Comfortable with Sunlight Design

Passive design strategies to improve comfort and health through natural lighting

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Preface

Introduction

How should a home be designed if the health and comfort of the occupant were the principal design criteria? Is it possible to design a building that promotes a healthy lifestyle?

The questions above are the drivers for the development of this manual. Most focus on sustainable buildings has been directed at the aspects of energy and materials: developing efficiency of energy while building with local, durable materials. However, health is the most valuable asset we have, while energy is only one factor of sustainability. Hence, the foremost target of sustainability should be to promote and maintain good health and healthy buildings, and therefore, this is the basis for the focus of this manual: a tool with which to create awareness for possibilities to design healthier homes.

This manual suggests a non-comprehensive vision to design, renovate, or remodel healthy homes or other spaces for living in order to support their occupants in terms of their general comfort, health, as well as their biorhythms and their sleep-wake cycles. Because health is determined by several factors it was decided to focus on an important aspect lacking in current homes: adequate natural light. Today, most people spend an average of 90% of their time indoors and many of the symptoms of ill-health are due to a lack of sunlight, and can be prevented through the benefits of the sun.

The manual is based on findings of literature research on the benefits of sunlight to health, and the best ways to harness these benefits through design interventions.

Currently, most buildings are designed or renovated to achieve more efficient energy output, and although we recognize the need to re-create the building stock to a more efficient level by means of better thermal insulation, more efficient windows, and heating, cooling, and ventilation systems, these changes should not be performed at the expense of health, wellbeing, and comfort of its occupants.
As a result, we believe that redesigning or renovating a building successfully should target the best health and comfort performances, in addition to good energy performance, since the primary objective of a building is to provide a healthy and enjoyable place for the residents.
The principles offered in this manual can be used as a guide to improve, design, remodel buildings of all types and are relevant for both new and existing buildings.

Comfort and Health

Natural light has more effect on your health than most people know of. This chapter is creating awareness of the positive and negative aspects of sunlight on your health.

Visual Comfort

Daylight is often the primary source of light for the interior. When designed with care, it can provide comfortable experience in the desired space. Comfort in relation to the sun, however, is not solely concerned with heat. The visual component of solar design can certainly be seen of equal importance. In most cases visual discomfort in relation to glare or contrast is caused by natural lighting and therefore should not be taken lightly.

When the light distribution into the indoor environment is more balanced, the occupants will have a higher level of visual comfort.
When it comes to visual comfort there are some principles to keep in mind:

-The more intense the task, the brighter the light required
-The greater the contrast, the easier the comprehension
-Glare makes it difficult to see the object of attention

It is important to realize that people value to have contact with the outdoor environment. To meet this demand, daylighting is a significant factor for the indoor environment. It is interesting to know that people spend the majority of their lifetime indoors. It is therefore important to design buildings with enough daylight access.

" That state of mind that expresses satisfaction with the visual environment."

Walter Grondzik

Mood

There are many ancient and modern examples where architectural design is based on daylight access to respond to the occupants. Lighting in sacred and religious places often have a significant impact on the viewers who get manipulated by dramatic lighting. Mood changes can be experienced in social places such as theaters and restaurants as well. Less dramatic lighting in a regular office building for instance, does have a more subtle influence on our mood.
The presence or absence of light can be positive or negative on a person's mood.

Stress

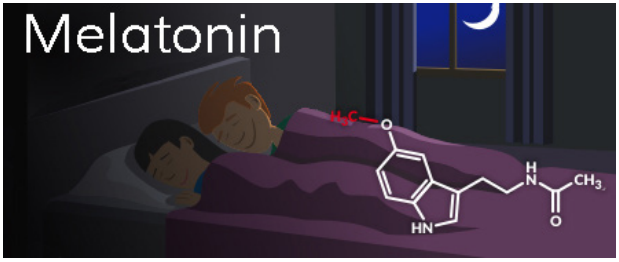
Our body produces cortisol, known as the 'stress hormone'. Our body needs it only in the right amount, as cortisol is involved in various processes like the regulation of blood pressure, maintenance of blood sugar and our immune system. Too little or too much cortisol can disturb these processes and cause multiple illnesses. The production of cortisol is related to the amount of daylight, with high levels during daytime and low values at night. This is also visible in seasonal changes, where the values are higher during summer than during winter.

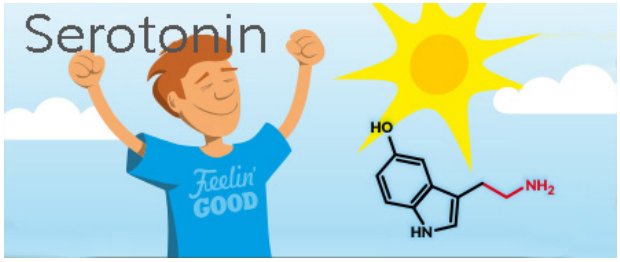
Sleep

High levels of daylight exposure during the day in combination with darkness throughout the night improves the biological perception time in your body, in turn that improves sleep quality.
Environments with windows have more daylight exposure and as a result a gain of 47 min. of sleep per night can be won in sleep efficiency as opposed to environments without windows and therefore less daylight exposure.

Restorative qualities

A variety of health-related problems like skin problems, depression, jet-lags and sleep rhythm disturbances are increasingly being treated with the restorative qualities of daylight. In turn this improves mood, energy and allows for a biological perception of daytime rhythm.



