviors that can not only adversely affect his or her performance but also that of fellow workers."*

5.1 Results from building occupant attitude surveys

Wotton and Barkow[55] (1983) found that employees highly value any size of window that they can have access to and value it more than privacy in their office. They also found that 74% of the

[52] Collins, B. "The Psychological Aspects of Lighting: A Review of the Work of CIE TC3.16." Gaithersburg, MD: National Institute of Standards and Technology; 1990.
[53] Finnegan, M.C.; Solomon, L.Z. (1981). "Work Attitudes in Windowed Versus Windowless Environments." *Journal of Social Psychology*; Vol. 115, pp. 291–292.
[54] Davidson Norris (IESNA, NASEA, NASS) Linnaea Tillett 8IESNA, IALD) "Daylighting and Productivity: Is there a causal link?" 13th Sept. 1997 ISBN 952-90-8959-7

surveyed employees prefer having a window close to their workspace. If offered a window, 57% of surveyed employees would like the window to be beside their workspace rather than in front or behind their workspace.

Markus[56] used a questionnaire to determine how satisfied office workers were with their workspaces. Ten environmental factors, including sunshine and view, were presented to employees for a satisfaction analysis. The survey lacked the ability to portray how strongly each employee felt about issues, but it did provide an understanding of their overall satisfaction. From the questionnaire it was found that;

- *approximately 96% of respondents preferred to work under natural light as opposed to electric lighting.*
- *approximately 86% of the respondents preferred having sunshine in their office year round as opposed to only one season of the year or not at all.*
- *employees sitting near windows were more content, whereas those sitting further away from the windows complained more.*
- *workers with daylight and a view may suggest having a window is not important, but workers without either believe having more light and a view is very important.*

In a 1983 study, Cuttle[57] examined England and New Zealand office workers on their attitudes toward their workplaces. Cuttle concluded that office workers believe large windows are important for an office environment. The workers preferred sitting close to a window, although in many office environments people of lower status are denied this privilege. Also, four out of five office workers preferred working in natural light because they believe working by electric lighting caused discomfort. The employees believed that short-term discomfort from the electric lighting was more of a concern than the long-term deleterious effects. Furthermore, employees did not believe working by electric lighting resulted in poor work output; they believed that their work output was achieved at greater personal stress levels.

5.2 Worker Performance

In 2003 HMG undertook an analysis for the California Energy Commission[58] of office worker performance and the indoor environment. Two different studies were conducted in the same organisation. One study examined the performance of 100 workers in an incoming call centre. The other study looked at the performance of 200 office workers. The key findings from this study are:-

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[55] Wotton, E.; Barkow, B. (February 1983). "An Investigation of the Effects of Windows and Lighting in Offices." *International Daylighting Conference: General Proceedings*. Washington, DC: AIA Service Corp; pp.405–411.

[56] Markus, T.A. (1967). "The Significance of Sunshine and View for Office Workers." *Proceedings of the CIE Conference on Sunlight in Buildings*. Rotterdam: Bouwcentrum International; pp. 59–93.

[57] Cuttle, K. (1983). "People and Windows in Workplaces." *Proceedings of the Conference on People and the Physical Environment Research*. Wellington, New Zealand; pp. 203–212.

[58] California Energy Comission 2003 P500-03-082-A-9 Windows and Offices:A Study of Office Worker Performance and the Indoor Environment http://www.h-m-g.com/downloads/Daylighting/A-9_Windows_Offices_2.6.10.pdf

- *Daylight illumination levels were significant and positive in predicting better performance*
- *The natural log of illumination and the daylight illumination level of the previous hour were found to have the best fit in predicting performance*
- *An ample and pleasant view was consistently found to be associated with better office worker performance*

6.0 Benefits in retail buildings

In 2003 the California Energy Commission published a major study undertaken by HMG[59] regarding the impact of daylight and retail sales. The key conclusions from this study are;

