Report on the Development of the Swedish Healthy Home

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Acronyms and Abbreviations used in this Report

CCT – correlated color temperature of a light source
CRI – color rendering index of a light source
COTS – Commercial off-the-shelf
CS – Circadian stimulus
DLMO - Dim light melatonin onset
K – Kelvin temperature – a measure of the correlated color temperature of a light source
LRC – Lighting Research Center
LED – Light Emitting Diode
Lx – Lux – A measure of illuminance or light level
SEA – Swedish Energy Agency

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1. Overview of the Swedish Healthy Home Concept

Introduction

A home serves several functions: it is a place to live, to celebrate, to rest, and to enjoy. It is a place where we gather with family and friends, a place where we can relax, do the things we most enjoy, and the place where we go to sleep. At its most basic, it is a place that keeps us safe and warm, no matter the weather outside. Shelter is a basic human need. Lighting, whether provided by daylight or electric light, is also a basic human need and should support all of the functions and activities within a home. It should also support the vision, safety, comfort, health and well-being of the home’s occupants and visitors.

For the past several thousand years, people have sought to “extend the day” within interior environments, including homes and work places, and augment the lighting provided naturally through daylight, first through the use of fuel-based lighting solutions, such as candles, lanterns, and gas lamps, and then through the use of electric lighting. This light brought with it a cost. Candles, for example, were very costly, and therefore were typically only used for a short period during the evening. With the advent of readily available and relatively inexpensive electricity, light could be extended far into the night. However, electric lighting still has a cost not only to home owners, who must pay for the electricity and the devices that produce the light, but also for society which must suffer the effects of pollution brought on by the ever-growing demand for electric power.

Readily available electric lighting has allowed people to perform tasks well into the night, no matter the season of the year or the availability of light from the sun. Most people in Sweden spend a majority of daylight hours indoors. This shift away from spending days primarily in outdoor environments with direct exposure to high levels of light from the sun, coupled with the ability to provide electric light well into the night, has disconnected our wake and sleep schedules from the natural rhythms of the day-night cycle, with many people working during periods when our ancestors would have been sleeping. Uncoupling our biological rhythms from the natural day/night cycle has been shown to cause difficulties including disrupting sleep patterns and other, potentially harmful, effects on our health. So, while we need electric lighting to support the enjoyment and function of our homes, we must be careful that the lighting also supports our overall health and wellbeing.

Many characteristics must be considered when designing a healthy home including building materials, temperature regulation, airflow, and even acoustics. However, this paper only addresses lighting considerations. This paper lays out a framework for lighting a healthy home in Sweden. At its most basic, this means the integration and control of daylight and electric light to properly support all of the functions that home occupants need, while also supporting their health and well-being, and eliminating wasted energy. Lighting in a healthy home is effective for people, energy-efficient, well-controlled, and environmentally sustainable.

The Swedish Home

Houses and apartments in Sweden are not unlike those in the United States (US), although they tend to be slightly smaller, on average. The average single family home in Sweden is 148 square meters (sm), and the average apartment is 73 sm. Approximately 80% of residential buildings in
Sweden were constructed before 1980. The floor plans of some typical homes in Sweden are shown below:

Ground floor of a typical single family home in Sweden.

First floor of a typical single family home in Sweden.
A current trend in Swedish homes is to have the living room open to the kitchen area, a configuration that is called a “great room” in the US. Homes in Sweden predominantly use light colored interior finishes on walls and ceilings. In Sweden there is limited access to daylight during the winter months, due to cloudy skies and long nights. 28% of residents in Sweden report that there is too little direct sunlight in winter, including 32% in Stockholm. Most homes have access to the internet and use computers or other visual displays. Perhaps due to limited daylight during winter months, the average hours of lighting use in Sweden is slightly higher than typical hours of use in the US. Therefore, energy savings potential from the use of more efficient lighting is greater. Typical annual hours of lighting use in Swedish homes is shown in the chart below:

<table>
<thead>
<tr>
<th>Light hours</th>
<th>Living</th>
<th>Kitchen</th>
<th>Bedroom</th>
<th>Bathroom</th>
<th>Laundry room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartments</td>
<td>1485</td>
<td>1365</td>
<td>868</td>
<td>637</td>
<td>11</td>
</tr>
<tr>
<td>Single family homes</td>
<td>1819</td>
<td>1676</td>
<td>1262</td>
<td>626</td>
<td>403</td>
</tr>
</tbody>
</table>

In Sweden, 27% of population reports sleep disorders, 46% are overweight or obese, and 20% report problems of anxiety, worry, or fear. Depression, obesity, and sleep disorders may all be affected by circadian disruption.
Design Goals

There are several design goals that must be kept in mind when laying out the lighting for the Swedish healthy home. A home should be able to provide what we need no matter our age or abilities. This concept is typically referred to as “universal design.” Lighting in a healthy home must support universal design and meet the needs of all home occupants and visitors. The following design goals will guide the development of a lighting plan for the Swedish healthy home.

**Provide good visibility**

Lighting in the healthy home must support the vision of home occupants, no matter their age or visual abilities. The interaction of lighting and visibility is a well-researched area and most current recommendations for lighting are based predominantly on visual parameters. We know through research, for example, that people need different levels of light depending on the tasks they are performing. If we are performing a visually-demanding task, such as threading a needle, we need more light than if we are simply eating a meal. Research also tells us that this light must be well-controlled. We cannot thread a needle, for example, if a bright light source is shining directly into our eyes. As we age, and for those with visual impairments, this need for light becomes more acute. Older adults need more light to see, but are also more sensitive to bright light sources in their field of view.

Good visibility is important, but lighting all areas of a home to high levels to support seeing fine tasks would lead to wasted energy and a home that would not support other functions such as relaxation, rest, and viewing self-luminous devices such as tablets, computers, and televisions. Therefore, the lighting system in a healthy home will need to be flexible and distributed to provide the levels of light when and where needed to support the wide variety of tasks that take place throughout a home, often simultaneously.

**Minimize falls and other visibility-related accidents**

Lighting supports vision. If we can clearly see around us, we can easily avoid tripping over objects or hazards within our homes and easily navigate through rooms, hallways, and outdoor areas. However, as we age vision becomes even more important to postural stability and control, and can assist in preventing falls.

Older adults rely heavily on their visual systems to give them horizontal and vertical cues in the environment. This allows them to properly orient themselves within the environment. A key to this concept is providing lighting that accents or accentuates vertical elements within a space, for example, outlining a doorway with light as seen in the illustration below. This vertical cue allows a person’s visual system to quickly identify proper orientation within the space. This leads to
increased postural stability and control. This is an area of lighting design that is not well understood by most people who choose and design lighting for homes and other residential settings. When properly designed, lighting can improve postural stability when getting up from a seated or reclining position and can also improve the stability and speed of an older person’s gate while walking. The lighting design in a healthy home will support these functions both during the day, when the home is typically lighted, as well as during the night, if a person needs to get out of bed when the home is typically dark and other home occupants are asleep.

In the experiment pictured above, researchers noted significant interaction between door frame position (correct orientation vs. tilted, both left and right) and stability when standing. Statistical analysis showed significant differences between the two door frame conditions for the first two seconds after standing. Older adults were more stable when the doorframe was upright.

**Provide a pleasing atmosphere, with good color rendering**

Lighting not only affects how well we see and the entrainment of our bodies to the 24-hour day, it also affects the atmosphere and aesthetics of our homes. Lighting can be designed or controlled to set a certain mood, to provide a pleasing atmosphere, to highlight a piece of art, or to accentuate the architectural features of a home. The color or tone of light and of objects and surfaces within our home are also important considerations and are greatly affected by lighting. When designing the lighting for the healthy home, careful attention must be paid to aesthetic considerations including the color-tone of the light sources (i.e., how white they appear), and ability of the light sources to render colors naturally and vividly. New metrics are currently being developed that allow people to better select light sources that will provide good color characteristics. These metrics should be employed when selected lighting for homes. Carefully considering each of these criteria will help to ensure that home owners and occupants are happy with the results.
Be easy to use and maintain
A lighting system that is not working properly can cause numerous problems for homeowners. If the light sources have short lives, if the lighting flickers, or the color of light changes over time, lighting conditions will not be acceptable, and home occupants will not be happy with the system. If it is difficult to use, manage, or change the settings of a home’s lighting control systems it will quickly cause frustration for homeowners who will likely override the system or not use it as intended. These are all problems that exist with some current lighting technologies.

In the healthy home, lighting systems must provide proper conditions over time without any negative aspects. Lighting and control systems must be simple to understand, use, and adjust over time as needs change. They must also be robust and not need a lot of time or effort to program or maintain. Light sources and other system components must also be long-lived and not need to be changed or upgraded too often. This not only helps to make the system sustainable over time, but also helps to ensure that homeowners and occupants will reap the benefits that the system is designed to provide throughout the lifespan of the home.

Be flexible and allow for changes as people age or needs change
The concept of universal design requires that the designer consider the needs of people of all ages and abilities. Where lighting is concerned, this means that the lighting system will need to change or adapt as the needs and functions of the home and its occupants change over time. For example, a home may at first be occupied by a family with young children each of whom will use spaces within the home in a particular way. However, as the children grow and parents age, the functions of the spaces will change, as will the lighting needs of the occupants as they age. This can affect the placement and use of light fixtures and controls. The system may need to provide more light for certain task areas, yet do it without producing glare that will be visually uncomfortable for aging adults.

This idea of universal design requires that a designer “think ahead” when the lighting system for a home is being designed. Over the years of a person’s life their needs will change as they age, and the lighting system should be flexible enough to change with them. For example, as a person ages, they may need the vertical light system to help prevent falls that is pictured above. Designs of door frames and electric receptacles should be placed so that such a system could be easily added if needed. Uses of rooms within a home may change overtime as well. For example, what was once an office or den on the main floor of a home, might become a bedroom for someone no longer able to climb stairs. The lighting system should be adaptable to meet this new function and needs of the person who will use the room.
It is also important for the lighting in a home to be easily adaptable to meet the different uses that each room may have. A table in a kitchen or dining area, for example, will be used for eating meals with the family, but may also be used by children doing homework, by adults paying bills or working on a computer, or for playing board games. This same space may be used when entertaining friends and visitors. All of these functions will require different lighting characteristics (e.g., light level, distribution, and appearance). Flexibility and adaptability will be important considerations in the design of lighting for the healthy home.

**Integrate daylight and electric light**

When surveyed, Swedish people indicate a clear preference for daylight. In the healthy home it will be important to make use of daylight when available during daytime hours. In new home construction, this means designing windows and/or skylights to take maximum advantage of daylight for the particular site of the home, while controlling heat loss during the winter, and glare from direct sunlight. It will also be important to integrate the daylight with the electric lighting system through the use of technology so that electric lighting is not used when sufficient daylight is available.

**Improving the spatial distribution of light and controlling the time of lighting usage to ensure that lighting is provided only when, where, and in the amount needed**

It will be very important to make the most effective use of available light and avoid its waste. This will be done by designing the lighting system to ensure that light of the proper level is provided where needed for only the time period needed. This will likely mean that there will be many more, smaller points of light, or lighting fixtures, distributed throughout the home, rather than having one large fixture in the center of each room designed to provide all lighting needs. Individually controlled lighting will be provided for task and relaxation areas of the home so that it can be turned on when an occupant is using that area, and automatically turned off when that area is no longer in use.

The overall design of the healthy home’s lighting system, therefore, becomes a critical component of its effectiveness and efficiency. Too many lighting control points can be bad, and lead to confusion and dissatisfaction with the system. Too few points will lead to wasted energy and the objectives of the system will not be met. Selecting where to locate lighting system components, what types of fixtures to choose for each area, and how many to install in each space will be important considerations in design of lighting for the healthy home.
Using the most efficient and effective technology for each application within the home

Light sources and fixtures have a wide variety of distribution types. Some are designed to provide diffuse lighting over a wide area, while others are designed to concentrate their light output onto a small area. Lighting in the healthy home will likely be accomplished through the use of both types of lighting, and light sources and fixtures will be selected that provide the lighting needed in an efficient manner. The key to this will be selecting the technology that best meets the design intent for each area of the home.

All lighting technologies have pros and cons. Linear and compact fluorescent lamps, for example, are a diffuse source of light that use energy efficiently, and can last for many years under typical home use. However, they do not work well in applications where light is being directed to a small area. There can also be variations between the color of the light emitted from each lamp, and these technologies take time to “warm up” when switched on, before providing their full light output. Many people find these characteristics to be objectionable. New light sources, such as light emitting diodes (LEDs), have characteristics that lend themselves to better matching the needs of each lighting application within a home, in a very efficient manner, especially in situations where well controlled, directional lighting is desired. However, LED products tend to cost more than conventional lighting products. This light source will likely play an important role in the design of lighting for the healthy home.

