

INTEGRATED ENERGY DESIGN IED

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SOME PRINCIPLES OF LOW ENERGY BUILDING DESIGN

Front page photo:

Hosta Blue Angel (Hosta sieboldiana var. elegans) (Liliaceae)

Huge, deep blue leaves, deeply veined but not puckered. One of the largest blues available, and since it multiplies more rapidly than most of the large blue hostas, it reaches significant size without the long wait. White flowers.

Good slug resistance.

Photo: Kirsten Sander, KS architects, Denmark.

Back page photo:

Green roofs. Model.

layout: KS architects, Denmark

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A GUIDE TO INTEGRATED ENERGY DESIGN

SOME PRINCIPLES OF LOW ENERGY BUILDING DESIGN

PREFACE

This booklet called “Some principles of low energy design” has been developed as an appendix to the IED process guideline, aiming to assist in the work of designing low energy buildings. It contains information that addresses issues of great importance concerning the total energy consumption of the building. The idea behind this booklet is to provide all members of the multidisciplinary team, having different backgrounds, with the necessary/basic information related to low energy building design, in order for them to be able to ask relevant questions on the subject and have a common understanding of related issues, so the design team can face different challenges in the best possible way to achieve optimal overall solutions.

In an Integrated Energy Design process focus is firstly on achieving as much comfort as possible through the passive qualities. Subsequently, focus will be on supplementing with as few but as efficient active qualities as possible in terms of installations, adjustments and other technical systems. Following these IED principles, the booklet is structured in three sections. First, some background information on the process of IED is given. Second, the topic of “how to minimise the energy needed” is covered. The third part gives all essential information related to the energy aspect of the building (e.g. lighting, fire issues, thermal indoor environment, air quality etc.). The fourth section focuses on the use of renewable energy sources to cover energy demands. Finally, resources on commonly used tools for the evaluation of the design are presented as appendix.

Use the principles described on the following pages actively as an assistance to achieve highly energy efficient buildings.

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SOME PRINCIPLES OF LOW ENERGY BUILDING DESIGN

The guide is intended to assist architects, engineers, clients and developers in designing high performance energy-efficient buildings.

The guide focuses mainly on the process of IED, i.e. how the design team may organize their work in order to reach the goals. Thus, the guide will not make the reader an expert in designing energy-efficient buildings, but rather make him/her capable of better understanding the basic ideas of the IED process and its application.

For guidance with respect to technical design issues such as ventilation strategies, etc, the book “Some principles of low energy building design” is provided as an appendix to the IED process guidelines.

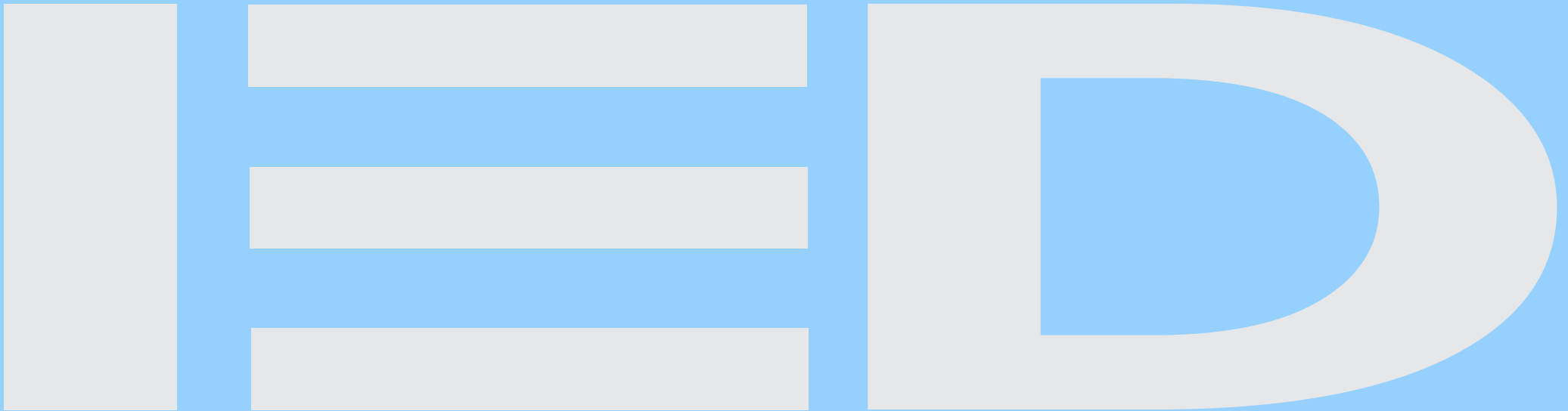
It should be noted that the guideline is made on a general level, which means that it may not fit exactly to each individual project. Since every building project is unique, the working methods, the design phases, and the contracts will differ from country to country and from project to project. Nevertheless, we hope that the guide will inspire the reader to further explore the exiting and rewarding process of Integrated Energy Design.