- *Average effect of daylighting on sales for all daylit stores in this chain was variously calculated at 0% to 6%, depending on the type of model and time period considered.*
- *A dose/response relationship was found, whereby more hours of useful daylight in a store are associated with a greater daylight effect on sales.*
- *A bound of an empirical daylight effect for this chain was detailed, with a maximum effect found in the most favorable stores of about a 40% increase in sales. This upper bound is consistent with our previous finding.*
- *Daylight was found to have as much explanatory power in predicting sales as other more traditional measures of retail potential, such as parking area, number of local competitors, and neighbourhood demographics.*
- *Along with an increase in average monthly sales, the daylit stores were also found to have 1-2% increase in the number of transactions per month.*
- *No seasonal patterns to this daylight effect were observed.*
- *The value of the energy savings from the daylighting is far overshadowed by the value of the predicted increase in sales due to daylighting: by the most conservative estimate of at least 19 times, and more likely, under current conditions, by 45-100 times.*
- *During the California power crises, when almost all retailers in the state were operating their stores at half lighting power, the stores in this chain with daylight were found to benefit dramatically, with an average 5.5% increase in sales relative to the other stores in the chain (which also increased their sales compared to the previous period).*
- *Employees of the daylit stores reported slightly higher satisfaction with the lighting quality conditions overall than those in the non-daylit stores. Most strikingly, they perceived the daylit stores to have more uniform lighting than the non-daylit stores, even though direct measurements showed the daylight stores to have much greater variation in both horizontal and vertical illuminance levels.*
- *Store managers did not report any increase in maintenance attributable to the skylights.*
- *The chain studied was found to be saving about $0.24/sf per year (2003 energy prices) due to use of photocontrols, which could potentially increase up to $0.66/sf per year with an optimized daylighting system.*

An earlier 1999 study for Pacific Gas and Electric Company on behalf of the California Board for Energy Efficiency Third Party Program by HMG[60] examining the impact of skylighting and retail sales found;

[59] California Energy Commission 2003 Daylight and Retail Sales P500-03-082-A-5 http://www.h-m-g.com/downloads/Daylighting/A-5_Daylgt_Retail_2.3.7.pdf

[60] Pacific Gas and Electric Company/Mahone1999 Skylighting and Retail Sales An Investigation into the Relationship Between Daylighting and Human Performance http://www.h-m-g.com/downloads/Daylighting/retailc.pdf

'Positively and significantly correlated to higher sales. All other things being equal, an average non-skylit store in the chain would likely have 40% higher sales with the addition of skylights, with a probable range between 31% and 49%. This was found with 99% statistical certainty. After the number of hours open per week, the presence of skylights was the best predictor of the sales per store of all the variables that we considered. Thus, if a typical non-skylit store were averaging sales of $2/sf, then its sales might be expected to increase to between $2.61 and $2.98 with the addition of a skylighting system.

The skylights are seen to have a major impact on the overall operation of the chain. Were the chain to add the skylighting system to the remaining 33% of its stores, yearly gross sales are predicted to increase by 11%. The difference between having none of their stores skylit and all their stores skylit is an increase of up to 40% in gross sales for the retail chain.'

6.1 Aesthetic and sales benefits of daylight in retail buildings

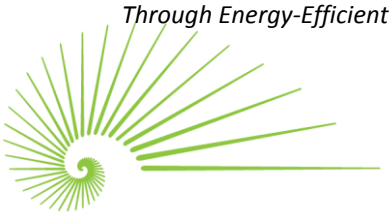
Some retailers have discovered the benefit or the affects that daylight can have on the retail environment. Retailers are starting to use daylighting in their stores specifically to enhance their store environment, increase sales, create a more pleasant shopping environment, attract customers, and improve colour rendering. Using daylighting also has aesthetic benefits that encourage customers to enter the store.

Edwards and Torcellini reported the following key findings from two retailers, which corroborates the findings of the studies presented above: -

- Substantiating the claim of increased sales, the chief architect of Southern California Edison, Gregg D. Ander, applied daylighting to stores for the largest retailer in the country and possibly the world. Ander said this retail chain has had successful sales for the daylit stores when compared to the non-daylit stores in the district. When comparing about 11 stores in one district, the daylit stores sold 28% more product than the other stores.