Promote sleep quality, health, and well-being

The effect of light on health and well-being is perhaps the most complex and least understood aspect of lighting. Lighting can affect many areas of our life from how well we sleep, to how we feel, to how susceptible we might be to a range of diseases and health disorders. We generally cannot control the lighting we experience in public environments on a daily basis, like our workplace or school. So our home becomes the place where we can make adjustments to lighting to promote good health. Our home becomes the hub for a healthy life. In order for lighting in our home to promote good health, we must know and keep track of our
light exposure throughout the day, understand how light interacts with our biological systems, and make adjustments to the lighting in our home to promote our health and well-being.

Biological rhythms that repeat approximately every 24 hours are called circadian rhythms. Light is the main stimulus that helps the body’s circadian clock, and thus circadian rhythms, maintain synchronization with the solar day. Humans need to be exposed to a sufficient amount of light of the right spectrum, for a sufficient amount of time, and at the right time, for our biological clocks to remain synchronized with the solar day. Otherwise, we may experience decrements in physiological functions, neurobehavioral performance, and sleep.

Lighting characteristics that are effective to the circadian system are different than those effective to the visual system. In order to maintain good health and well being, people need a lighted environment throughout their day that helps their body maintain harmony with the solar day. Because most family members work or go to school outside the home, their daily light exposures will vary. Lighting in a healthy home will need to respond to the needs of family members by providing the quantity, spectrum, timing, duration, and distribution of light that best helps each of them to maintain circadian entrainment. This means it will be necessary to track each family member’s light exposure throughout each day, and then adjust lighting in the home as needed to promote sleep quality, health, and well-being.

There are several health concerns about which research is beginning to uncover possible links with circadian disruption including sleep disorders, obesity, type-2 diabetes, and certain forms of cancer. Therefore, tracking the light exposure of family members, and helping to keep their circadian rhythms entrained to the 24-day, becomes an important factor in maintaining good health. Our home is the place where can adapt lighting to help support circadian entrainment and promote good health.

**Performance Specifications**

Specifications for lighting the healthy home will detail the lighting characteristics needed to achieve each of the design goals explained above. A performance specification is a written requirement that describes the functional performance criteria required for a particular piece of equipment, a material, or a product. In this case, the specification will refer to the home’s lighting system. The specification will indicate the characteristics that the lighting system must provide for each functional area of the home and will be written in terms of the following attributes.

**A. Both electric light and daylight** – Electric light can be specified in great detail and a homeowner can be assured that the lighting system will provide very close to the amount specified, when the lighting system is properly designed. However, daylight is variable and
so at some times it will provide a specified amount of light, and at other times it will not. Therefore, the lighting specifications for the healthy home will be written so that electric light provides the lighting required at any given time, and when daylight is available in a space, a room occupant will be notified that the electric lighting system can be turned off so that energy is not wasted and lighting is provided as specified for a particular time and duration.

B. **Amount of light** – The amount of light, typically referred to in terms of illuminance or light level, will be specified using two measures: photopic illuminance (typically specified or measured on a room surface or plane), and circadian illuminance (typically specified or measured at the eye of a room occupant). Photopic illuminance is a specification of visual acuity, in other words, it is the amount of light needed to easily see and perform a particular task. Circadian illuminance is a specification of the effectiveness of the light to maintain regular circadian rhythms. Both measures will be important to maintaining a healthy living environment, and therefore both will be included in the lighting specifications for the healthy home.

C. **Spectrum** – Every white light source contains radiant energy in various regions of the visible spectrum. This is known as the light source’s spectral power distribution or SPD. The spectrum of a light source is important to defining its characteristics because the different receptor systems within our eye are more or less sensitive to different regions of the visible spectrum. Therefore, SPD will need to be included in lighting specifications for the healthy home to ensure that the lighting is meeting its goals.

D. **Spatial distribution** – The distribution of light from each lighting fixture, lamp, or lighting installation is important to meet the design goals of the healthy home. Spatial distribution refers to where the light is dispersed in a space, for example, up onto a ceiling or onto a wall or other room surface.

E. **Temporal, or time of use** – For the visual system to function properly light only needs to be provided when undertaking a visual task, or for general ambiance or circulation around a home. The time of day that light is provided is not important to vision. However, the timing of light, (i.e., when it is provided) is very important to the entrainment of the human circadian system. Therefore, a lighting specification for the healthy home will include temporal characteristics (timing) of light provision.

F. **Duration of light exposure** – Just as with timing of light, the visual system only needs light when there is a visual task, be that reading a book, or walking from room to room. A light can be turned on and visual system immediately begins to respond. However, the circadian system is much slower to respond to light and therefore typically needs it applied for a longer period of time to be effective. The duration of light exposure for the circadian system will be part of the specification for lighting the healthy home.

**Base Case Specification**

In some cases, families already living in an existing home may not be able to make significant changes to their homes’ lighting systems. Some families may also have very regular schedules and live in parts of Sweden where they are typically exposed to high light levels during daytime hours and darkness while sleeping at night. For these families, minimal interventions to their
existing lighting systems may be needed to provide a healthy, efficient, and effective lighted environment in their homes. Therefore, a design specification will be developed that can be easily implemented in an existing home where family members have regular hours synchronous with the 24-hour day/night cycle, and where no lighting-related difficulties (e.g., sleep disorders, seasonal affective disorder) exist. We will call this intervention level one.

More Complex Lighting Specification

There will be cases where some family members are working on non-traditional schedules that might include rotating shifts, night work, or travel to different time zones. Some families will also have members who might be particularly sensitive to changes in lighting conditions and may have trouble sleeping or have depression when daylight is not as available. Some families might also want to have the ability to adapt their lighting to the individual needs of family members, and desire a lighting system that has the capability to do so. In Northern Sweden, where the variations in seasonal daylight levels are more extreme, the design of the electric lighting systems and of daylighting control systems in a healthy home will be more important than in southern areas of the country where seasonal daylight shifts are less pronounced. In these cases a more complex specification will be developed that will allow for the provision of light that best meets the needs of each individual living in the household, no matter how those needs may change from day-to-day and over time. We will call this intervention level two.

Implementation

Because we have little or no control over the lighting we receive throughout our day while we are working, going to school, shopping, or undertaking other activities in public spaces, it is only in our home that we can make the lighting adjustments needed to help ensure the entrainment of our circadian systems and thus promote good health. The interventions below are examples of ways we can design home lighting systems to allow us to do this.

Intervention Level One

Intervention level one is for a household where minimal changes to existing lighting systems are desired, but the people who live in the home, who may be of different ages and abilities, want to help ensure that their lighting supports their health and well-being, while not wasting energy. For these homes, a 24-hour lighting scheme can be implemented that will positively impact family members’ visual, circadian, and perceptual systems. The lighting scheme will provide:

- High circadian stimulation during the day and low stimulation at night,
- Good visual conditions during waking hours, and
- Night lights that provide perceptual cues to increase postural control and stability for older family members who may need them.

High circadian stimulation by light can be achieved by providing at least 400 lux at the cornea using daylight and/or a circadian-effective white electric light source (i.e., more short-wavelength energy) during the daytime. Light levels recommended here are high enough and sustained long enough to assure an effect on the circadian system of people of a wide range of ages, based on a model of human circadian phototransduction developed by Rea and colleagues (2005). No more than 100 lux at the cornea of a less circadian-effective white light source (i.e., less short wavelength energy), such as a 2700 Kelvin temperature (K) lamp, and minimizing any exposure to daylight, is recommended for evening hours. The illustrations below show how a
room might look under each of these lighting conditions during daytime (left) and evening (right) hours.

This lighting scheme will include the specification of light sources and fixtures that will efficiently provide the spectrum and intensity of light needed for the daytime and nighttime recommendations. A key to providing the daytime levels will be making use of daylight where available and switching off electric lighting, either manually or automatically, when there is sufficient daylight to provide the desired levels. Electric lighting should also only be turned on in spaces that are occupied. To help ensure that lighting is not left on when rooms are not in use, automatic lighting controls (i.e., vacancy sensors) should be used. These can be easily installed as part of the existing light switches in each room. These should be manual on, automatic off sensors to avoid electricity use when there is sufficient daylight. Manual override of these controls would be provided in cases where home occupants wanted to leave lights on in a particular room, for example, a light in the front window of a home.

During nighttime hours, task lighting should be used to provide higher light levels where needed when performing more visually-demanding tasks (e.g., reading, sewing, writing). These task lights should use the same 2700 K lamps as the ambient lighting in the space, but should provide higher light levels needed by the visual system (i.e., 300 to 500 lux) depending on the difficulty of the task and the age/visual abilities of the person performing the task. These task lights should be adjustable so that they provide the light where needed and only to the level needed by the user.

These lighting interventions may be able to be accomplished using existing lighting fixtures already installed in the home, although, in some cases, it will make more sense to provide portable light fixtures in areas where people are sitting or working, rather than lighting an entire room unnecessarily. In new home construction, the lighting system or the location of electrical outlets to power lighting fixtures can be designed from the outset to provide lighting in task-areas of each room that can be individually controlled to provide lighting when, where, and at the level needed, and prevent waste. Daytime light levels will be able to be efficiently provided using daylight, fluorescent, or LED-based light sources of the appropriate SPD. These electric light sources can be purchased with the spectral characteristics needed to meet the specification. The nighttime light levels will likely be able to be most efficiently provided using LEDs of the appropriate SPD. Transparent, but low transmission shades might be deployed on bright summer
evenings to limit daylight during these hours. In all cases, manual lighting controls would be provided so that family members would be able to adjust lighting as desired.

**Intervention Level Two**

In cases where the “one-size-fits-all” specification described above is not sufficient and a more exact specification for healthy lighting is needed or desired for the various individuals that live in a household, people will be able to choose to make additional, more individualized lighting interventions. In order to do this, each individual will need some way to track their light exposure throughout the day. This is of particular importance for individuals who might work rotating shifts, changing schedules, or who work in different environments (e.g., some days outdoors, some days indoors) depending on the day of the week.

Keeping track of daily light exposure is the only way that lighting inventions in the home can be properly selected to meet each individual’s needs.

At the heart of this specification is a personal lighting measurement device that each person who lives in a household will wear throughout the day. This device will continuously measure and record each family member’s exposure to light. This device will be small, and will be able to be mounted on an eyeglass frame (if the person wears glasses), around the neck, or pinned to a lapel, similar to piece of jewelry. When the person arrives home each day, the information in the device will be downloaded into a software program on their home computer, tablet, or smart phone which will analyze and interpret the information for each member of the household. It will then determine what lighting that person will need during the period they will be at home.

The information from the computer program can either be supplied to the person so that the individual can set the appropriate home lighting regimen for his or her needs, or it could be automatically fed into the home’s lighting control system. The home’s lighting control system will be able to sense the device each home occupant is wearing and will adjust the lighting in the room where each person is spending time to provide the lighting needed to help him or her to maintain a healthy circadian entrainment. If multiple persons are using a room at any one time, the system will be able to adjust the lighting in a particular area of the room to best suit each individual’s needs. If that is not possible because multiple people are grouped in one area at the same time, the software will use a pre-set hierarchy (e.g., select the lighting for the person most in need of circadian adjustment or most sensitive to circadian disruption). Also, in these cases of conflict, personal light “dosing devices” or filtering devices can be indicated such as light goggles or spectrally filtered glasses.

The lighting for the home will be well distributed with lighting being provided at various points throughout each space within the home, depending on how each area is used. The light fixtures in each area will have the capability of providing light of various spectra, distributions, and
illuminance levels. All of the light fixtures can be tied into a central control system for the home, if homeowners opt for automated control of their lighting. The control system will have a network of sensors in each area which will be able to sense when an area is in use, which family member is using it (by recognizing their personal light measuring device), what the current light level is in that area, and then be able to adjust the lighting for the needs of each individual using that area at any given time. Occupants will also have the ability to override the control system when needed to help ensure that the lighting provides the amount of light preferred for the activity they are undertaking. The control system will also turn lights off when no one is using the area, and adjust the electric light levels if there is sufficient daylight to provide the lighting needed. The control system will also control the timing and duration of the light received by each individual in the home. All adjustments to lighting (e.g., timing, duration, spectrum, irradiance) will be made by the control system based on the information received each day, from each home occupant’s personal light measurement device.
2. Design Parameters for the Swedish Health Home

In this section of the report, ÅF Lighting has outlined their ideas on the design parameters and important considerations, as well as next steps for the development of the Swedish Healthy Home.

Introduction

As lighting technologies and knowledge of the effects of lighting on human health and wellbeing are evolving, new possibilities on how lighting can be designed to better meet the visual and biological needs of people are emerging. The main goal of this project is to develop a framework for lighting a ‘healthy home’ in Sweden. Lighting in a healthy home is effective for people in terms of vision and circadian entrainment, attractive, energy-efficient, well-controlled, and environmentally sustainable.

The aim of this project is to create a demonstration of a home in Sweden that can respond to the light exposure that a person receives during the day and help synchronizing the biological clock in accordance with his or her own personal needs. The idea is to make something real, test it and evaluate it.

In this project phase, the main project goal for ÅF Lighting is to provide SEA with a clear action plan of what has to be done to move the healthy home project forward and outline the design goals.