Both available on www.EcoArchWiki.net or www.intendesign.org

The guideline was made as a part of the Intelligent Energy Europe project INTEND – Integrated Energy Design in Public Buildings. The following partners contributed to the guide:

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01. WORKING WITH IED

What is important?

When planning the design process it is important that it supports the entire design team and that it provides an overview and clarity about which problems should be treated in which order

The three basic elements in this process is:

1. Programming
2. The passive qualities of the building
3. The active qualities of the building

The programming is dealt with separately in fact sheet 3 concerning the client.

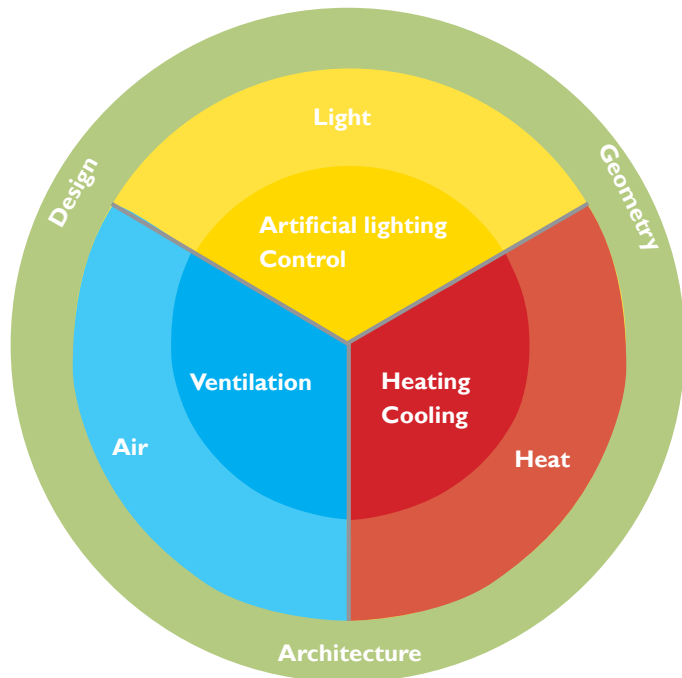
What to do?

The focus areas concerning environmental sustainability are all about

- creating high thermal comfort (experienced temperature, heating and cooling) visual comfort (light and shading),
- high air quality (fresh air, removal of pollution, surplus heat etc.) and
- architectural quality.

All these circumstances are affected by the *passive qualities* of the building, which deals with qualities regarding geometry, design and choice of materials and affect the light, temperature and air in the building.

The *active qualities* deal with the technical installations (lighting, heating, ventilation and cooling) which supplement the passive qualities of the building in order to create a comfortable indoor climate.



In an Integrated Energy Design process focus is firstly on achieving as much comfort as possible through the passive qualities, (the second circle of the chart). Subsequently, focus will be on supplementing with as few but as efficient active qualities as possible in terms of installations, adjustments and other technical systems (the inner circle of the chart).

How is it done?