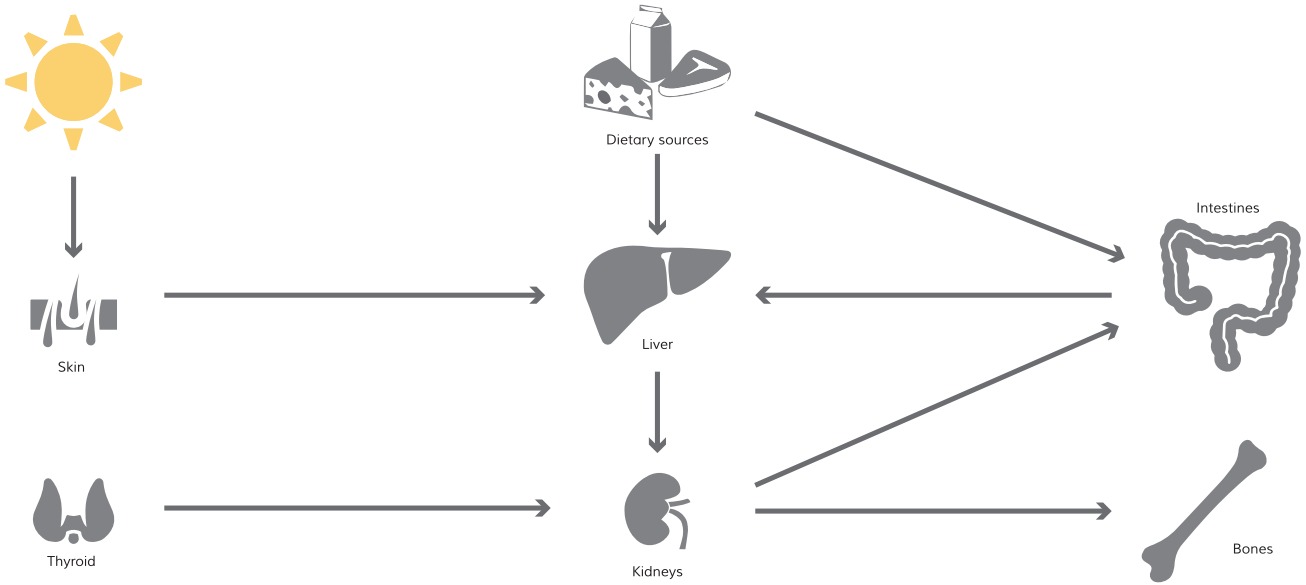


Sunlight and vitamin D

We cannot directly consume vitamin D; we need sunlight for it to be produced. By eating meats, fish, and other nutrients, we consume a type of cholesterol (7-Dehydrocholesterol), which is stored close to the skin surface. When sunshine hits our skin, this cholesterol is slowly converted into vitamin D as it moves downwards towards our blood vessels (illustration below).

Vitamin D regulates absorption of nutrients in the intestine and kidneys. It helps maintain balanced concentrations of calcium and phosphorus in the bones, essential elements for growth and bone structures. Inadequate sunlight causes declined Vitamin D levels (hypovitaminosis D) , which can cause a number of health problems: bone thinning, depression, cancers, immune, and cardiovascular problems.

By spending the majority of our time in indoor environments with inappropriate daylight, the prevalence of those disorders has been steadily increasing since the industrial revolution.



Bones

From the skin, vitamin D travels to the liver and kidneys, where it is helps in the processing of phosphate and calcium for bones.
With age, the skin gradually loses its ability to photosynthesize and produce vitamin D, as a result, elderly people suffer more from deficiency than younger populations. The relationship between hypovitaminosis D and bone thinning among older people has been demonstrated abundantly: the problem peaks at the end of the winter seasons, when daylight is short and exposure has been minimal for months.
Similarly, in countries where dress codes requires women to overly cover themselves, rates of rickets- a disease of deficient bone growth due to lack of vitamin D, calcium, and phosphate, which has been eradicated in western countries- are relatively high. This is due to the fact that as women have less pigmentation than men, they need more Vitamin D, thus, more sunlight exposure.

Sunlight as disinfectant

Sunlight has effects in our bodies that directly impact our health, but sunlight also has effects in the environment that influence health. For example, UV radiation exposure on linen, fabric, carpets, mattresses, has shown to kill bacteria, some viruses, dust mite, and other pathogens that cause diseases, allergies, or other reactions to people.

Cancer prevention

a. Skin cancer

There are many causes of skin cancer (malignant melanoma), one of them being excess UV-B radiation. Excessive UV-B radiation can damage DNA of skin cells, when this damage affects the growth of skin cells, they become cancerous. These harmful effects of radiation can be prevented by avoiding excessive exposure to direct sunlight during the midday and by seeking natural shade.

On the other hand, UV exposure helps in the treatment of skin diseases, such as eczema, vitiligo, or psoriasis.

b. Other cancers

While one of the causes of skin cancer is UV radiation, research also suggests that the exposure to UV-B radiation has been inversely correlated to the prevalence of 16 types of cancer, mostly in the digestive and reproductive systems. Thus, through Vitamin D, daylight can prevent a number of internal cancers, such as rectal-, prostate- and breast cancer. Laboratory experiments showed that the growth of cancer cells exposed to active Vitamin D was suppressed.

It has been shown that in the UK, excessive sunlight exposure caused 1600 skin cancer deaths in 2007. However, 25000 deaths were recorded from internal cancers due to insufficient sunlight exposure.

Sunlight, heart and blood

a. Cardiovascular system

Cardiovascular disease represents 30% of yearly global deaths. Medical tests show that people with heart failure commonly have a vitamin D deficiency, which is also responsible for cardiovascular disorders, such as hypertension. Hypertension is a major risk for stroke and infarcts, among other diseases. It has been shown that sunlight exposure lowers blood pressure, and in summer people with hypertension tend to have lower pressure than in the winter. In addition, the average hypertension increases as the distance with the equator increases.