If one compares the little development that home lighting in Sweden has had in the past 90 years, one can see that today is the right moment to make a change, essentially due to three new actors that have come into play. The first is the last decade’s discoveries of how light has an effect on health; the second one is solid-state lighting, and the third one is the development of technology that allows people to more easily track and control their environments.

SEA and LRC developed a draft white paper outlining ideas for lighting the Swedish healthy home in June 2013. This concept was in line with discussions that SEA and ÅF Lighting had on how energy could be saved while improving the quality of life of home occupants through lighting controls and better daylighting.

In November 2013 LRC and ÅF Lighting were commissioned to combine their expertise and join forces to work in the pre-study of the healthy home project. ÅF Lighting and the LRC will work jointly on the project, with ÅF Lighting taking the lead on the design issues and the LRC taking the lead on the development of the technology and the evaluation methods.

Project Structure

ÅF Lighting envisions the project to be divided in the following phases:

- **First phase:** laying out the structure of the project and a common vision. Establish general principles, technologies and partners.
- **Second phase:** light, control and design principles, and development and production of the technology and final lighting designs for the home.
- **Third phase:** installation, demonstration, and evaluation.
- **Fourth phase:** new guidelines, certification and/or standardization.
Opportunities and Challenges

Opportunities

- Health is a significant topic to focus on since Swedish people are very interested in health aspects of their daily lives. Diets, step counters, pulse sensors and other devices are already popular among Swedes as a stimulus for having a healthier life.
- There is great awareness among Swedes about how the lack of light affects mood, performance and daily life.
- Most of the Swedish population have access to smart phones and the internet, and can adapt very quickly to new technology.
- Healthy home – certificate/stamp (like LEED, BREEAM etc.) could be an effective tool to put the principles in practice.
- If SEA, LRC, and ÅF Lighting as independent parties do not carry out this project, new guidelines might soon arise from the manufacture’s side, where neither energy efficiency nor quality of light may be taken into account in a way that is beneficial to society.

Challenges

- Building companies may not see an added value in the healthy home’s principle.
- There is a risk of creating a solution that is too unnatural for a home environment and that will be difficult for homeowners and occupants to accept. A compromise between research and design must be found.
- Integrating daylight into the healthy home can be difficult to achieve when considering already built households.
- Family members and their different needs, and how the healthy home can be beneficial to all of them.
- Interfaces should be user friendly to prevent and mitigate people’s apprehension about the lighting. Interfaces should be intuitive, like the iPhone, for example.
- Prevent the healthy home principles to become something restricted only to the wealthy.

Issues to be taken into account when planning the second and third phase of the Healthy Home project:

Light quality and light quantity necessary for health benefits, as well as the relation between them and the time exposure.

Design principles to be consider when planning the lighting design for the healthy home. Occupants should have a number of options on how to receive the light they need, when they need it.

Emotional and Cultural Preferences, Desired Light Levels in Swedish Homes

With the aim of finding a reference for preferred light levels in Swedish homes, a survey was performed by ÅF Lighting where 14 subjects living in Sweden, were asked to measure the light levels at home at AM and PM time at their dining table. AM measurements were taken around equinox time under daylight conditions. PM measurements were taken after sunset. Both horizontal and vertical illuminance were measured. An additional questionnaire was given to the
subjects to measure satisfaction levels and quality of light, details about orientation of windows, weather conditions and type of light sources.

Results confirmed Stockholm’s statistics on most commonly built size of apartment showing the 2 room apartment to be the most typical.

Results regarding AM illuminance levels – with electric light OFF, measured in average 170 lx on the horizontal plane and 130 lx on the vertical plane at eye level. Desired levels under same daylight conditions now including electric light on were higher for the horizontal plane at 215 lx average, whilst the desired level for vertical illuminance stayed the same.

The survey also showed that the majority of subjects have values both for horizontal and vertical illuminance at AM time below 100 lx.

With regards to the desired light levels at AM time the preferences are more varied when looking at each answer separately, having 50% of subjects preferences between 100-300 lx, a 20% preference of levels below 100 lx and a 30% above 300 lx.

PM illuminance levels- with electric light ON at desired level, showed the preferred levels on the horizontal plane to be around 85lx in average, with 45lx on the vertical plane. Results also show that 92% of the subjects show preferences for vertical illumination below 100lux at PM time.

When comparing results of desired levels of light at AM and PM time the survey shows that the majority of subjects prefers values between 100-300 lx at AM time while at PM time values below 100lx on the horizontal plane, levels that can be considered quite low if we compare them to illuminance recommendation for other kind of environments.

Further to these results, the survey also showed that a 35% of subjects use candle light at PM time, a 57% of them has dimmers on their dining table lamp and that 83% considers their dining table lamp to be glare free.

Regarding the use of different lighting sources, 77% of subjects still use incandescent or halogen lamps, while only a 15.5% uses CFL and a 7% uses LED.

The overall satisfaction rate on the lighting conditions at AM time showed to be very high, having 85% of subjects satisfied with the natural conditions they have. At PM time the satisfaction drops to 62%, with most of subjects feeling unsatisfied due to not having a dimmer, having the wrong type of lamp or not having one lamp directly above their dining table.

Even if this survey is considered too small to make conclusions about lighting preferences among the general Swedish population, it does shows a tendency on desired light levels at home in Sweden and user satisfaction, and could be taken into account in the next phase when planning the lighting and control systems for the Healthy Home demo.

**Exiting Standards for Residential Lighting in Sweden**

A retrospective on home lighting in Sweden was conducted by ÅF Lighting to find out the existence of any recommendation or regulation on home lighting in the past years. The retrospective done from 1927-1954 showed a series of guidelines written by the magazine Ljuskultur on how home lighting should be planned, mostly information for the end user. A handbook published by Ljuskultur in 1954 called ‘Good Home Lighting’ discussed the most
relevant aspects to be considered when designing lights for your home and already by then used terms such as visual experience, visual task and lighting principles. This book also explained technical terms such as illuminance, color of light, light distribution and shadows, all with examples within the home environment. Reference illuminance levels were also given in this book such as an average of 150 lx for task areas, and 20-40 lx for the living rooms. It also discussed the importance of avoiding direct glare, something that has since the 30’s been of great importance in Swedish culture. The book also shows examples of practical applications within the house. Unfortunately we do not know how many people had access to this book, and if ever reached end users.

Besides this book in 1954 that summarizes how Swedish lighting at home should be done, there’s no other standard on home lighting available today. The only standard that exists and that indirectly affects how home lighting is designed and installed up until today, is the standard for electrical installations, that talks about minimum outlets per room. Still up until today this is the only standard that has an influence of how lighting is planned in homes. There’s definitely a need for updating guidelines or even creating a standard for home lighting that not only includes the installers perspective but also design, control and health issues.

List of Potential Partners and Other Competences Needed in the Project.

- Building company
- Architect
- Lighting Designer
- University and local researcher unit
- Electrical consultant
- Software developer
- Real state owner
- Manufacturers of light fixtures
- Energy consultant
- Communication and marketing consultant
- Environmental psychology
- Behavioral scientist

- Reference group
- Local Municipality
- EIO (Electrical Installer’s Organization)
- SIS (Swedish Standard Institute)
- Association of building environment and building industry
  - Boverket (Swedish National Board of Housing, Building and Planning)
- Energimyndigheten (Swedish Energy Agency)
- SKL (Swedish Association of Local Authorities and Regions)

Selecting the type and size of dwelling that would have the largest impact on the Swedish population during the demonstration phase

Stockholm is the largest municipality in Sweden in terms of population, but one of the smaller in terms of area, making it the most densely populated county in Sweden. The very fast growth in
population, the limited housing and the latent housing needs supports the estimate of the need for new housing in Stockholm to be between 179,000 and 319,000 units by 2030, about 9,000 to 16,000 homes on average per year. The most common size of newly built apartments in the Stockholm Region are the 2-rooms apartments followed by apartments with 3 rooms. Coincidentally during the Miljonprogrammet era these two sizes of apartments were also the most commonly built, being 31% 2-room and 38% 3-rooms, with the rest divided between 1, 4 and 5 room apartments. One fourth of Swedish population lives in the so-called Miljonprogrammet apartments built in the 60’s and 70’s. Environmental initiatives for improving the quality of life of tenants and energy efficiency and environmental impact of these apartments are ongoing and are a priority for the municipalities.

Looking at the statistics of Sweden population and the number of type of apartments built per year in the past and in the future, we conclude that the major impact the healthy home project could have would be by intervening apartments with 2 and 3 rooms, whether they are newly built or to be renovated. Thus the vision for the third phase of the project will be to at least implement one demonstration of a Healthy Home in a newly built apartment and one in a Miljonprogrammet apartment.

Strategy for the Demonstration Phase

A strategy is needed in order to interest and engage building companies and property owners, both for investing in the demonstration phase and also for supporting the outcome of the Healthy Home project to have in a bigger impact in how Swedish homes are to be built in the future.

ÅF Lighting believes that the key for this is to develop and outline a certification program for healthy and energy efficient home lighting as part of the research project. This certification should be able to communicate to the public and tenant-owners the benefits of the Healthy Home concept in an easy and understandable way in order to create a bigger demand from public. The certification could be also used as a marketing tool and thus validate the additional investment that the implementation of the Healthy Home concepts will require.

The certification program could be set in different levels regarding the levels of implementation of the Healthy Home concept. Moreover the certification could be managed by the Swedish Energy Agency in collaboration with the Public Health Agency of Sweden.

What will property owners and building companies gain by taking part of the Healthy Home project? Companies that take part in this research project as sponsors will, for example, be able to influence the different certification levels, something that can be advantageous for them and for the business strategy and realization of future project in a larger scale. Another advantage of taking part as sponsors can be the access to the latest research outcome and scientific knowledge at a very early stage and to be able to market themselves as a company that stands on the frontline.

In the next phase of the Healthy Home project the possibility to create a certification program at the Swedish Energy Agency and the Public Health Agency of Sweden has to be investigated further. Parallel to this a discussion should start with property owners and building companies to see how they envision their future business strategy and evaluate if this certification can be a part of it.
Background on Nordic Culture of Light

Many books have been written about the concept of Nordic Light. Henry Plummer writes about it in “Nordic Light: Modern Scandinavian Architecture”. Another book is “Nordic Light: Interpretations in Architecture” which captures the phenomena in essays and pictures from projects in Nordic Countries. Nordic Light is first of all the result of the geographical latitude. The relationship between sun and earth throughout the year produce special conditions that create the phenomena called Nordic Light.

In no other place on earth are so many people subjected to this special Nordic Light. It surrounds Swedes all the time, not only during the Midnight Sun or the Aurora Borealis. When one is in the Nordic Countries one lives the experience. It affects Swedes all the time. It is a basic condition of Swedish life that gives Swedes the unique experience of both light and darkness.

Nordic light conditions:

1. **Slow movement of the light.** The angle of the earth towards the sun makes the sun’s path change slowly. In Stockholm on June 21, twilight last for 1h 20min. Swedes need blackout curtains to be able to sleep.

2. **The angle of the sun.** In Stockholm the angle ranges from as high as 54° in June to as low as 7.2° in December. The low angle creates not only long shadows but also brings a warm coloring to the cities and landscapes. This also creates a need for blinds to avoid glare into working spaces and homes. In cities where that have dense housing, the color of the facade opposite a home becomes a reflector, affecting the light entering the home.

3. **The amount of light during summer and the lack of natural light in winter.** These extreme conditions affect the body’s production of melatonin for the inhabitants of the Nordic countries. Similar to how plants convert sunlight into carbohydrates through photosynthesis, the human skin uses sunlight to synthesize vitamin D, which is lacking during winter. There is a connection between low vitamin D levels and depressions, where the most severe cases of the disease and most cases of suicides are seen in March when levels are at the lowest after the winter. It is believed that Swedes have created a more sensitive relationship towards light because of these conditions. After the long, dark winter everybody is affected by the return of the light, and in terms of sensitivity towards glare and lack of natural light, it also creates a fundamental need for well-planned electric light for people to work and live.

4. **The change in nature during seasons.** When there is snow to reflect the light, it is coming from below. Sweden also has many cloudy days. During January 2014, Stockholm only had 14 hours of direct sunlight. The normal amount is 40 hours. During June, Stockholm has 290 hours of sun as a comparison according to statistics between 1960-1990. The air is also very clear with little moisture, which creates good visibility.

These special qualities are very interesting for architecture and urban planning and the way it has affected culture and art. The absence of strong colours in both our interior and exterior architecture shows direct links to our daylight conditions. But for me the most interesting aspect is how it affects our homes, our daily life and the way we use both electric and natural lights.

Swedes use candles in the winter season to create cosiness and warmth, both on the dinner table but also while watching TV or socialising. This light character has transferred into electric
(incandescent) light with the use of many small decorative light fittings in Swedish houses, mostly placed in the windows and corners of the room to avoid dark areas. These light sources are always well protected to avoid glare. The tradition of Scandinavian Design with its pure design and functionality has also affected the design of light fittings. The use of dimmers is well spread in all of the fixtures in a home today, for functionality and for creating a cozy feeling. We also prefer a warmer light temperature to a colder one. During Christmas Swedes use specific electric lanterns in the windows called "adventljusstake” with 7 light points. A candle light version with four candles is also used. An old custom mostly found in the countryside was to "Kura skymning”; this was a social gathering in stillness where you didn’t turn any lights on until dark. You simply experienced the day turning into night together with your family and friends.