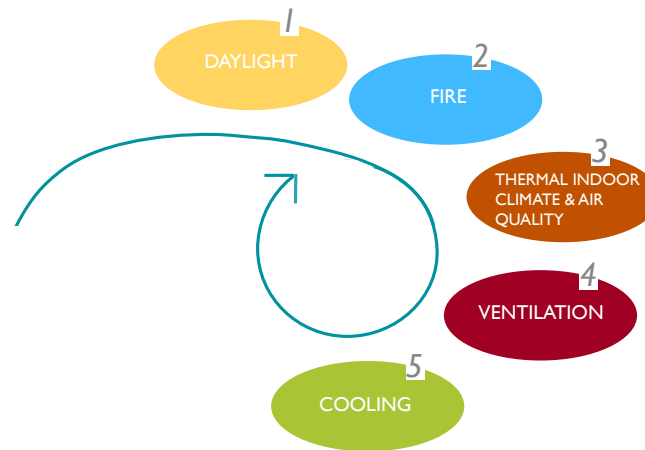
The process steps in Integrated Energy Design (IED) suggest an examination of six central themes in a specific order. The process is iterative and has to be run through several times to reach an optimal design. The order is set from the following argumentation:

1. **Daylight** is the first step after programming, since there is no “technical fix” to compensate for the lack of daylight (besides artificial lighting, which increases energy consumption and adds more heat to the building than daylight, which subsequently must be actively cooled). In the analysis phase, the building is mapped and organized according to the possibilities for using daylight and it gives an overview for planning artificial lighting and its adjustments to this.
2. **Fire** is the next step, as a well planned fire strategy offers the best opportunities for creating free movement of the air and gives the possibility of co-thinking fire ventilation with natural comfort ventilation which works by the same principles.

3. Thermal Indoor climate & Air quality is the third and often most demanding step, due to the high complexity and many parameters that influence the experienced air quality and thermal comfort in the building. The result of these analyses deals with insulation, heating and cooling needs, heat accumulation, heat insulation of windows and specifies the dynamic ventilation needs in the building.

4. Ventilation deals with an analysis of the possibilities for firstly natural ventilation, which does not need electricity, and secondly analysis of mechanical ventilation. The fire analysis provides parameters offering conditions for free movements of air. Further on, important steps will be the design of openings, adjustments of openings and checking for acoustic requirements and odour from the surroundings. When planning the mechanical ventilation focus should be on supporting the natural ventilation (hybrid ventilation) and on designing in accordance to the maximum demand for fresh air in the building.

5. Cooling is the last step in the IED-process. First we examine the possibilities for using free-cooling which is then supplemented with traditional mechanical cooling in zones needing this.



References

- www.iea-shc.org/task23 Collection of material regarding various process models for IED
- www.intendesign.com EU project on Integrated Energy Design of public buildings
- www.ied.no The NICE project has guidelines and examples of Integrated Energy Design with focus on Nordic conditions



Norwegian Wood project Marilunden
Arkitekt: Eder Biesel Arkitekter AS,
Noncon:form
Photo: Per Anda

02. BUILDING PROGRAM Setting up the goals

What does the client want?

It is of primary importance to come to an understanding about the client's requirements so all future activities meet the demands, wishes and expectations of the client.

In the preliminary phases inquiries through open questions should be made about:

- *The organization and company strategy.*
 - o What is the vision and mission of the client
 - expressed or unconscious?
 - o Client awareness about sustainability, energy, environment, climate, Carbon-policy etc.?
- *Demands/wishes*
 - o Function
 - Specific demands for function, everyday life, experiences - not only traditional demands for function.
 - How does the client regard comfort and what are the expectations to this area (besides observing the general legislation?)
 - Should dress codes, planned vacation periods, periods with special usage or other work tasks etc. be taken into consideration?
 - o Environment
 - What environmental goals, stories and messages does the client want to attach to the project in question?
 - What is it worth in terms of branding and marketing, internally and economically in construction and operation?
 - o Economy
 - How does the client capitalize future savings?
 - o Time frame
 - What is flexible and what is not?
 - What is the decision-making processes and important deadlines?
- *Other*
 - o What is the ultimate contribution of the building to the client?
 - o What does the client appreciate in other buildings?
 - o What is "nice-to-have", "need-to-have" and "nice-to-need" for the client?



Tools:

In the preliminary phases enquiries through open questions are used. Elaborated questions uncover requirements, wishes and expectations.

All clients are different - all questions must be adjusted to the clients, so the dialogue is on their terms.