Though the process of how sunlight lowers blood pressure is still not clear, it has been proposed that UV-A transports nitrogen oxides stored in the skin towards blood circulation, allowing for increased blood vessels, thus, lowering blood pressure.

b. Diabetes

Diabetes is a metabolic disorder whose characteristic is high blood sugar. Two types exist: one and two. Type one diabetes requires insulin injections, as cells from the pancreas are unable to produce insulin – a hormone that feeds sugar to the cells from the blood.

Sunlight exposure, and specifically UV-B radiation increases insulin secretion in adults. Studies have shown that in the summer, lower levels of blood sugar are recorded. In addition, the insulin secreting cells in the pancreas have been shown to increase their performance in the presence of vitamin D. Finally, vitamin D was shown to drop insulin resistance in diabetic women, while increasing their insulin production.

Lighting strategies

With efficient lighting solutions it is possible to distribute or block direct sunlight without reducing the illuminance level. Many solutions even increase the illuminance by light distribution towards the back of a room.

Icons explained

On the following pages possibilities for daylighting strategies are presented, these are divided into top lighting and side lighting. Each of these strategies present a possible solution for making use of natural lighting. Between these strategies, a number of characteristics are identified, as every strategy has its strengths. The icons on the following pages represent the characteristics mentioned above, for each strategy it shows whether it is applicable or not.

Reflection
Solution reflects direct light

Diffuse reflection
Solution reflects diffuse light

Glare
Solution has a risk of glare

Altitude
Solution works optimal with a particular altitude of the sun.
H represents high altitude, L represents low altitude

Sunny day
Solution works optimal with sunny day conditions

Overcast
Solution works optimal with overcast conditions

View
Solution does not block the view towards outside

Static
It is a static solution

Dynamic
This solution can be made dynamic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Side Lighting

Traditional designed side lighting systems often have the problem of uneven distribution of natural light. Additional systems have the ability to distribute daylight farther into the building.


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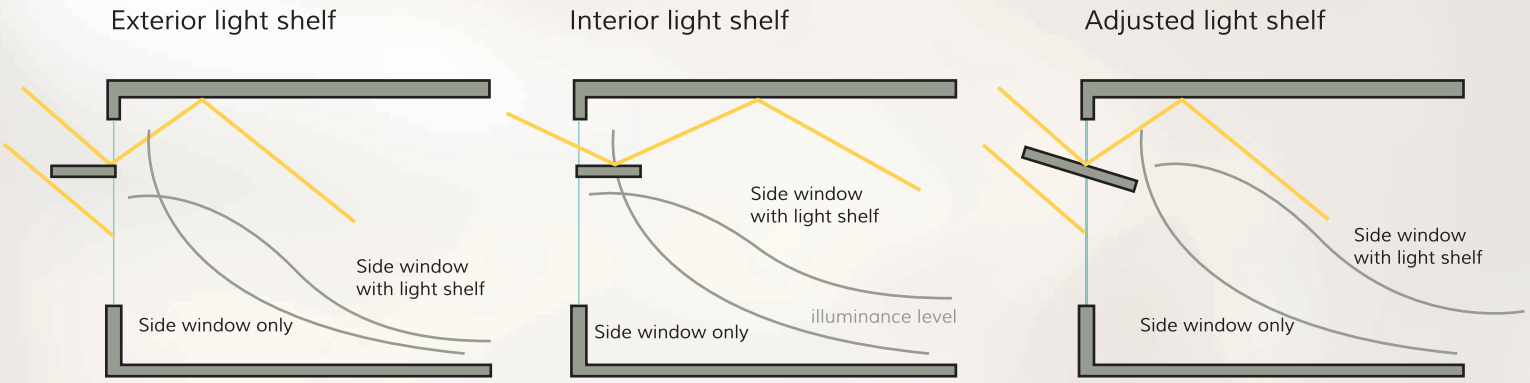
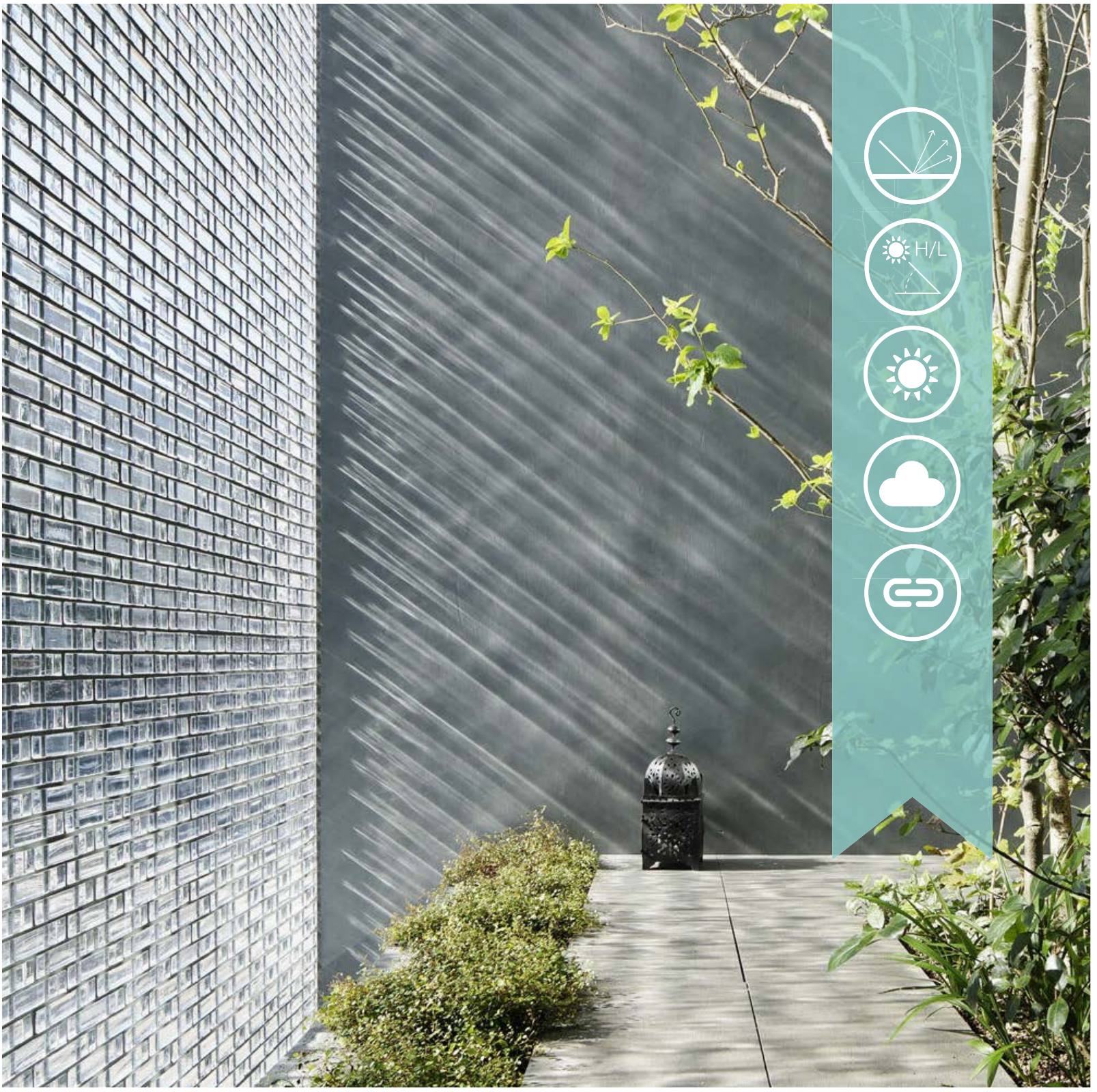