How can designers use electric light to move Nordic Light qualities inside, or help to battle the restraints that these conditions produce? Use the light to create better health, to improve our quality of life and also bring the beauty of light into our homes?

With the full potential of the modern technology ÅF Lighting is positive this is possible.

Why this Research Project is Relevant for Sweden

Located in Northern Europe, Sweden is the third-largest country in the European Union by area, with a total population of about 9.6 million, and with around 85% of the population living in urban areas.

Because of its high latitude, the length of daylight along the year varies greatly. North of the Artic Circle, the sun never sets for part of the summer, and it never rises for part of the winter. In the capital, Stockholm, daylight lasts for more than 18 hours in late June but only for 6 hours in late December. The great variations in daylight from summer solstice to winter solstice, give about 5 minutes of more or less daylight every day. Although the Swedish winters are cold and dark, the long summer days are well worth the wait. Due to the lack of daylight in the winter months about 8-10% of Swedish population experiences some form of SAD, seasonal affective disorder, a psychological disorder characterized by depression, tiredness, decreased motivation, a tendency to sleep excessively and craving for carbs and sweets. In the dark months of the year, appropriate lighting at home and at work, light therapy and longer exposure to natural light could help lessen the symptoms.

Regarding the energy use, lighting accounts for around 20% of the total household electricity consumption.

With the Healthy Home project the project team has the possibility of creating new guidelines, standards and certifications that can materialize improvements in the lighting design and lighting technology in homes, and not only from the energy perspective but also from the light and health point of view, with the final aim of raising the quality of peoples’ lives, while still being respectful to the environment.
3. Design Concepts for the Swedish Health Home

In the Spring semester of 2014, under the guidance of Professor Russ Leslie, the “Lighting Workshop” class at the LRC developed several design concepts for the Swedish Health Home, based on the white paper that the LRC wrote in 2013. These concepts are not meant to be complete design specifications, but rather a group of ideas on how the lighting parameters and requirements of the Healthy Home could be implemented in an actual Swedish home. The concepts are outlined in this section of the report.

**Design Principles**

The design concepts were developed in line with these design principles:

- Lighting to support vision, comfort, and esthetics
  - Color rendering
  - Comfort
  - Culturally relevant
  - No glare
  - Visibility
- Circadian regulation
  - Promotes sleep hygiene
  - Promotes good health
- Universal design and safety
  - Accommodates typical, aging and disabled populations
- Optimizes energy use
  - Energy management
    - Daylight harvesting
    - Occupancy sensing
  - Increased ratio of benefits to watt-hours consumed

**Design Challenges**

The following design challenges were addressed in the development of these design concepts:

- Asynchronous schedules of home occupants
- Circadian stimulus regulation
- Prescriptive lighting solutions
  - Personal light history collection, analysis, and implementation
- Seasonal fluctuation in solar rhythms
  - Lack of daylight in the winter
  - Overabundance of daylight in the summer
- Swedish Energy and Building Code restrictions
  - Less flexibility in placement of outlets and construction

**Technology Challenges**

The students outlined the system that would be needed in order for the lighting in the home to be able to respond to the health (i.e., circadian regulation) needs of the home occupants. The basic
system design is shown in the diagram below. A personal light measurement device (i.e., Daysimeter) would be needed to track and record the light exposure of each home occupant, this information would be fed into a data integration system in the home, which would then provide information to the home occupants on their lighting needs while at home, or could be used to directly control the home’s lighting system.

This system would also incorporate photosensors and occupancy sensors placed throughout the home which would both allow it to sense which home occupants were using each space and also the amount and characteristics of the lighting being provided in each space. This would allow the system to control the lighting to provide what would be needed for each occupant at any particular time, and also to prevent the waste of energy by turning lights off when spaces were not in use, or by dimming lights when sufficient daylight were available in spaces with windows or skylights.

One component of this system would be the incorporation of portable or built in touch screens which would recognize each home occupant and provide him or her with information on their own lighting needs and allow them to adjust the lighting within the home.
The complexity and array of functions that the home’s lighting and control system could provide, would largely be dictated by the ability to incorporate it fully into the design of the home’s lighting system. In new construction or substantial renovation, the system would be able to provide full benefits. While in a retrofit of an existing home, or a situation where home occupants where renting space and were not allowed to make changes to the existing electrical system, the controls would be able to provide less overall functionality and response. This is outlined in the chart below:

<table>
<thead>
<tr>
<th></th>
<th>New construction</th>
<th>Renovation</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Controlled by</strong></td>
<td>Lighting history &amp; users’ upcoming schedule</td>
<td>Lighting history &amp; users’ upcoming schedule</td>
<td>Pre-program</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>Primary architectural integrated controls</td>
<td>Primary portable controls with some architectural integration</td>
<td>Portable controls only</td>
</tr>
</tbody>
</table>

**Design Concept Implementation**

This section provides some idea on how lighting could be integrated into a home.

**Windows**

The students developed the idea of a tunable lighting system for real and faux windows.

- Real windows deliver natural light when it is available, and use electric light reflected off the blinds to mimic daylight from a window when it is unavailable.
- Faux windows allow the delivery of circadian stimulus in areas where real windows and daylight are not possible.

This windows concept allows light of the proper spectrum and amount to be delivered to a home occupant(s) at the time needed, taking advantage of daylight, when available through real windows, or using a tunable LED-based lighting system when daylight is not available, or in areas where windows are not possible, by using faux windows. This concept for vertical light transmission is an excellent idea for delivering light in the direction needed to reach each person’s eyes most effectively, using the lowest possible energy. This concept would be most applicable to new construction, but could also be incorporated cost-effectively into homes undergoing substantial renovations. The windows concept is illustrated below:
**Interior Architectural Elements**

Vertical light delivery could also be done by incorporating lighting into architectural elements such as valences or soffits, as illustrated below:

Architectural elements can also be used to provide indirect lighting in areas where ceiling height would allow the use of coves or coffers. These will generally require a ceiling height of 3 meters or greater to provide lighting effectively throughout a space. These concepts are illustrated below:
**Skylights**

In single story houses, or spaces with access to a roof, a skylight can be an excellent means of bringing daylight into a space when high light levels are needed and desired. Adjustable baffles or shutters in the interior well of the skylight can be used to control glare from overly-bright daylight, or to prevent daylight from entering an interior space during times when it was not needed or desirable, for example in the evening when it might be counterproductive to the circadian entrainment of home occupants. In a similar way to the windows illustrated above, the skylight could also include LEDs which would provide lighting during times when daylight is unavailable. A skylight concept is illustrated below:
**Roof Monitors**

Roof monitors are an exterior architectural element which can be incorporated into the roof of a single story home to bring daylight into spaces within the home. These would typically be faced toward the south, in Sweden, to allow the roof monitor to collect the maximum amount of daylight. The back wall of the monitor would be made of a mat white surface which will diffuse the daylight and allow it to enter the space without being too direct or bright. Similar to the skylights shown above, these could be illuminated from the interior to provide lighting during times when daylight was not available. The concept is illustrated below:

![Circular Style](image1)

![Square Style](image2)

A rendering of what the interior of a circular style roof monitor might look like is shown below:
**Tunable Electric Lighting**

As shown in the windows concepts above, important lighting elements within the home, either built directly into the home’s architecture, or portable, will be able to be tuned by the home occupants or the home’s data integration control system automatically.

**Lighting for Nighttime Safety**

To allow home occupants to safely navigate throughout the home during nighttime hours, without having to turn on all of the lighting within a space, nighttime lighting system would illuminate doors, pathways, and other areas to a low level. This would provide vertical and horizontal cues to improve the postural stability of older adults, while also assisting all family members to easily and safely move through the home at night. These elements would be controlled by sensors to only illuminate at night and when motion was sensed. These concepts are illustrated below.
Portable Lighting Interventions

In cases where tunable lighting could not be incorporated into a home, or in situations where the lighting needs of different home occupants using the same space were in conflict, portable lighting interventions could be employed to provide the lighting needed by each person. Some ideas of how this might be done are shown below:

Illustrations of Lighting Concepts

The renderings below show some illustrations of how the concepts mentioned above could be incorporated into the design of rooms within a home.

Bathroom

- **Recessed soffit with tunable light** (surrounds room): Provides ambient light and can be tuned to the users circadian needs.

- **Recessed downlight**: Provides extra illumination in the shower area.

- **Vanity lights with tunable lamps**: Provide higher illumination at the mirror that can be tuned to the users circadian needs.
**Bedroom**

**Valance with tunable light:** Provides flexible lighting with direct and indirect options. Can be tuned to users circadian needs.

**Window:**
Allows daylight in when available.

**Task light with tunable lamp:**
Provides extra illumination tuned to users circadian needs when necessary.

**Faux Window:**
Provides tunable light meet users circadian needs and to balance space.

**Living and Dining Room**

**Orange Goggles:**
To avoid circadian stimulus, when not needed.

**Faux Window:**
Provides circadian stimulus when needed.

**Window:**
Allows daylight in when available.
4. Technology Development Needed for the Swedish Healthy Home

Introduction

One of the key components of the Swedish Health Home is the technology that will collect information on each home occupant’s light exposure throughout the day, feed that information to the home’s central data integration system, and allow it to be used for the control of lighting in the home.

The way in which lighting affects our health and well-being, depends on our light exposure throughout the day. This will vary from day to day, depending on lighting conditions largely outside of our control. We have limited control over the lighting we experience in public buildings, for example, like our workplace or school. So our home becomes the place where we can make adjustments to lighting to promote good health. Our home becomes the hub for a healthy life. In order for lighting in our home to promote good health, we must track and record our light exposure throughout the day, understand how light interacts with our biological systems, and make adjustments to the lighting in our home to promote our health and well-being.

At the core of this idea is a technology that would track, record, and interpret light exposure. The system pictured at the left, mounted on a pair of eyeglasses, is a version of a personal light exposure detector or “Daysimeter.” This device, or something similar, would be used to track each family member’s light exposure throughout a day. The information collected by the device would be transmitted and stored in each person’s “smart phone” or other personal electronic device. When the family member arrives home each day, the smart phone would transmit the information collected to the central light control system automatically. This information would then form the basis of a lighting plan for that person during the time that they are at home, for example, that evening and the next morning for someone with a typical daily schedule.

The person would wear the Daysimeter device outside as well as inside the home. As the person moves from room to room within the home, the home’s lighting system would recognize this person’s device and could adjust the lighting as needed to provide the person with the lighting intervention they need to counterbalance the light exposure they received outside of the home. Or, if people do not wish the lights in the home to be controlled automatically, the device could simply notify them of their lighting needs and they could take action accordingly. In either case, manual override of controlled lighting would always be provided so that family members could change the lighting as desired. The intervention, provided through the Daysimeter system, would help to ensure that each family member’s circadian system remains properly entrained each day. This technology helps to provide healthy lighting and the home becomes the place where lighting invention can happen to promote good health and well being.
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Lighting Research Center
ÅF Lighting
Appendices

ÅF Lighting PowerPoint presentation
Retrospective on lighting in Swedish homes from 1929-1954
Summary of existing Swedish standard for electrical installations (ENG)
Summary of needs for new apartments in the Stockholm Region up to 2030 (SWE & ENG)
Results of ÅF Lighting Survey – Emotional and cultural preferences (ENG)
LRC student’s PowerPoint presentation on design concepts
Lighting in Swedish Homes
Retrospective 1929 - 1954
The first electric source in a home was always a light bulb. Which shone in most of the homes for the first time in the late 1910s or early 1920s.

The light bulb differed greatly from kerosene lamp's flames, which for half a century had been the Swedish standard lighting. The electric light shone without a flame that burned. Therefore no risk for fire and could be even left unattended. An electric bulb did not need to be refilled with fuel, required no cleaning of the glass and burned with a steady light, without flickering or producing smoke. Neither smelled or used the room's oxygen while they shone. And they could even been turned on by pressing a button on the wall.

Strangest of all was the light efficacy. Kerosene lamps had been a bright spots in a surrounding darkness. A single electric bulb in the ceiling provided a whole room with both general light and task lighting.

Sure, there were light bulbs already in the 1880s, but they shone weakly and were both expensive and fragile. Kerosene lamp retained until the 1910s its position as the number one Swedish lighting, both in the countryside and in the city, both at farmers and working-class and even bourgeois levels, on offices, workshops and classrooms.

During the First World War years everything changed. In its wake came the shortage of imported goods, including oil for kerosene lamps. From 1917, kerosene was no longer sold for private use and trade of candles became rationed.

The war swept darkness over Sweden.

The best alternative to overcome darkness was to try to get electric light. Every place where flowing rivers, lakes or less abundant waterways were, power stations were built and electrical lines were drawn to farms, villages and larger communities.

The Swedish countryside was in the early 1920s, probably the best electrified in the world, with many local hydro power stations and had by 1919 more than a thousand registered distribution compounds.