The following process concerning holistic sustainability will be organized in the work with **Integrated Energy Design**.

References

http://en.wikipedia.org/wiki/5_Whys Technique for asking - 5 x Why
www.sbi.dk/miljo-og-energi/miljovurdering/miljorigtig-projektering-af-byggeri/ Environmental safe projecting

03. THE DESIGN PROCESS

What is important?

The Trias Energetica is a very useful method in connection with energy optimization of a specific design after clarifying the client's wishes for the program and completing the Integrated Energy Design process. The Trias Energetica principle can be used as a superior principle under each step of the Integrated Energy Design process.

What to do?

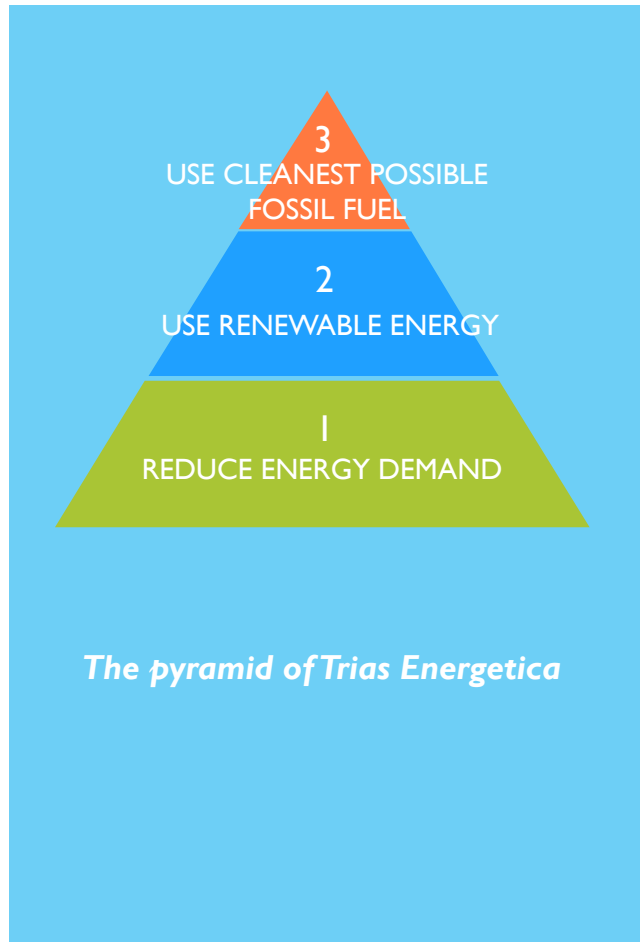
The Trias Energetica method prioritizes various initiatives in connection with the use of energy.

The method consists of 3 steps:

1. Reduce the demand for energy
2. Use sustainable sources of energy
3. Use fossil fuels as efficiently as possible

How to do it?

The starting point in a specific design process will always be user comfort, especially in commercial buildings. It is important to have a differentiated view on each comfort situation, and to consider simultaneity, dress-code, level of activity etc.



The first step in the design process is to focus on minimising the energy need.

This can be done by:

- Analyses of the site (solar and wind conditions, orientation etc.)
- Optimization of the building geometry
- Using good windows
- Optimize daylight use
- Sufficient insulation
- Minimising thermal bridges
- Tightening the building
- Using any free heat supplements
- Avoiding overheating (which produces cooling needs)
- Using energy efficient artificial lighting
- Avoiding standby losses
- Etc.

The second step is about covering the building's energy need through the use of as much sustainable energy as possible. In terms of design, it means focusing on e.g.:

- Using free solar heat supplements for heating
- Prioritizing low temperature heating like floor heating, which can be combined with solar heat
- Examining the possibilities for using biomass boilers
- Designing for the use of active solar heat and solar cell systems
- Etc

Third step is about efficient use of fossil fuels to cover the remaining energy demands in the building. This is done in the design process by ensuring:

- An efficient energy supply
- Adjusting for the actual operating profile of the building
- Dividing into zones of similar functions and needs, which can be supplied from the same unit
- Etc.

It is important that the engineer and the architect work close together from step one to ensure that passive measures are integrated in the design of the building.