Light Shelf

Light shelves are designed to allow for daylight and sunlight to pass into the back of a room. By catching daylight on a surface and reflecting it up against the ceiling, it in turn refracts against the ceiling and extends the reach of daylight. When a light shelf is applied, the window is divided in two. The lower half serves more for the view while the upper half is more efficient allowing daylight to reach into the room. In addition to facilitating a farther reach of daylight into the room, a light shelf also provides shade and reduces glare from the outside sun. It is important that the reflective surface of light shelf is not too polished, as that might cause spots on the ceiling like a watch is know to do when sunlight reflects off it. The placement of light shelves can be done in three general ways;

- In the interior, this allows for the daylight to reach into the room farther but offers less shade.
- On the exterior, this provides more shade but the daylights' reach is limited.
- A combination of in- and exterior or an adjusted angle.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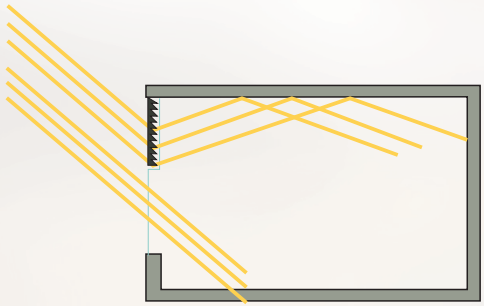
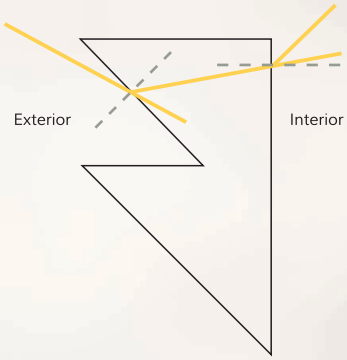
Refraction of sunlight
a prismatic panel

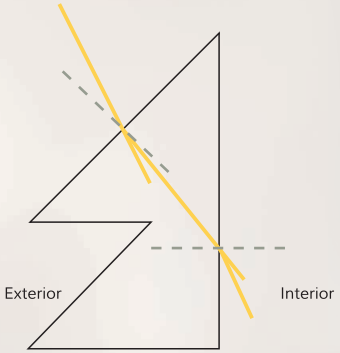


Prismatic panel inserted in a window.
Redirecting hindering sun while allowing direct sunlight at a lower level.

Different orientations of prismatic elements



Sun rays are refracted upward, against the ceiling and reflected into the back of the room