But not only the availability of running water and WWII made of the 1910s the electric enlightenment breakthrough period. The third factor was the technology. New technology for the production of drawn wire of tungsten meant that the light bulb in the 1910s reached its almost technical perfection. So brilliant there was no fire or kerosene lamp.

The thin tungsten wire into the glass sphere had the technical potential to make a difference between the dull evenings from the past and a brighter future ahead. In the countryside, with its occasional and seasonal gloomy outdoor world, a lit light bulb on the corner meant a decisive change from the external reality. With electric lighting, it also became easier for people to choose their own circadian rhythms. Darkness laid in all cases no longer in the way. All this meant a dramatic change for people, who were biologically best tossing for an active life in daylight.

Good and plentiful lighting had historically always been a matter of money and hence a class issue. Now the light was on the way to become one of the qualities of everyday life that was available for all. The event coincided with democratic parliamentary breakthrough in Sweden and with the formation of the movement boost. There was a reason for the labour movement song, “out of darkness we rise up to the light.”

Initially just one bulb per room was installed and it was placed in the middle of the ceiling.

In the 1920s bulbs also shone as street lighting in more and more cities, even where gas was still available.

In the 1930s Sweden started to have gradually more and more lighting in shop windows, on even after closing time. The most striking
visual impression was the still new and strong coloured crackling neon signs outside the shops, restaurants and cinemas, or illuminated advertising on the facades. The first neon sign was lit in Sweden in 1924, and in the 1930s neon lights became a symbol for the city.

The swedish newspaper Svenska Dagbladet wrote at the end of the decade that electric light had become one of the key factors in the modern cityscape.

By this time also a number of artists and writers incorporated lighting and lamps words in their works.

Politics and violence
In the 1920s, the lighting industry and the electric company’s interest increased in the homes electric lighting and use of electricity. More power consumption in homes would therefore create a more stable financial footing for the electricity companies.

But in the 1920s all the electricity in homes was especially used for the lighting, maybe also for an iron machine, and possibly an electric stove or soon a radio. In the 1930’s electric cookers and other kitchen appliances got more spread, but it was not until the 1950s that electric stove, refrigerator and vacuum cleaners became standard in homes.

At the same time the lights went from a one bulb per room to a culture of more planned lights, performed in many homes in the 1930s, but in many others not until twenty years later. And if in homes it was almost natural to switch from kerosene to electric lighting instead it became politics and business stakeholders who actively spread the idea of the new a lighting culture.

In 1926 the Swedish Association of Lighting Culture, Ljuskultur, was formed as an initiative from, among others, Scandinavian Glödlamps-fabriken, Elektraverken and Swedish Philips. Four years later, Ljuskultur could look back on as many years of successful campaigns for “good light”, a term which according to Ljuskultur should be defined as glare-free light, in sufficient quantity, at the right place.

In 1928 the exhibition “Light in the service of people” was inaugurated on Liljevalchs in Stockholm. Where in autumn 1928 modern lighting fixtures were shown for homes and industries and in staged-lighting environments of living rooms and bedrooms, offices and schools. The exhibition was organized by Ljuskultur in collaboration with the FERA, the association of rational use of electricity.

Ljuskultur next campaign was “Good lighting - good works”, 1929. And then the campaign propaganda for good lighting in the home, not least in its most used room, kitchen.

The next large light event was the Stockholm Exhibition in 1930 when functionalism in design and architecture became popular in Sweden. Stockholm’s Exhibition was also designed as a manifestation of electric lighting and “light architecture”, a then ultra modern architecture concept.

When dusk descended on the exhibition area’s entrance a twelve feet high, opal white shining pillar was lit to welcome visitor, sculptures were lit and fountains shimmered with light. Over the whole area shone the eighty-meter high advertising tower with a rotating searchlight at the top. The mast was the largest illuminated advertising structure set in Sweden. It spoke its advertising language with lights from red and blue neon and several thousand 25W and 15W lamps in various colors.

For posterity, on the other hand, extensive residential areas with small houses, apartments and townhouses appeared as Stockholm exhibition’s key features. Everything was built on the spot and decorated with modern furniture. Ljuskultur had been an adviser for lighting planning. Ljuskultur’s campaigns for household lighting was well timed, even politically.

KF (cooperative association) had previous
experience of challenging cartels between companies producing consumer indispensable staples, such as flour and margarine. Production at the cooperative's light-bulb Luma, began in 1931 and was a sign as good as any that the bulb becomes the given bright spot in the Swedish home, as attractive as the flour in the loaf.

*Rational and hygienic*

When the Social Democrats won more power, the government charged their slogan "people's home" with a concrete political energy.

Hygiene was one of the decade's words in the 1930s, from housing hygiene to social hygiene and eugenics. In the lighting industry magazine Ljuskultur was discussed light hygiene, and engineer Ivar Folcker, light Kultur's chairman, stressed that the goal of the lighting technology was to meet the 'eye's right to claim the light hygiene'.

The word rational became, like hygiene, a programmatic concept. Axel Annell went a step further and inserted it in the company name - "Axel Annell, Efficient Lighting." The rationally planned lights to be glare-free and functional, but no one had to wonder about the source of light that gave a good light. The only electric light source was incandescent lamp, whose light qualities still in the 2010s were seen as desirable.

In 1939 an ambitious attempt was made to provide a good fitting on the basis of the sense of the sight's needs. The result was Se-Bra lamp, in different variants, which was created in accordance with the first Swedish standards for lighting equipment. Several companies manufactured Se-Bra lamps, but success did not occur. It will take at least ten years before modern styled fixtures and new interior ideals were to made its mark on home lighting. Meanwhile, two new concepts came into the picture - form and design.

In the kerosene lamp times you found yourself with all others at the same time in the same room in the evenings. Lighting and living fire was the same thing and they reluctantly left lights burning, other than for a short while.

Empty rooms were therefore dark rooms. Most also tried to get by with only one lit lamp. With a light bulb in each room it was given the opportunity to everyone to be able to sit by himself or herself, which in turn laid the foundation for the family's spatial fragmentation. This was a decisive change, reasonably equally unplanned and unexpected.

Despite the importance of lighting for health, home-work and well-being are rarely mentioned in the public inquiries about housing issues. Also at the time in ambitious housing surveys lighting ended easily unnoticed.

**Arrival of fluorescent**

In homes incandescent bulbs lit long without competition. While fluorescent lamps, a novelty in the late 1930s, stood mostly undesirably. First, in the 1950s, even later, fluorescents were to be found in one or another kitchen.

**Nordic light**

On 1 September 2009 the EU phase out of incandescent light bulb, which by then had lit for almost a century homes in Sweden. In 2009 the bulb was replaced by fluorescent lamps, halogen lamps and other light sources, but it was still the preferred light if compared to others. On average, you find 42 light sources in a Swedish home, of which an average of 25 are incandescent bulbs. Unlike in most of southern Europe Swedish homes are in love with the warmth of the incandescent bulb and it's gentle light.

The years 1920-1965 were characterized as the period when light became accessible to everyone, regardless of each one's finances or where in the country they lived.

Sweden's cultural history is also marked by the country's northern location, where daylight a few weeks each summer makes the sky bright.
almost round the clock. The other side of the coin is autumn and winter darkness. December is night all over, at least sixteen hours of the day (Skåne). Whilst in summer lighting becomes uncessary in northern Sweden. During the dark season electric light makes all hours available. Before electric light the freedom to choose your own daily rythm was almost an unreasonable thought.
Physical problems that occur because of lighting are always related to glare or too low levels of light.

Problems with adaptation occur when moving from bright to dark areas.

Lighting should be planned before the electricity and not the other way around.

*Hushållsbelysning*/Household lighting defined as the light for kitchen, corridors, closets, laundry room, bathroom etc. In these areas in general the goal is to have “functional” lighting. The recommendations have to do with avoiding disturbing shadows by using diffused light and discussed suggested light levels. The general recommendation is to have one outlet or luminaire in the middle of the room and add lighting for work places and mirrors.

**Kitchen**
General lighting is recommended with a diffused luminaire in the ceiling and an average of 60-90 lux. In a normal sized kitchen, one lamp in the middle of the room is enough. Additional lighting recommended are for example a row-mounted lighting underneath shelves or a diffused wall luminaire near the task area.

**Bathroom**
General lighting from a diffused luminaire is recommended in the middle of the room with an average of 50 lux. Additional lighting could be for example two diffused wall lamps next to the mirror (one on each side).

**Special workspaces**
Movable table lamps with non-visible light source are recommended.

**Laundry room**
A diffused luminaire in the middle of the room is recommended, average 40 lux.
Interview with NK:s interior specialist.

Lighting should be beautiful, enhance the space, the proportions, the furniture etc.

New building materials such as plywood make it possible now to integrate lighting in walls, ceilings, corners, shelves etc... Electric lighting should not aim to look like daylight, since women look better in soft warm lighting with low levels of light.

Curtains should be there to block the light when you want, but should not take away sunlight.

Automatic turn on and off of lighting integrated in furniture – make up table as an example.

Example from a place in Paris where integrated lighting in the bath had different colors of light.

They criticize that there are way to few outlets in homes. The author thinks that this problem is caused by a delay in the old use of kerosene lamps while neither electric lamps nor other electrical machines were used.

This delay can be due to:

1. The building companies that do not prioritize lighting since they think that other investments (such as luxury bath rooms, expensive materials) have a bigger impact on the decision to rent or buy the apartment.

2. The installer get free hands of deciding how the lighting and electrical installations should be. By competing reasons, they tend to spend as little money as possible.

The fastest way to change this situation would be to talk and persuade the building companies, who most probably think that this is a question, rose by self-interest reasons. The most effective way would though, would be to influence the users/the public so that they are the ones putting higher demands on the building companies.

A standard of quantity and not only quality should also be put in practice so that houses with better lighting/installations are marked in a special way.

A proposal would be to have one fix lamp in the ceiling in kitchen, WC, closets above 1 m2. Kitchen above 10 m2 should have additional lighting above the sink. 2 outlets in every room except for rooms bigger that 20 m2 where there should be 3. There should be also possibilities for installing mirror lights in bathrooms and entry areas.
In this article they described an experimental villa in Ohio, where the indoor lighting is integrated in the ceilings, walls, windows, mirrors, shelves etc.

In this house, the lighting in the living room has the possibility to change colour temperature/colour. And there is also a possibility to turn on and off lighting centrally, like for example from the bedside.

The lighting in closets have an automatic control of turning on and off.
As a rule, you should have in a room general and local lighting. In the rule general lighting sits the middle of the ceiling and it is an old relic of the kerosene lamp days when the whole family gathered in the lamp's light and the lamp hung over a table, so that you would not hit your head with it.

With the electric light it is not at all necessary to place the fixtures in the middle of the ceiling. One can well and sometimes with stately power, arrange it for example with a light outlet above the window.

Concerning the local lighting, you must also have the requirement for the installation, that first and foremost must be impeccable from a lighting technology point of view. It shall provide adequate light and give light in the right way. Lots of light fixtures appear to have the main task to brighten up their own interior.

Would you like to save on the lights so do it instead in the way that you do not let the lights burn in the room where nobody is. But when they actually are in use be generous, for it actually means a saving – for the eyes.

People move no longer after the light, the light moves after the people.
Home lighting issues are in practice not always a bright chapter, due to the fact that the knowledge of how to create good lighting is not sufficiently widespread among the public. As the author of this paper rightly emphasizes, the central problem in home lighting is to adequately find a balance between the two functions of lighting: the practical and the mood-provoking. There is unfortunately a widespread tendency to underestimate the objective and practical responses of lighting and to exaggerate its mood-provoking function. When it comes to fitting choices, there is unfortunately a strong tendency to primarily consider the luminaire as something to look at, rather than to look with, which often results in an overemphasis of the luminaire’s decorative form.

For the lighting to really fulfill its task it is required that the objectives on lighting’s practical function are primarily met. Only thus can the lighting even be psychologically satisfying, so as to attain the favorable emotions that characterize well-chosen lighting: work quiet, focused lighting, the party glitter and the contrasts. When the factual side is well achieved, you can even get a greater prerequisite to reach the lighting aesthetic values: a balanced play between light and shadow, and a light fixture that from the design point of view satisfies both practical and aesthetic requirements.

Guidelines

1. Visual experience
Through light and the sense of sight is that we perceive the environment. We put ourselves in an active state when in a rich abundant light, while soft lighting promotes rest, relaxation and stress relief. We think it’s festive when the light sparkles and glitters and find it ceremoniously when using live flames. We feel the impression of warmth, when red and yellow predominate the image or coolness, when green and blue have a stronger presence in the color of the light. What we like about an object’s shape or a room’s appearance is a natural interaction between highlights and shadows, we feel tired of a diffused, shadowless light that makes the surrounding flat and uninteresting. We get irritated when the light from the lamps comes directly into our eyes, or if we get glare from white papers or when the light on the book is too weak.