References

www.triasenergetica.com

Introduction to trias Energetica and links to papers etc.

04. ANALYSES OF THE SITE-URBAN PLANNING

What is it?

Site analysis is the process of studying the contextual forces that influence how we might situate a building, lay out and orient its spaces, shape and articulate its enclosure, and establish its relationship to the landscape. Any site survey begins with the gathering of physical site data.

How is it done?

- Draw the area and shape of the site as defined by its legal boundaries.
- Estimate the area and volume required for the building program, site amenities, and future expansion, if desired.
- Analyze the ground slopes and subsoil conditions to locate the areas suitable for construction and outdoor activities.
- Locate soil areas suitable for use as a drainage field, if applicable. Map existing drainage patterns. Determine the elevation of the water table. Identify areas subject to excessive runoff of surface water, flooding, or erosion.
- Locate existing trees, water surfaces and native plant materials that should be preserved.
- Map climatic conditions: air temperature, relative humidity, solar radiation, the path of the sun, the direction of prevailing winds, and the expected amount of rainfall. Calculate degree days.
- Consider the impact of landforms and adjacent structures on solar access, prevailing winds, and the potential for glare.
- Evaluate solar radiation as a potential energy source.
- Ascertain the availability of utilities: water mains, sanitary and storm sewers, gas lines, electrical power lines, telephone and cable lines, fire hydrants.
- Cite potential sources of congestion and noise.
- Evaluate the compatibility of adjacent existing and proposed land uses. Consider how the existing scale and character of the neighbourhood or area might affect the Building design.

Some important things:

1. Landform or modulations of earth has the ability to modify, ameliorate or accentuate climatic variations in different ways.

- In hot climates, building in a depression implies relatively lower air temperatures. When building on a slope, the leeward side is preferable, as long as the orientation is acceptable. In both cases warm breezes would be minimized. The collection of water in a depression might allow for a water body. This would also be beneficial in cooling the place.



Photos: Kirsten Sander,
KS architects

- In cooler climates, not only do we not place our building in the depression we also avoid the path of the cool air down the slope. Here again, vegetation could help in protecting from cool breezes.
- In humid climates, our primary concern is maximizing air movement. We must, therefore, place our building on the top of the windward slope where the air speed would be the highest.

2. Vegetation and trees in particular, very effectively shade and reduce heat gain. It also causes pressure differences, thereby, increasing and decreasing air speed or directing airflow. They can, therefore, direct air into a building or deflect it away.

- In hot-dry climates where heat gain is to be minimized, trees can be used to cut off the east and west sun. Hot breezes can be effectively cut off. Planting deciduous trees is very useful because they provide comforting shade in summer and shed their foliage in winters allowing sun.
- In cold climates evergreen trees can be used to cut off breezes. However, they would also absorb solar radiation and, thereby, cool the place.
- In warm humid regions vegetation can be employed to maximize airflow through occupied places.



3. Water surfaces absorb relatively large amount of radiation. They also allow evaporative cooling. As a result, during the daytime areas around water bodies are generally cooler. At night, however, water bodies release relatively large amounts of heat to the surroundings. This heat can be used for warming purposes.

- In hot-dry climates, water/ water bodies can be used both for evaporative cooling as well as minimizing heat gain. Taking into account wind patterns and vegetation they can be used to direct cool breeze into the house. A roof pond minimizes heat gain through the roof.
- In cold climates, water bodies are beneficial only if their heat gain and loss can be controlled. However, we may be faced with a large water body in a cold region. The best thing to do then is to stay away from it.
- In warm-humid regions water bodies are best avoided. The minimal benefit provided by evaporative cooling would be offset by the heightened humidity levels.