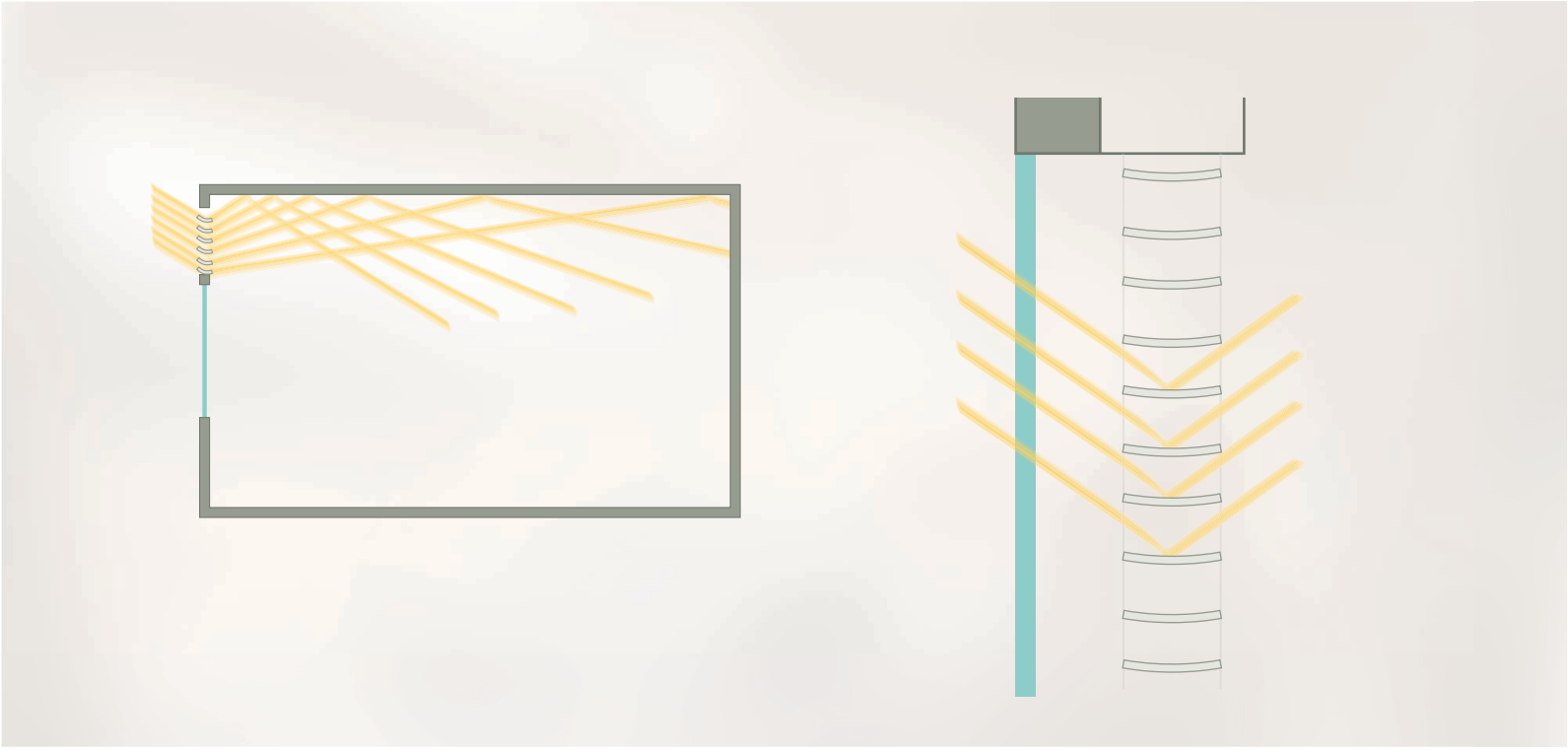


Sun rays are refracted downward, resulting in less light making it to the back of the room.
This makes for more of a shading effect

Prismatic panels

Prismatic panels have a variety of different appliances, they can be the entire facade, part of a facade or a film for an existing facade. The principle of a prismatic panel is refracting the light that hits it. Meaning the light is dispersed though the area behind it making it less focused and intense. In addition to refracting the light, prismatic panels may also shade by reflecting sunlight away from the interior. The Prismatic panels technology has been around for a while but the lack of transparency compared to regular glass made it less desirable. The advance of the technology of prismatic film makes it an interesting choice nowadays. Apart from the gain in transparency the film allows for more flexible appliances.