Light affects the rhythm of life. This is especially pronounced with daylight, which has a rhythmic variation itself. But this is also of decisive importance for the art of lighting technology, within which the goal must be to seek to design lighting in such a manner that the desired visual experience is obtained. Within the home environment the light should be both task and mood lighting, to provide a visual experience, in which we feel comfortable. The central problem in home lighting is to satisfactorily combine these functions.

2- Visual tasks
Those in which you clearly, easily and quickly are be able to discern details in connection with an actual visual object. Near vision places greater demands on concentration and accommodation of the visual system than distance vision and therefore requires particularly good lighting to be performed without sight effort. This includes sewing of various kinds, reading, writing, sock knitting, and tasks like cooking, baking, washing, ironing and dusting. Visual tasks for near vision require good efficient lighting in the places where they are performed. For distance vision ambient lighting is required.

3 - Lighting Principles
The general requirements, which home lighting must meet based on visual perception and the visual tasks, are partly quantitative and partly qualitative in nature. Lighting quantity is characterized by a particular value of illuminance on the current visual field. The unit is lux, which is easily measurable. With light quality we associate glare, perceived light color, color rendering, light distribution, light direction and shadows.
**Illuminance:** for tasks of the same fineness as in homes where recommended for professional work illuminance, levels in the order of 150 – 1000 lux. For home-work should be considered satisfactory to meet a target value of 150 lux. In those cases where higher values are required, this can be easily achieved by moving the lamp closer to the work area. Along with task lights there should always be ambient illumination in the rooms. This is to lower the contrast. The average for ambient illumination intensity in the room should be not less than \(1/10\) of the work lighting. Proper target value 20–40 lux.

**Light color:** in the visual experience of our environment color impressions are of great importance. For color experience the nature of the light and spectral composition are very important. The impression of the color of the light is normally assessed generally as ‘warm or cold’. Lighting with light sources of daylight-like character should always be implemented with higher illuminance than those who have warm light. Fluorescent lamps are manufactured however nowadays even in warm tones, these should be implemented in cases where fluorescent are to be used in home lighting.

A room where the light sources vary widely in the perceived color of the light, gives us an uneasy impression.

**Light distribution:** As a general principle, one must seek to get the light concentrated in the places where it is most needed from the utility point of view. It is important that appropriate local light points are available or can be readily fixed to these sites. Along with task lighting, ambient lighting is needed. Separate light sources for ambient light should be used. Also, for practical reasons, this is recommended.

As a rule, the lighting for your home has been conducted by the principle of good general lighting with additional task lighting. Meaning that the ambient lighting is dominant, task lights, however, relatively poor. This is significantly inappropriate, given that the visual tasks requiring near vision, represents by far the largest group in the homes. The lighting system shall be designed as good task lighting with additional ambient light. Both with respect to benefits such as comfort instead to the reverse principle.

**Shadow:** are of two types, self-shadow and cast shadows. Self shadows are very important for the experience of the object’s shape.

At work, it is important to avoid distracting shadows from for example, hand and head.
Summary
The following general guidelines should be the basis for home lighting technical layouts:

1. The lighting system is carried out with the main emphasis on a post-work (job sites) oriented local task lighting, which is complemented by ambient lighting.

2. Work lighting shall be so designed, that the lights at a convenient placement of a visual object provide an average illuminance on the current task area of about 150lux

3. Ambient lighting should soften contrasts between task lighting and its immediate environment, enabling distance vision and contributing to the pleasant 'light atmosphere'. Target: in the living and bedroom 20-40 lux, in the kitchen, nursery, hobby room 50-80 lux.

4. To avoid direct glare, light sources should be shielded in the visual field.

5. The perceived color of light from light sources with surrounding screens must have some uniform character in the same room. Warm color tones are preferred to cold.

6. The incandescent bulb is the most suitable principal light source. Fluorescent, always combined with incandescent bulbs, can be implemented in places where their shape and good light economy brings practical advantages.

7. The light is concentrated on those places in the home, where it is most needed. Light direction and shadows have practical and aesthetic significance.

Technical Means
These are: electrical installation, which will allow the light points to be installed at desired places, tungsten sources, which deliver light of the required quantity and suitable spectral composition; light fixtures, which are responsible for the anti-glare, light distribution and direction of the light, touch/contact protection and general lighting atmosphere.

The electrical installation
The lights are connected to the grid via outlets in the walls and ceiling. Wall outlets are fitted with connectors, which are connected by a plug, and lamp outlets in ceilings have an equivalent structure with connections through a plug. The light points should be adjusted to the furniture layout, which is variable, so it is important that necessary outlets are available wherever needed.

An outlet on every 5 mts, which for the given example gives 4 outlets, approximately are equal to the need. As the absolute minimum standard is required 3 outlet in a living room and 2 in a bedrooms.

Getting ceiling outlets in the desired location is a much more difficult problem, as this implies that the furniture is fixed to the installation execution. Generally a ceiling outlet placed in the middle of the room avoids this difficulty.

Directly inappropriate are midpoint placement of ceiling outlets in areas such as the living room, where the furnishing is bonded or the impression of the room where often inappropriate lighting is enforced. Also in the kitchen the central placement is inappropriate.

To achieve greater freedom in ceiling light points placement is recommended now 2, in large living room until 3, ceiling outlets in the room’s central long line.

Electric Light Sources
The main light source for the home is artificial light, the electric light bulb.

Luminaires, designed by rational engineering principles, can provide attractive decorative effect by suitable colors, casual grouping and hanging of the different shades.

From a light-financial point of view large lamps are more favorable than small. A 100W lamp gives as much light as 6x 25W.

The color of the light from fluorescent tubes
can, unlike incandescent lamps, which are completely determined by the visible temperature of the wire, fluctuate within a wide range by varying the composition of the phosphors. Standard colors are: daylight, sun white, white and warm white. For getting a better color reproduction they manufacture variants of these, which are named deluxwhite and deluxwarmwhite.

**Light fixtures**

The luminaire’s functional role is to protect against glare, and to direct and distribute the light in a desired way in the room. A large selection of good luminaires for use, where the emphasis on functionality is combined with aesthetic design and overall performance, are now available. Home-luminaires can basically be divided into two main groups: light fixture for task lighting (spot lights, task lighting) and fixtures for ambient lighting (general lighting).

Task luminaire’s aim is to illuminate a small area with incident light of a definite strength. Even when reading in bed, mirror lighting, etc. is good light in the vertical plane of great importance.

Reflector-shield’s bottom side should be slightly below eye level of a person seated at the table, giving a height above the table top of 30-35cm. With the light on this height, it can achieve the average light illuminance of 150 lux set as guideline, with a bulb of 60-75W.

See Good-lights (Se Bra Lampa), are provided with an upwardly open opal glass bowl in which the bulb is located. Above this is a display of parchment or fabric attached, likewise open up. The light distribution is thereby direct and indirect.

The requirements that home task lamps should fulfill can be summarized in:

1 - **Screen.** Shall direct the light with minimal losses in the desired direction, and have such thickness so that the lights get dimmed. Consideration is given to lumen output and heat dissipation at maximum questioned bulb.
2 - **Height.** Table lamps direct acting type: height to bottom of the screen not less than 30, not more than 40cm. ‘See Good Lights’, the screen bottom 50cm, 75cm to top. Floor lamps direct acting type: height above the floor to the bottom of the screen 100-120 cm. We greater heights follow ‘See Good’ principle.

3 - **Adjustment.** For table and floor lamps adjustability of screen position is desirable. For floor lamps, if necessary, also adjustability in height.

4 – **Lamp effect.** For table lamps (not adjustable) light bulbs in 60 - 75W , for adjustable 40 - 60W. Floor lamps, adjustable 60 - 75W , fixed 75 -150W.

5 - **Security.** All lamps with leads and balls of metal should be S - label and approved for a lamp power of 60W or higher.

6 - **Appearance.** The general appearance is to be aesthetically pleasing. Variation and individual adaptation is achieved through good design, materials and colors. ’

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**Practical applications**

Possibilities to arrange proper lighting in homes on a varied and personal way, within the context of the principles, as previously stated, are very large.

On the desk: the light should be strongest in the current field of view.

At the armchair: Easily adjustable. Adjustments of the light direction in different planes and customization oh their height.

Above the table: a lamp above the table provides a family with a common unifying light area. Mounting height not less than 50cm above the table surface.

Bedside: reading in the bed is carried out most conveniently in the supine position; the current field of view is disposed in approximately the vertical plane. Reading light at the bed is best achieved with reflector light fixtures on the wall or headboard behind the pillow.

Along with light fulfilling practical purposes, it should also contribute to a pleasant ‘light atmosphere’ in the room. This is a result of a combination of different light sources and the environment’s (paintings, carpets, furniture, et.)

reflected light, in which are included also the experience of colors.

At the sewing machine: Sewing requires a concentrated vision, which requires good lighting to reduce eye straining.

At the mirror: Special lighting is needed at some mirrors, e.g. bathroom mirror, toilette table mirror, is therefore a practical feature. Mirror lighting shall illuminate the person standing in front of the mirror.

In the kitchen: Mainly for visual tasks and near vision. Long illumination time. For work relief and hygiene, lighting is an essential feature: Building standardization recommends (BR 570001 ) for the work benches two options: a) 100W bulbs in closed opal - or plastic fittings b ) 20W fluorescent lamps ( ljusfärg lyxvit ) in closed armatur. Illumination of about 150lux at the workbenches; and about 80lux in average.

Bright lights are placed in the ceiling right above the front edge of the workbenches at a suitable distance from each other, and preferably also beside fixed workstations.

Ambient light: shall mitigate the contrast between working lights and surrounding areas, enabling distance vision and create a pleasant lighting atmosphere in the rooms.
What is meant by light atmosphere is not so easy to describe. It arises as a result of all light sources in the room, the appropriate distribution of highlights and shadows, a glare-free light, the appropriate light color and not least of the additional ambient colors and surfaces give, when they reflect light

Indirect light from linear lights in the ceiling. Restful, exclusive lighting. When illuminating surfaces are large the shadows become weak.
Swedish standards for electrical installations that have a direct
effect on home lighting:
SS 437 01 46 (for planning)
EL AMA 12 (for installation)
EL RA 12 (for specifying)

SS 437 01 46: Electrical installations in buildings—connection
points—mode and range
(summary includes only those chapters relevant to lighting)

1. Scope
In this standard number of connection points and other points
and their placement are mentioned. When deciding how many points
are necessary for light fixtures and their placement, you should
take into account needs for good lighting, for cleaning for
example and other various activities. The number of outlet
points recommended in this standard are based on spaces with
bright and matte surfaces. (walls, ceiling)

3. Power switches
Always power switches should be placed next to the room’s
entrance door.

4. Power outlets
The number of outlets should be L/4 rounded upwards. L is the
total length of walls (incl. openings) in a room in meters. In
every room one power outlet per room should be placed next to
the door under the switches.
Outlets are placed max 200mm above floor level. Outlets next to
windows and doors besides the entrance door explained above are to
be placed 800mm above floor level.
Outlets on walls should be placed when possible 500mm from
corner of room.

5. Connection points for fixtures
Connection point for general lighting are placed in ceilings or
walls not lower than 150mm under ceiling.
Number of connection points:
- in room that you can enter there should be at least
  one
- in rooms bigger than 15 m² there should be one
  additional point for every 10 m²

11–21. Standards specified for each room

11.5: Kitchen
The number of fixtures is adjusted to the size of the kitchen so
all workspaces and shelves are lit. Two outlets are to be placed
on a wall 1150mm above the floor for lighting up the workspace
or having lights under the shelf.
Connection for stove lighting is placed on wall 2000mm above
floor, exception if light is integrated in fan.
Connection for dinning table lighting is placed on wall, minimum
150mm under ceiling or in ceiling.
For general lighting in kitchen and as a complement to other
lighting, two outlets are placed in ceiling to fulfill good
lighting for the sink and stove. Points are placed 700mm from
wall.

12.3 Bathroom
Connection point for a fixture is placed above mirror on wall
2100 from floor. Optional on each side of mirror c-c at least
750mm, 1700 above floor.
General lighting if floor area is bigger than 4 m², another
outlet placed in ceiling or on wall is recommended.

EL AMA 12: appliances, equipment, cables: electricity and telecommunications systems
SMB: Power outlets

SMB.11: Placements
- in housing 300mm above floor level or next to list by the floor and if possible 500mm from corner. One outlet in entrance hall should be placed1000mm above floor.
- in attic, basement and other secondary areas outlets to be placed 1300m above floor
For specific reasons, furniture or similar, outlets may be placed at other heights.
In case of obstacle, outlet should be placed at least 100mm from obstacle.
Outlets should be planned to shape a vertical symmetrical line.

SMB.3: Lamp outlets (3 general, specific situations 31-35)
Lamp outlets for general use should be 2-pole with earth 6A, 250V, and fulfill standards SS 4280831.
Outlet for fixture in ceiling should have a plastic outlet of a light colour if no fixture is being mounted.
Lamp outlet on wall should be mounted with earth downwards and above widow with earth upwards so that the cable from lamp comes in the right direction.

SN: Fixtures, light sources
Material and product demands regarding technical details, mounting, sound, earth, security
Installation in appropriate way regarding mounting in different ceilings, pendants, temperature.