Photo: Kirsten Sander,
KS architects

4. Open spaces and built form can allow for freer air movement and increased heat loss or gain.

- In hot-dry climates, compact planning with little or no open spaces would minimize solar heat gain. If the heat production of buildings is not low, the size and scale of open spaces should be optimized to have also sufficient heat loss at night.
- In cold climates open spaces should be small. Surfaces could be hard and absorptive. Compact planning is preferred. They should allow the south sun into buildings.
- In humid climates buildings should preferably not be attached to one another. Streets and the open spaces should be oriented with respect to wind patterns. The open spaces and the funnel effect can be used to maximize airflow within the complex

5. Street lay-out and orientation affects the urban ventilation conditions and solar exposure of buildings.

- In hot-dry climates, small street width to building height ratio ensures shading. In particular, streets running north-south should be narrow to enable mutual shading from the horizontal morning and evening sun. East-west streets are avoidable as they allow uncomfortably low sun in the mornings and evenings. However, if unavoidable, they too should be narrow.
- In cold climates, wide streets, especially the east-west streets allow buildings to receive the south sun.. North-south streets should be narrow. Low building heights are preferred. This would enable heat gain from the roof to be maximized. However, heat loss also has to be minimized.
- In warm-humid climates the primary need is for air movement. Streets, should therefore, be oriented to utilize the natural wind patterns.

References

www.learn.londonmet.ac.uk/packages/clear/index The CLEAR project.
www.facilities.ufl.edu/projects/ University of Florida project information.

Passive cooling of buildings. Editors: M. Santamouris and D. Assimakopoulos,
James and James (1996)

05. BUILDING CONFIGURATION

What is it?

A building's shape, solar orientation, layout, and size are factors that affect its energy use, daylight availability and its sustainability.

How does it work?

Physical obstacles in the path of airflow create pressure differences. This causes a new airflow pattern. Air tends to flow from high pressure areas. Knowing the direction of air movement, the plan form can be determined also as to create high pressure and low pressure areas. Building openings connecting the high pressure areas to low pressure areas would cause effective natural ventilation.

- The plan form of a building affects the airflow around and through it. The perimeter to area ratio (P/A) of the building is an important indicator of heat loss and gain. It, therefore plays a role in ventilation, heat loss and heat gain.
- The building orientation determines the amount of radiation it receives. The orientation, with respect to air patterns, affects the amount of natural ventilation possible.
- The surface area to volume (S/V) ratio (the three dimensional extrapolation of the P/A ratio) is an important factor determining heat loss and gain.

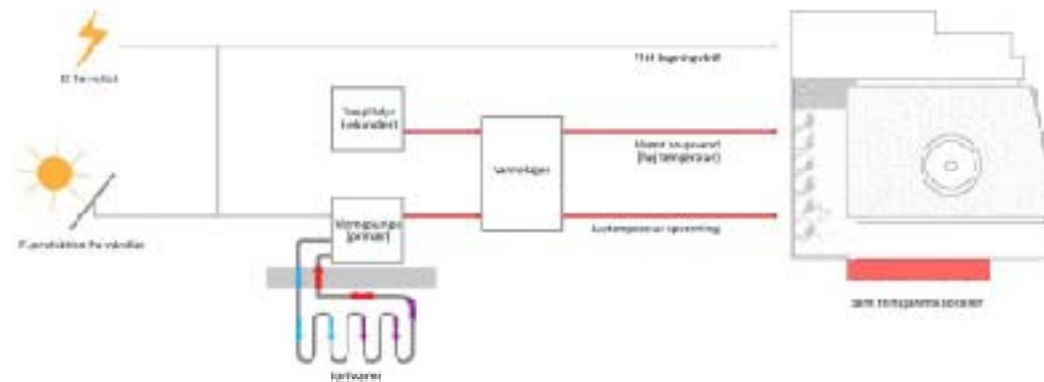
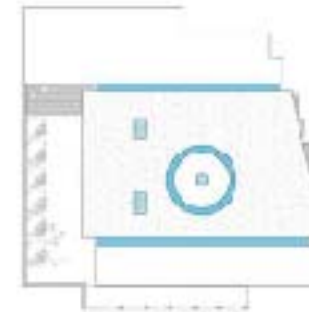
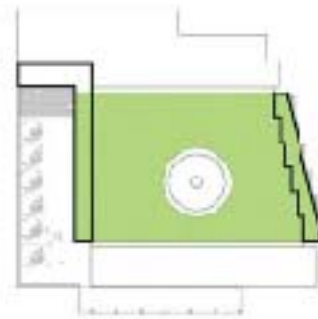
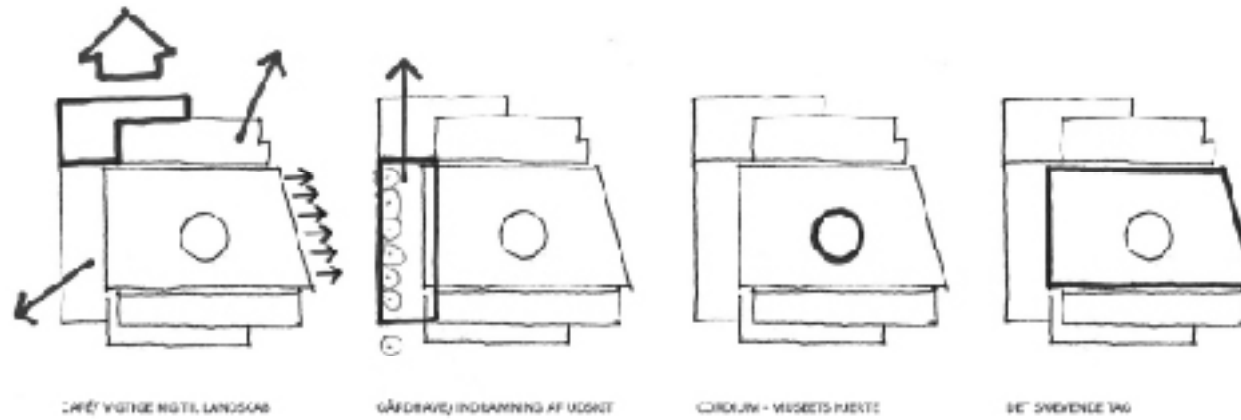
Some important things:

In hot climates the P/A ratio should be kept to a minimum. This would cause minimum heat gain. Plan form for enhancing ventilation is not a compelling proposition as breezes are often quite warm.

- In cold climates too the P/A ratio should be minimal. This ensures minimum heat loss. Heat gain can often be achieved by solariums etc.
- In warm-humid climates the prime concern is a plan form for maximizing air movement. Here too, minimizing the P/A ratio is useful as it minimizes heat gain.
- For the northern hemisphere a building should be oriented east/west rather than north/south in order to take advantage of daylighting, passive heating, and easier sun control
- In hot dry climates S/V ratio should be as low as possible as this would minimize heat gain.
- In cold-dry climates also S/V ratios should be as low as possible to minimize heat losses.
- In warm-humid climates the prime concern is creating airy spaces. This might not necessarily minimize the S/V ratio. Further, the materials of construction should be such that they do not store heat.

References

www.learn.londonmet.ac.uk/packages/clear/index The CLEAR project.
www.facilities.ufl.edu/projects/ University of Florida project information.
Passive cooling of buildings. Editors: M. Santamouris and D. Assimakopoulos, James and James (1996)



06. DAYLIGHT

What is it?

Daylight comes from the sun. The surrounding atmosphere of the earth spreads the sunlight and skylight is produced. From the surface of the earth three different types of lights are seen - sunlight, skylight and reflected light.

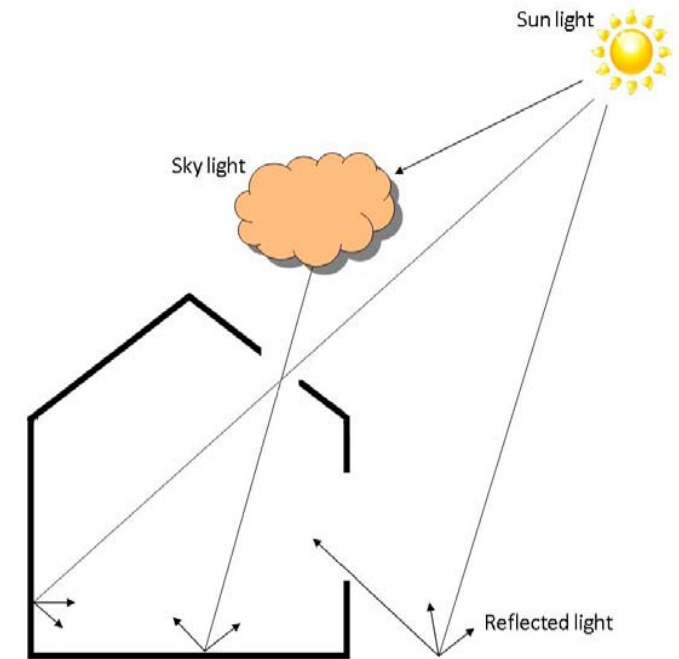
- **Sunlight** is the dynamic light, which, according to the time of day and year, is positioned differently in the sky.
- **Skylight** is the constant and diffuse light.
- **Reflected light** - When the sunlight and the skylight hit a surface they are reflected and a third type of light, reflected light, is added to the previous types.