Accès aux trains
Voie
4
Sortie
H/L



Louver systems

This system is designed to capture sunlight falling in the front of the room and to redirect it towards the back of the room. The daylight level in front of the window will be reduced, but the daylight in the back of the room will be increased. The system works optimally under sunlight conditions. Louvers can be designed to be static or dynamic. Dynamic louvers can be controlled automatically by the movement of the sun. Automated louvers tend to perform better than static ones but require calibration and algorithms that need adjustment depending on the illumination needs.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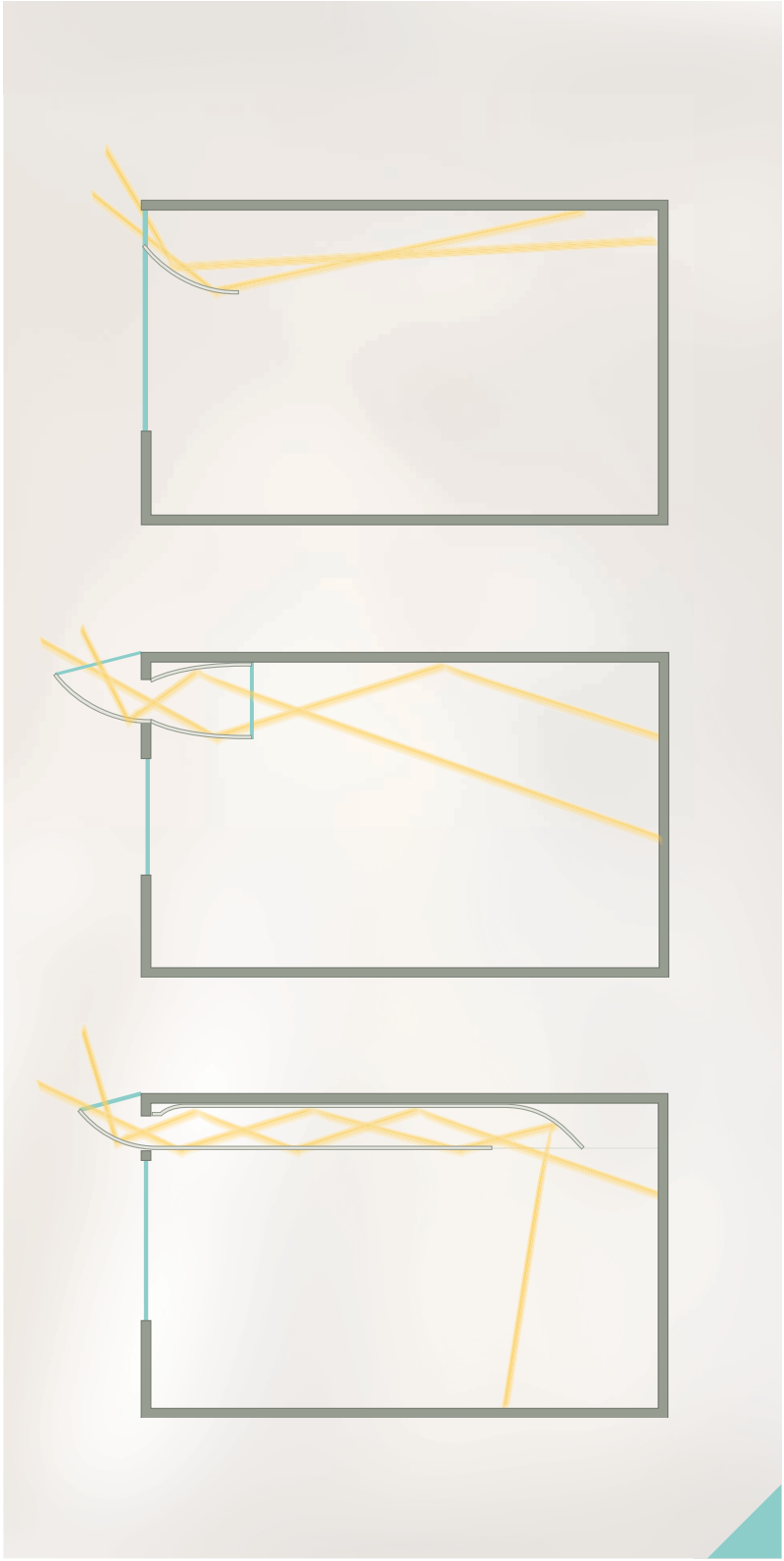
Anidolic Systems

The principle of an Anidolic System are two concentrating mirrors of parabolic shape that capture the incoming light over a wider area and distributes it inside the room.

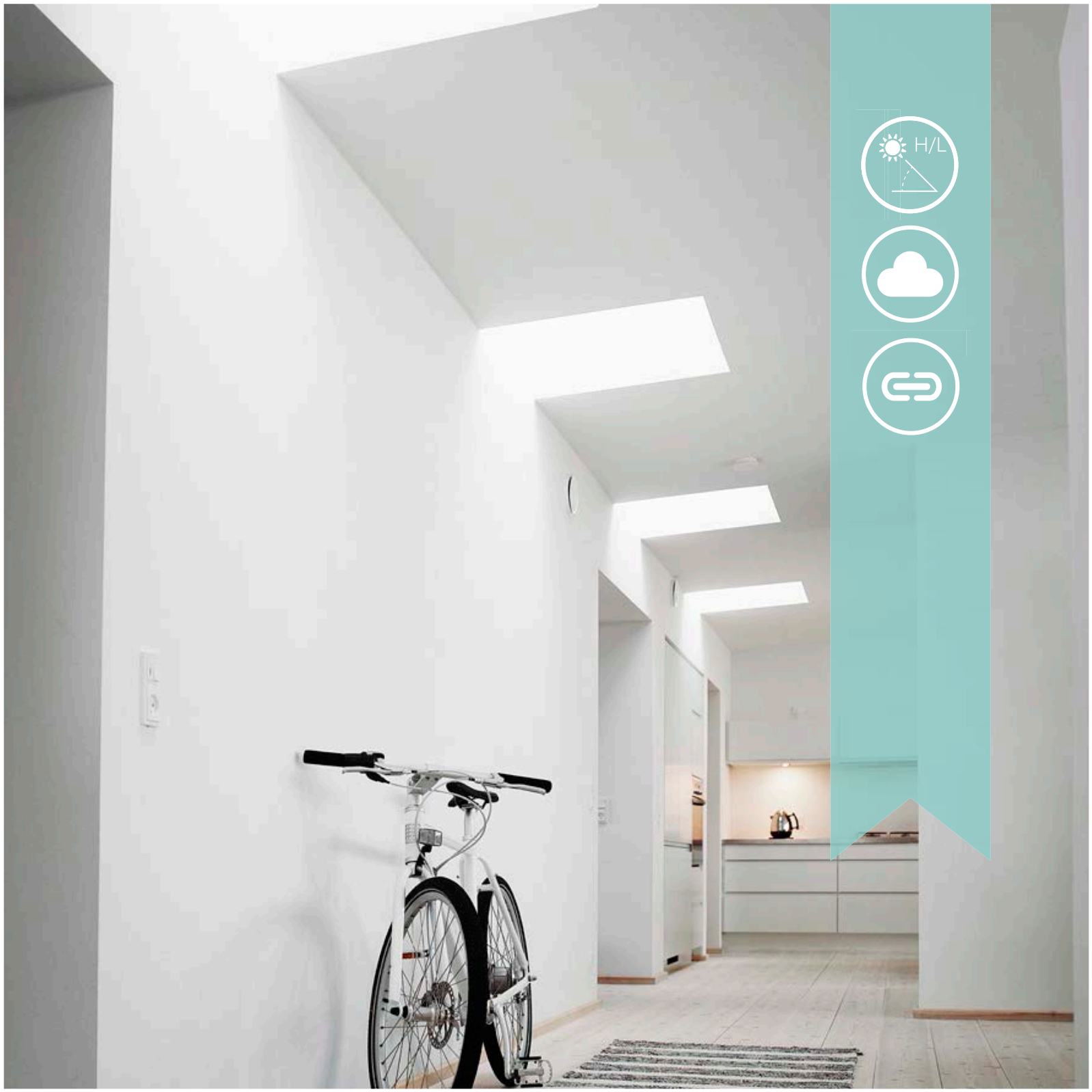
This system can be combined with a light duct to lead the light through the light tube and distribute it inside a room in a more controlled manner.