SNB: Fixed fixtures
Fixed fixtures for general lighting should comply with standard SS-EN 60598-2-1.

SNC: Mobile fixtures
Mobile fixture should have cable and plug.

EL RA 12: appliances, equipment, cables: electricity and telecommunications systems
SMB: electrical standards regarding power outlets should be specified
SMB.3: electrical standards and montage regarding lamp outlets should be specified

SN: fixtures and light sources for example; mounting, type of light source and effect, protection for corrosion, colour, light spread, glare shields and reflectors etc, should be specified

SNB: fixed fixtures should be specified

SNC: mobile fixtures should be specified

SND: outdoor fixtures should be specified
SNT: Materials for example; socket, type of light source and code, current and effect, colour temperature (for each light source type a specific standard) should be specified.
Statistics Swedish Housing in Stockholm

Stockholm Data

Figure 6. Population structure by sex in 2012 and 2022

Figure 28. Housing construction in the municipality and population growth between 1982-2012 and the planned construction and projected population growth between 2013-2022

Statistics of Stockholm – Housing – Housing construction in 2013

1 Stockholm Läns Landsting, Planområde Prognoser och Demografi, Stockholm 2013
This report belongs to a series of Statistics of Stockholm and reports a collection of statistics on new construction, renovation, demolition, and net surplus of housing in the city during the previous year (2012).

Statistics deals mainly with the new construction and renovation or extension of finalized dwellings. As a basis for the statistics lies the granted planning permission and building permit for new constructions as well as single-family apartment buildings, and renovations of apartment buildings.

**Summary**

During year 2012 a total of 4,356 newly build homes were completed in the City. This is slightly more than in 2011, reflecting the recovery that occurred in the real estate and housing market in 2010, when most of these projects’ construction started.

Renovations and extensions led to a total of 852 homes during the year. In relation to the total contribution of housing in the city, it means a 16 percent. The majority of the contributions took place in the Southern Suburbs, 552 apartments.

The total net addition of housing was 4,969, an increase of housing stock by 1.2 percent. The number of homes in the City at the end of the year is estimated therefore to be 452,563.

Table 2 shows the number of completed apartments per building type, size and area. The most common apartment size in new construction is the two-bedroom apartment, with a total of 1408 pieces. In the inner city are apartments with three rooms and a kitchen somewhat more common.

![Finalized apartments in new buildings by building type, size and area. City of Stockholm in 2012](image)

<table>
<thead>
<tr>
<th>Tabell 2 Färdigställda lägenheter i nya hus per hustyp, storlek och område. Stockholms stad år 2012</th>
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<td><strong>1+,</strong> 1+ <strong>rkv</strong></td>
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<td>Flerbostadshus</td>
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<tr>
<td>Västerort</td>
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<td>Samtliga hus</td>
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<td>Västerort</td>
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**Home renovations and extensions**

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This section shows how many apartments were completed with renovations and extensions and how big the net contribution of apartments is expected to be as the result of remodeling and reconstruction projects started the same year.

During 2012, the rebuilding and construction led to an addition of a total of 852 residences. Seen in relation to the total contribution of housing in the city, this means 16 percent. Table 7 gives the net contribution of apartments by apartment size and area. In the inner city the rebuilding and extensions of apartments has led to an injection of apartments with two to four rooms and kitchen, while the number of smaller apartments decreased by more than 60 pieces. In Söderort and Västerort, approximately half of the contribution of apartments is with one room and a kitchen.

Table 7. Number of apartments before and after remodeling per apartment size and area in 2012

<table>
<thead>
<tr>
<th>Område</th>
<th>1+rv</th>
<th>1 rk</th>
<th>2 rk</th>
<th>3 rk</th>
<th>4 rk</th>
<th>5 rk</th>
<th>6+ rk</th>
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<td>-59</td>
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<td>78</td>
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<td>151</td>
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<td>2</td>
<td>571</td>
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<tr>
<td><strong>Västerort netto</strong></td>
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<td>42</td>
<td>7</td>
<td>3</td>
<td>20</td>
<td>5</td>
<td>1</td>
<td>79</td>
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<tr>
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<td>3</td>
<td>9</td>
<td>6</td>
<td>0</td>
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<tr>
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<td>45</td>
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<td>9</td>
<td>20</td>
<td>5</td>
<td>1</td>
<td>97</td>
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<tr>
<td><strong>Hela staden netto</strong></td>
<td>87</td>
<td>241</td>
<td>231</td>
<td>117</td>
<td>124</td>
<td>34</td>
<td>18</td>
<td>852</td>
</tr>
<tr>
<td>före</td>
<td>6</td>
<td>90</td>
<td>64</td>
<td>40</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>225</td>
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<tr>
<td>efter</td>
<td>93</td>
<td>331</td>
<td>295</td>
<td>157</td>
<td>131</td>
<td>43</td>
<td>27</td>
<td>1077</td>
</tr>
</tbody>
</table>

Housing stock by the end of year
To estimate the number of housing units in the City at the end of 2012 net changes during the year are added to the estimated housing stock from 2011. The result gives an estimated number of 452,563 dwellings in the city by the end of 2012.
Table 10. Number of apartments by area, building type and size in year 2012

<table>
<thead>
<tr>
<th>Area</th>
<th>1+rk</th>
<th>1 rk</th>
<th>2 rk</th>
<th>3 rk</th>
<th>4 rk</th>
<th>5 rk</th>
<th>6+rk</th>
<th>Uppgift saknas</th>
<th>Totalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inre staden</td>
<td>26 421</td>
<td>42 001</td>
<td>54 347</td>
<td>38 228</td>
<td>20 019</td>
<td>7 708</td>
<td>3 919</td>
<td>312</td>
<td>192 955</td>
</tr>
<tr>
<td>Flerbostadshus</td>
<td>26 408</td>
<td>41 992</td>
<td>54 312</td>
<td>38 149</td>
<td>19 923</td>
<td>7 569</td>
<td>3 736</td>
<td>302</td>
<td>192 391</td>
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<tr>
<td>Småhus</td>
<td>13</td>
<td>9</td>
<td>35</td>
<td>79</td>
<td>96</td>
<td>139</td>
<td>183</td>
<td>10</td>
<td>564</td>
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<tr>
<td>Söderort</td>
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<td>16 530</td>
<td>53 322</td>
<td>46 954</td>
<td>22 009</td>
<td>9 217</td>
<td>5 037</td>
<td>272</td>
<td>162 025</td>
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<tr>
<td>Flerbostadshus</td>
<td>9 579</td>
<td>16 428</td>
<td>52 723</td>
<td>42 087</td>
<td>15 580</td>
<td>3 460</td>
<td>548</td>
<td>31</td>
<td>141 334</td>
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<tr>
<td>Småhus</td>
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<td>102</td>
<td>599</td>
<td>3 967</td>
<td>6 429</td>
<td>5 757</td>
<td>3 491</td>
<td>241</td>
<td>20 691</td>
</tr>
<tr>
<td>Västerort</td>
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<td>8 282</td>
<td>24 706</td>
<td>25 481</td>
<td>15 329</td>
<td>9 227</td>
<td>6 698</td>
<td>285</td>
<td>97 583</td>
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<tr>
<td>Flerbostadshus</td>
<td>7 459</td>
<td>8 194</td>
<td>24 248</td>
<td>23 033</td>
<td>9 261</td>
<td>1 487</td>
<td>343</td>
<td>26</td>
<td>74 051</td>
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<tr>
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<td>116</td>
<td>88</td>
<td>458</td>
<td>2 448</td>
<td>6 068</td>
<td>7 740</td>
<td>6 355</td>
<td>259</td>
<td>23 532</td>
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<tr>
<td>Hela staden</td>
<td>43 680</td>
<td>66 813</td>
<td>132 375</td>
<td>110 663</td>
<td>57 357</td>
<td>26 152</td>
<td>14 654</td>
<td>869</td>
<td>452 563</td>
</tr>
<tr>
<td>Flerbostadshus</td>
<td>43 446</td>
<td>66 614</td>
<td>131 283</td>
<td>104 169</td>
<td>44 764</td>
<td>12 516</td>
<td>4 625</td>
<td>359</td>
<td>407 776</td>
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<tr>
<td>Småhus</td>
<td>234</td>
<td>199</td>
<td>1 092</td>
<td>6 494</td>
<td>12 593</td>
<td>13 636</td>
<td>10 029</td>
<td>510</td>
<td>44 787</td>
</tr>
</tbody>
</table>

The term "spatial unit" includes in addition to regular rooms the kitchen. An apartment with four rooms and a kitchen thus consists of five room-units apartment, while an apartment with a room and kitchenette consists of a one room-unit. The apartments in the City by the end of 2012 had an average of 3.5 room-units per apartment. Table 11 shows the number of apartments and room-units, and the average number of room-units per apartment per area and building type.

The homes in the western part of Stockholm have and average with the most room-units per apartment, 3.9 compared with 3.6 in the Southern suburbs and 3.2 in the Inner City. There is no difference between Söderort and Västerort regarding apartments (3.4 room units per apartment). There are small houses that are on average larger in the Western Stockholm than in the Southern suburbs (5.8 compared with 5.4 room units per apartment).

Table 11. Number of apartments and room-units by area and building type in Stockholm year 2012
Housing density

At the turn of the century the apartments were, on average, relatively large, 3.20 room-units per apartment (kitchen counted as one unit). When housing construction took off in the inner city in 1924 most apartments were built as 1 bedroom apartment or smaller. Since 1945, however, the apartments on average have become larger. The value had at the turn of the century was not hit until 1975.

The most common household at the turn of this century was a 4 - or 5-person households. Often in a house that does not belong to the family. Room-unit per person was 1.4 - the highest value ever recorded. Space standards have gradually increased up until 1990 and then decreased slightly.

Table below: Housing density in Stockholm City 1894-2004

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Assessing the need for new housing in Stockholm up till 2030

Situation in Stockholm’s County:
- Very rapid population growth (30,000 new residents per year over the last five years)
- Limited housing
- Latent housing needs

The Government intends for Stockholm County Council to come back every fourth year with the same report.

Objectives for provision of housing
The government aims to achieve a well-functioning housing market where consumer’s demands meet the provision of housing that responds to needs.

Today, there are about one million apartments in the Stockholm region, in a population of about 2.1 million.

Regional assessment of the need of new housing in Stockholm’s County
The regional assessment of the need for new housing in Stockholm’s County is between 179 000 (Low) and 319 000 (High) units by 2030, or about 9000-16000 homes on average each year.

Conclusion

The very fast growth in population, the limited housing and the latent housing needs help estimating that the need for new housing in Stockholm will be of between 179 000 and 319 000 units by 2030, about 9 000 to 16 000 homes in average by year.

Currently the most common size of newly built apartments in Stockholm City is the first 2-rooms followed by the 3-rooms apartments. Coincidentally during the Miljoprogrammet era these two sizes of apartments were also the most commonly built, being 31% for 2room and 38% for 3 rooms, with

---

4 Stockholm Läns Landsting, Tillväxt, miljö och regionalplanering, Regional Bedömning av behovet av nya bostäder i Stockholmsregionen fram till 2030, LS 1206-0914, published 2012
the rest divided between 1, 4 and 5 room apartments.\textsuperscript{5}

Even if there are similarities there are also two main differences between Miljoprogrammet apartments and newly built ones, being one the fact that the kitchen and living room are together in the latest and that the balconies are not set-in from the facade as they used to be in most of the Miljonprogrammet buildings.

\textsuperscript{5}FormasFokusera, Miljonprogrammet-utveckla eller avveckla?, 2012
Survey results
Measuring lux levels at home
Emotional and cultural preferences
14 subjects were asked to answer a questionnaire and measure the light levels on the horizontal and vertical plane at their dining table at home both AM and PM.
They were also asked to draw a plan of their own kitchen with the positioning of windows and light fixtures.

Details about orientation of windows, time of measurements, weather conditions and kind of light source in dining table were additionally asked in the questionnaire form.
The measurements were done around the time of equinox during March 2014.

**Location:** Stockholm, Sweden

**Latitude:** +59.33 (59°19'48"N)

**Sun elevation 21st March – Equinox:** 31°

**Sunrise:** 05:47am

**Sunset:** 18:03pm

**Length:** 12hr 16m
Survey results – Measuring lux levels at home *Emotional and cultural preferences*

Gender

- **Male**
- **Female**

![Bar chart showing gender distribution with higher lux levels preferred by males.]
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

![Bar chart showing age distribution with different categories and color codes for each age group: 26-35, 36-45, 46-55, >55.](chart.png)
Survey results _ Measuring lux levels at home

Emotional and cultural preferences

Country of Origin

- Sweden
- Outside Sweden

![Bar chart showing lux levels in Sweden compared to outside Sweden. The chart indicates significantly higher lux levels in Sweden.]
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

**Size of Apartment**

- 1r
- 2r
- 3r
- 4r
- >5r
Survey results _ Measuring lux levels at home Emotional and cultural preferences

Is the kitchen a separate room?

- Yes
- No
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

On which floor is your apartment?