- The first Wal-Mart Eco-Mart store was built with half the store having skylights. Increases in sales, employee perspective, and shopping habits have occurred in the section of the store with skylights compared to the section without skylights.
    - *'The effects of the skylights on retail sales, the employees, and shopper reactions were unexpected. Retail sales in the daylit area of the store are higher than the area without skylights, and other Wal-Mart stores in the area. "…The sales pressure [sales per square foot] was significantly higher for those departments located in the daylit half of the store[61]'.*
- Target constructed an entirely daylit store in Phoenix, Arizona in 1998. It is claimed that this store has provided a 15% to 20% increase in sales over equivalent non-daylit stores. The impact was so beneficial it resulted in Target opening another fully daylit store in 2000.

[61]Romm, J.J; Browning, W.D. (1994). "*Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design*," Snowmass, CO: Rocky Mountain Institute.



Conclusions

The majority of peer-reviewed research associated with the benefits of daylight has been undertaken in healthcare and educational buildings, where the body of evidence is clear and compelling. Research has also been undertaken associated with the workplace and in retail buildings which confirm the findings from healthcare and educational establishments.

Surprisingly little research has been undertaken associated with optimum use of daylight in residential buildings. Since a key function of the home is to provide a place to rest and sleep, it is recommended that further research should be undertaken to determine the health and wellbeing benefits associated with daylight in the home environment.

The key findings have demonstrated that in healthcare, access to daylight provides; a reduction in the average length of hospital stay, quicker post-operative recovery, reduced requirements for pain relief, quicker recovery from depressive illness and disinfectant qualities. There is also a growing body of evidence that daylight plays a critically important role in the prevention and treatment of obesity, heart disease and other illnesses exacerbated by stress.

In educational buildings access to daylight has been shown to result in a dramatic (and demonstrable) improvement in student academic achievement, behaviour, calmness and focus.

In the workplace numerous studies have identified a preference to work near windows and under conditions which fully utilise natural rather than artificial light. In retail establishments, research shows that a substantial improvement in sales can be achieved in daylit shops.

In buildings of all types, studies show that occupants' value very highly views from windows (ideally of the natural world). The impact on staff stress reduction, patient outcomes and educational attainment are all clearly established and demonstrably linked to being able to establish a visual link from inside a building to the world outside.

Daylight deprivation in buildings has been shown to have hugely damaging consequences. Without access to daylight the human body-clock becomes disrupted –it needs recalibration on a daily basis and unless we receive adequate daylight overwhelming medical evidence suggests that humans become stressful and agitated. Any disruption to our circadian rhythm has highly negative consequences in terms of our health, happiness and wellbeing.

The body of evidence of the benefits of daylight in buildings was researched in very specific building types, e.g. hospitals, schools, offices, etc. Studies demonstrating that the same benefits can be realised in the residential sector have not been identified. This is possibly due to the complexity of undertaking such a study (given the number of variables in the home environment).

However, there is a high degree of probability that the same generic benefits, (i.e. well-being, quality of life, health benefits etc.) exist in homes associated with the positive benefits of daylight in establishing and recalibrating the circadian rhythm. This is likely to be particularly important, given the role of the home in providing a place to rest and sleep. This would also be consistent

with the observation of architecture in different parts of Europe which reveals that, in the Northern parts of Europe where daylight is limited during winter, glazed areas in houses and apartments tend to be larger as occupants wish to maximize daylight.

Glazing has a key role to play in enabling the construction of buildings which are sustainable from an environmental, social and economic perspective. Designers sometimes neglect the social impacts of sustainability. The provision of adequate daylight and establishing views to the natural world through appropriately sized and positioned glazing is of fundamental importance –genuinely sustainable buildings must not only reduce environmental impact, they must also be fit for people.

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