Family

Top Lighting

Top lighting in general is more suitable for colder climates with overcast prevalence compared to side lighting. This is because the sky luminance at the zenith is three times higher than at the horizon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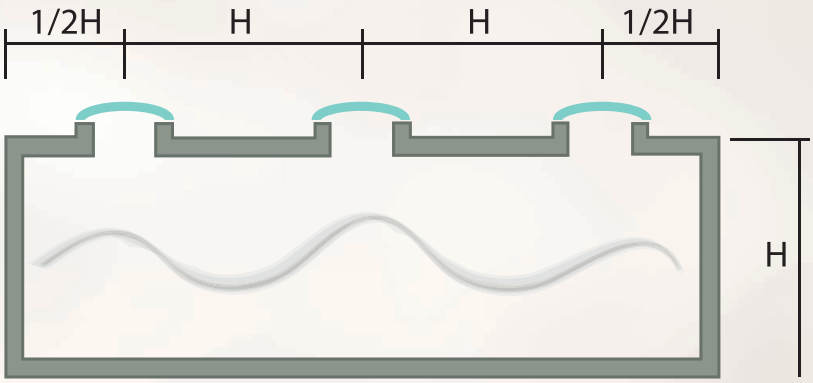
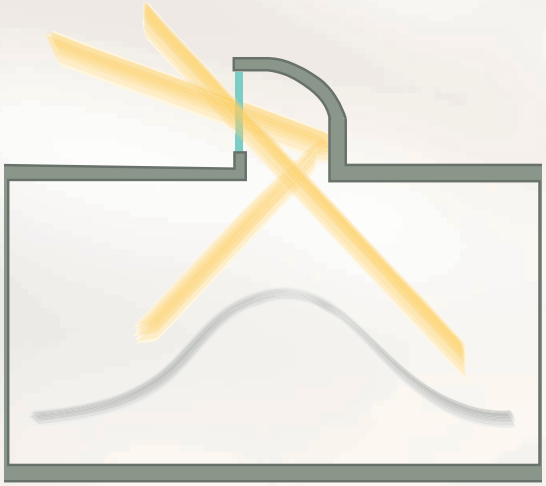


Rule of thumb for spacing and uniform distribution of Sunlight

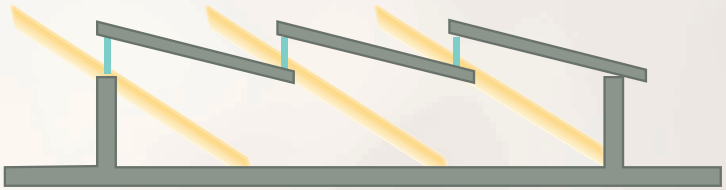
Sky-lighting 1

Skylights are one of the simplest forms for daylight strategies. These are roof openings that let daylight pass into the interior. Recommended for residential buildings in colder climates that tend to have overcast skies. The best strategies with skylights is to install multiple of them which will allow for a more uniform distribution of daylight.

The effectiveness of the skylights depends on its size, the reflectance of walls, and the light transmittance of the chosen glazing. Glazing choice can be used to avoid glare and to better diffuse daylight into space. Even with overcast, skylights are up to ten times more efficient than side lighting in terms of illuminance, exposure, and diffusion.



Single sided roof monitor
to allow Winter sunlight, but not
Summer sunlight



Sawtooth strategy for directional distribution

Sky-lighting 2

Sawtooth roofs, originally used in factories and currently implemented in residential buildings, are top lighting strategies that have a vertical glass for sun admittance, that when facing north, its function is to admit diffuse sunlight, while when facing south, direct sunlight enters. This strategy is particularly effective for summer periods or high sun because the solar furnace effect, which overheats the space, is eliminated by reflecting sun for summer altitudes but allowing sun for winter altitudes to enter. A disadvantage of sawtooth solutions occurs in the winter, when the windows let warm air to rise in the space, causing heat loss.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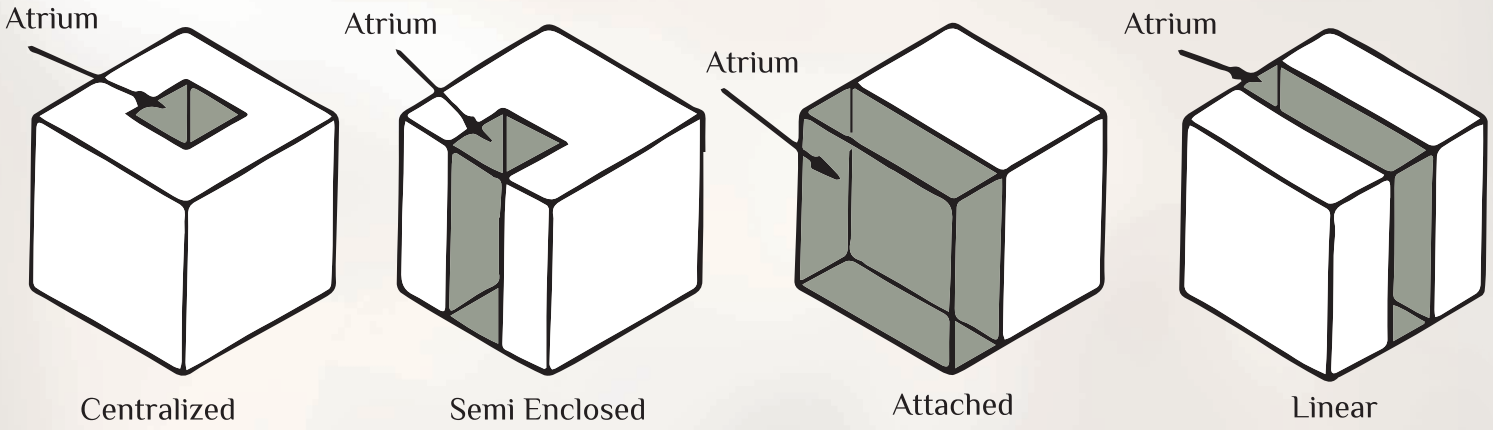