![Bar chart showing floor distribution](chart.png)

- **Ground**: 2
- **1st**: 7
- **2nd**: 1
- **3rd**: 2
- **>4th**: 2

Legend:
- Blue: Ground
- Purple: 1st
- Green: 2nd
- Orange: 3rd
- Pink: >4th
AM lux levels - with electric light OFF
Horizontal

Near equinox between 06:00-08:30 Av.170lx
Survey results _ Measuring lux levels at home \textit{Emotional and cultural preferences}

\textbf{AM lux levels - with electric light OFF}  
\textbf{Horizontal}

\begin{center}
\begin{tikzpicture}
\begin{axis}[
    ybar,        
    enlargelimits=0.1,    
    legend style={at={(0.5,-0.15)},anchor=north},    
    symbolic x coords={<100lx, 100-300lx, >300lx},    
    xtick=data,    
    nodes near coords,    
    nodes near coords style={anchor=west, align=left, font=\footnotesize},    
]
\addplot coordinates {
(1, 7) \node at (axis cs:1,7) {8};
(2, 3) \node at (axis cs:2,3) {3};
(3, 4) \node at (axis cs:3,4) {4};
};
\end{axis}
\end{tikzpicture}
\end{center}
AM lux levels - with electric light OFF
Vertical

Near equinox between 06:00-08:30 Av.130lx
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

**AM lux levels - with electric light OFF**

**Vertical**

- **<100lx**: 7
- **100-300lx**: 5
- **>300lx**: 1
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

**AM lux levels - with electric light ON at desired level - Horizontal**

- Near equinox between 06:00-08:30 Av.215lx
Survey results _ Measuring lux levels at home Emotional and cultural preferences

AM lux levels - with electric light ON at desired level - Horizontal

- <100lx
- 100-300lx
- >300lx
AM lux levels - with electric light ON at desired level - Vertical

Near equinox between 06:00-08:30 Av.130lx
Survey results _ Measuring lux levels at home Emotional and cultural preferences

AM lux levels - with electric light ON at desired level - Vertical

- <100lx
- 100-300lx
- >300lx
PM lux levels - with electric light ON at desired level - Horizontal

Near equinox between 18:30-22:00 Av.85lx
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

**PM lux levels - with electric light ON at desired level - Horizontal**

- <100 lx: 10
- 100-300 lx: 2
- >300 lx: 0
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

**PM lux levels - with electric light ON at desired level - Vertical**

- Near equinox between 18:30-22:00 Av.45lx
Survey results _ Measuring lux levels at home Emotional and cultural preferences

PM lux levels - with electric light ON at desired level - Vertical

- <100lx
- 100-300lx
- >300lx
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

**Does your PM desired level include candle light?**

- Yes
- No
Survey results _ Measuring lux levels at home *Emotional and cultural preferences*

Do you have a dimmer on your dining table lamp?

- Yes
- No

---

*Graph showing survey results.*
Do you wish to have more natural light?

Survey results — Measuring lux levels at home Emotional and cultural preferences
Do you wish to have more electric light?

Higher lux levels

Survey results _ Measuring lux levels at home Emotional and cultural preferences
What kind of light source do you have in your dining table lamp?

Survey results _ Measuring lux levels at home *Emotional and cultural preferences*
Do you consider your dining table lamp to be glare free?

Survey results _ Measuring lux levels at home *Emotional and cultural preferences*
Survey results _ Measuring lux levels at home Emotional and cultural preferences

Overall, are you satisfied with the lighting conditions you have AM?
Overall, are you satisfied with the lighting conditions you have PM?

Yes: 8
No: 4
Conclusion
Survey results _Measuring lux levels at home Emotional and cultural preferences

• Most common size of apartment is a 2r apartment. This results is in line with the national statistics of the most commonly built apartments.

• The mayor number of kitchens are in a separate room, this shows that most of subjects live in an old-layout apartment.

• AM lux levels – with electric light OFF, measured in average 170lx on the horizontal plane and 130lx on the vertical plane. However desired levels under the same daylight conditions were higher for the horizontal plane 215lx, whilst for vertical iluminance stayed at 130lx.

• The majority of subjects have values for both horizontal and vertical iluminance at AM time below 100lx.

• When setting up their desired levels at AM time the preferences are more varied having 50% of subjects preferences between 100-300lx, with 20% of subjects below 100lx and 30% above 300lx.
Conclusion

- PM lux levels- with electric light ON at desired level, measured in average 85lx on the horizontal plane and 45lx on the vertical plane.

- The majority of subjects show preferences for horizontal and vertical illuminance below 100lx during PM time.

- 92% of subjects shows preferences for vertical illumination below 100lux at PM time.

- Comparing values of desired levels of light AM and PM the survey shows that the majority of subjects prefers at AM time values between 100-300lx while at PM time values below 100lx.

- 35% of subjects use candle light at PM time.

- 57% of subjects have dimmers on their dining table lamps.
Conclusion

• Even if lux levels at AM time can be considered low, only 22% of subjects wish to have more natural light at this time of the day. While only a 14% of subjects wishes to have higher lux levels at PM time.

• 83% of subjects consider their dining table lamp to be glare free.

• Regarding the use of different lighting sources, 77% of subjects still use incandescent or halogen lamps inside their dining table lamps, while a 15,5% uses CFL and only a 7% uses LED.

• The overall satisfaction rate about the lighting conditions at AM time is very high, having 85% of subjects satisfied with the conditions they have. At PM time the satisfaction goes down to 62%, with most of subjects feeling unsatisfied about not having a dimmer, having the wrong type of lamp or not having one directly above their dining table.
Swedish Healthy Home

Graduate Lighting Workshop
April 28, 2014
Lighting for a Healthy Home

- Principles of good lighting design
  - Color rendering
  - Comfort
  - Culturally relevant
  - No glare
  - Visibility

- Circadian regulation
  - Promotes sleep hygiene
  - Promotes good health

- Safety
  - Accommodates typical, aging and disabled populations

- Optimizes energy use
  - Energy management
    - Daylight harvesting
    - Occupancy sensing
  - Increased ratio of benefits to watts consumed
What Makes it Swedish?

Image courtesy of Ljusarkitektur - part of AF Lighting
Typical Swedish Home

- Light color finishes
- Clean environment
- Embracing daylight
- Built-in storage
- High-tech lifestyle
- Lighting provided by tenant

Image courtesy of Ljusarkitektur - part of AF Lighting
Swedish Cultural Lighting
Integrate healthy home concepts seamlessly with Swedish culture
Challenges

- Asynchronous schedules
- Circadian stimulus regulation
- Prescriptive lighting solutions
  - Personal light history collection, analysis, and implementation
- Seasonal fluctuation in solar rhythms
  - Lack of daylight in the winter
  - Overabundance of daylight in the summer
- Swedish Energy and Building Code restrictions
  - Less flexibility in placement of outlets and construction
Healthy Home Road Map

Data Integration System Composer (DISC)

Light history collection

Prescriptive lighting solutions
Light History Collection
DISC: Data Integration System Composer

Integrate with your Healthy Home by incorporating portable or built-in touch screens.
DISC: Data Integration System Composer

Examples of the touch screen interface capabilities
# Controls for lighting solutions

<table>
<thead>
<tr>
<th></th>
<th>New construction</th>
<th>Renovation</th>
<th>Retrofit</th>
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</thead>
<tbody>
<tr>
<td>Controlled by</td>
<td>Lighting history &amp; users’ upcoming schedule</td>
<td>Lighting history &amp; users’ upcoming schedule</td>
<td>Pre-program</td>
</tr>
<tr>
<td>Interface</td>
<td>Primary architectural integrated controls</td>
<td>Primary portable controls with some architectural integration</td>
<td>Portable controls only</td>
</tr>
</tbody>
</table>
How Do We Implement?

- Architecturally integrated solutions
- Daylight integration and harvesting
- Occupancy and vacancy sensing
- Personal interventions
- Tunable lighting
  - Intensity
  - Spectral variation (changes in color)
Architecturally Integrated Solutions

Image courtesy of Ljusarkitektur - part of AF Lighting
Window

- Tunable light system for real and faux windows
  - Real windows deliver natural light when it is available, and use electric light reflected off the blinds to mimic daylight from a window when it is unavailable.
  - Faux windows allow the delivery of circadian stimulus in areas where real windows and daylight are not possible.
Vertical Illumination

Valance:
- Linear LED source
- Valance housing, blocks all direct light

Soffit:
- Built-in soffit blocks direct view of light
- Downward LED washes wall with light
Indirect Lighting

Cove

Coffer
Direct \ Indirect Combinations

Cloud Ceiling Drop
Skylight

Typical daylight collector raised to harvest daylight and tilted south when possible.

Seals for waterproofing

Extends through ceiling layers

Automated shutters

Diffusive panel for effective daylight distribution throughout the room. Internally illuminated with tunable LED lighting for continued use, even when sunlight is not readily available.
Roof Monitor

Circular Style

Square Style
Portable Interventions
Goggles

Orange goggles filter out the short-wavelength radiation to avoid circadian stimulus.

Blue goggles are fitted with 470-nm (blue) LED light, which is known to be a strong circadian stimulus.
Self-illuminating Surfaces
Tunable Lighting
Prescriptive Changes in Lighting
Prescriptive Changes in Lighting

Lighting tunable between cool white (left), blue (center), warm white (right), and 0-100% dimming levels for prescriptive circadian stimulus interventions and occupant comfort
Safety
Lighting for Aging Populations

Plan view

Wall

Door

Night-light
(horizontal element: yellow line above door frame; vertical elements: star-shaped symbols running along door frame)

Detail, plan view

Door frame and door

Wall

Maximum intensity at approximately 5-deg from wall

Motion Sensor Detects at 10'
Photo-Cel Activates
LED Only at Darkness
Nichia Bright White LED
Face Reflects Light
4 AA Batteries (not included)
Provide 2,400 Activations
Weatherproof – (Lowest Cost LED Light to be Weatherproof)
Mounting Bracket for Easy Installation
Attach with Tape or Screws (all included)
30-Second Auto Shut-Off

Vertical and horizontal night-light elements in yellow, mounted to wall/door frame with double-sided tape after being cut on site to length. Optics designed to provide illumination on the back wall and a diffuse glow for ambient illumination.
Optimizing Energy Use
Occupancy and Vacancy Sensing
Daylight Harvesting

Photosensor (left) detects low daylight levels within the space, and raises the energy to the luminaire (right) to maintain task illuminance levels.

Photosensor (left) detects high daylight levels within the space, and lowers the energy to the luminaire (right) to maintain task illuminance levels.
How It All Looks in Your Home
Walkthrough of a day in a New Construction Healthy Home
Scenario Definition: A Farmer and a Bartender

- Mr. Farmer is constantly on a day shift
- Mrs. Bartender is constantly on a night shift
New Construction: Summer Farmer in the Morning
New Construction: Winter Farmer in the Morning
New Construction: Summer Farmer in the Morning
New Construction: Winter Farmer in the Morning

Provides lighting tuned to users’ circadian rhythm entrainment needs when there is not enough daylight available.
New Construction: Summer Bartender in the Afternoon
New Construction: Winter Bartender in the Evening
New Construction: Summer Farmer and Bartender in the Evening
New Construction: Winter Farmer & Bartender in the Evening
How It All Looks in Your Home
Walkthrough of a day in a Renovated Healthy Home
Renovated Apartment: Winter Farmer in the Morning

Recessed soffit with tunable light (surrounds room)
Provides ambient light and can be tuned to the users circadian needs.

Recessed downlight:
Provides extra illumination in the shower area

Vanity lights with tunable lamps:
Provide higher illumination at the mirror that can be tuned to the users circadian needs.
Renovated Apartment: Summer Bartender in the Afternoon

Valance with tunable light: Provides flexible lighting with direct and indirect options. Can be tuned to users circadian needs.

Window: Allows daylight in when available.

Task light with tunable lamp: Provides extra illumination tuned to users circadian needs when necessary.

Faux Window: Provides tunable light meet users circadian needs and to balance space.
Window:
Blackout shade with reflective interior side closes to allow electric light delivery with the window light system when daylight is not available.

Data Integration System Composer (DISC):
Wall panel can be installed to allow users control of lights in their home.
Renovated Apartment: Summer Farmer & Bartender in the Evening

Window: Allows daylight in when available.

Faux Window: Provides circadian stimulus to the bartender.

Orange Goggles: For the farmer to avoid circadian stimulus.
Renovated Apartment: Winter Farmer & Bartender in the Evening

**Coffer lighting with tunable light:** Provides flexible lighting. Can be tuned to users circadian needs.

**Blue Goggles:** Provides circadian needs to the bartender.
How It All Looks in Your Home
Walkthrough of a day in a Retrofitted Healthy Home

Pre-programmed regular lighting schedule
Retrofit Apartment: Summer Kitchen CS
Retrofit Apartment: Winter Kitchen CS
Retrofit: Summer Unoccupied
Retrofit Apartment: Summer Evening
Retrofit Apartment: Winter Evening
Acknowledgements

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Thank you!

Please contact us with any questions!

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