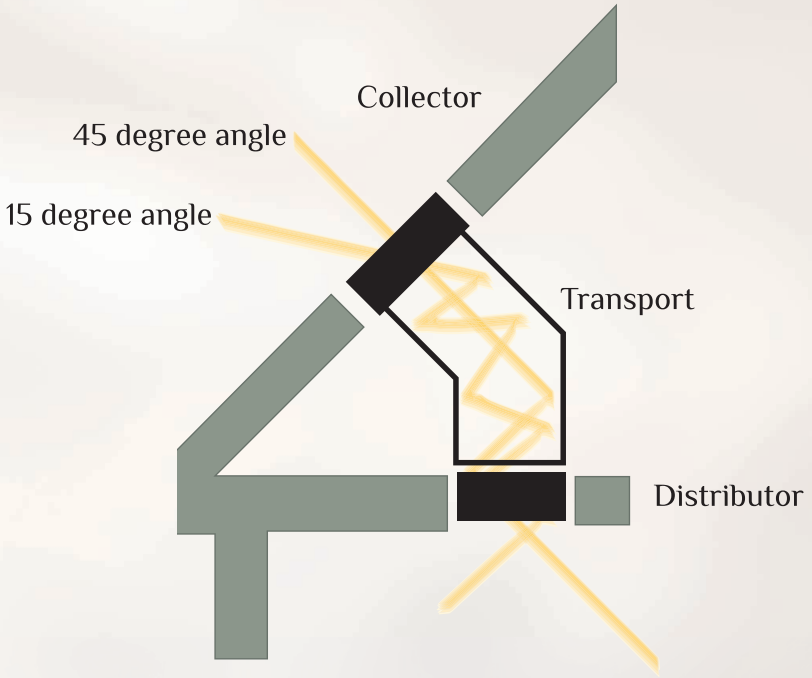
Atria

Atria are large light wells that allow the core area of the building to be properly lit by daylight. Though popular in office or commercial buildings, at homes it is beneficial for spaces situated far away from exterior walls.

The atrium allows daylight to the spaces around it, while at the same time illuminating the core of the building with natural daylight. During winters it acts as a hot spot, concentrating heat and light for the occupants. Atria can take any shape that best suits the building and their distribution of daylight depends on its proportions rather than size and to the reflectance of the inner surfaces of the atrium. These elements can contribute to light loss within the atrium.

A final design element of atria are their canopy systems, which can also determine the light admittance. For overcast conditions, pyramidal canopies are recommended over sawtooth canopies.


H/L



Solar Tubes

Solar tubes are designed to transfer daylight into lower floors or core areas of buildings with multiple stories. With solar tubes one can experience weather changes, passing clouds, and the moonshine. Areas that are not suitable for skylights can be illuminated by solar tubes, in addition they provide several benefits over artificial light in a given location. An increase in the amount of natural sunlight exposure, contributes to peoples' wellbeing, reducing the possibility of SAD, while saving energy.

Solar tubes consist of three elements: the collector, transport, and distribution.

The light collection systems may be a simple hole covered with a clear polycarbonate dome, an optical lens or a solar tracking mirror. Light transportation consists of mirrored or coated ducts whose coating can achieve 99% reflectance. Transport can also be achieved with several lenses, fiber optics, or prisms. Light pipes can be made by combining all three systems, making for a wide diversity.

Residential pipes and the most widely available are the mirrored systems. Their efficiency depends on the reflectance of the mirror and the light ray entry angle. The smaller angle, the higher efficiency. In addition, bending to change the direction of the pipe to avoid obstacles, can cause 14% of efficiency per bend.

Strategies compared

Side lighting	Light shelf
	Prismatic panels
	Louver system
	Anidolic system
Top lighting	Sky-lighting 1
	Sky-lighting 2
	Atria
	Solar tubes

✓			✓H/L	✓		✓	✓	✓
	✓		✓H/L	✓	✓		✓	
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✓		✓	✓H	✓		✓	✓	
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Images in order of appearance

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This manual on designing healthy buildings through sunlight design is divided into three parts: the benefits of the sun in humans and its effects in comfort and health, design strategies to improve daylight in homes, and finally a comparison of the different strategies.

Sunlight can bring health from a physical to a psychological level: it can relieve stress, improve the mood, while also balancing hormones. This lets us lead a healthier lifestyle and allows for better sleep. Additionally it can help lower risks of cancers, and provide more hygienic environments.

The design strategies proposed for harnessing these benefits are presented in two ways: side- and top-lighting. Each strategy has advantages depending on the orientation of the building and their location within the building as well as seasonal differences.