What are the requirements?

In Denmark it is overcast during 60 % of the working hours (8.00-17.00), and daylight is therefore estimated compared to an overcast sky and is called the daylight factor. The daylight factor is independent of the orientation of the window. The requirements for access to daylight are described in the Danish building regulations, where it says that:

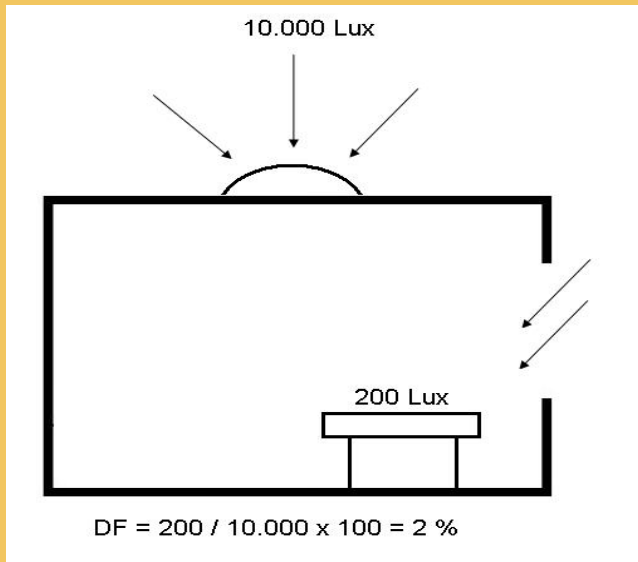
- Working spaces, institutional living rooms, classrooms, dining rooms and residential rooms must have sufficient access to daylight.

In practice this means that daylight is considered adequate, when there is a daylight factor of 2% in working spaces or when the window area through sidelight corresponds to at least 10% of the floor area or when light from above corresponds to at least 7%.



Average daylight factor / demand for artificial lighting

- > 5% Relatively high level of daylight. Artificial lighting is normally not necessary during the day.
- 2-5% The daylight is the main light source in the room but it would normally be necessary to add artificial lighting at workstations
- < 2% Artificial lighting is necessary and will be the main light source in the room.



Daylight factor

This is percentage ratio of the instantaneous illumination at a reference point inside a room to that occurring simultaneously outside in an unobstructed position.

How to do it?

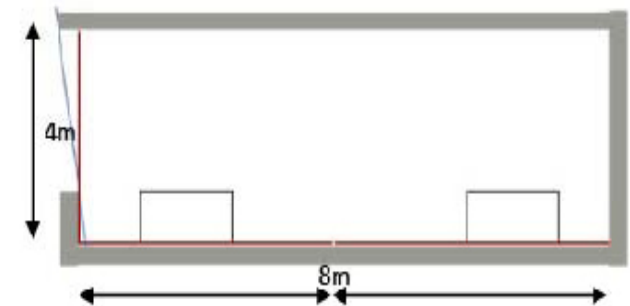
It is important to work with daylight in the beginning of the design phase, as it is not possible to compensate with technical solutions later on. Daylight is decisive for many aspects of the geometry and organization of a building, as the designing of the light inlets in the building is decisive for the distribution and the intensity of the light.

The following factors influence the access of daylight:

- the geometry of the room (height/depth relationship)
- the area and placement of the window
- the size and
- the placement of surrounding

Geometry of the room

The intensity of the light decreases the further it gets from the light source (the window). Therefore, the back of a room can be dark although the light inlet is rather large. To achieve a well lighted room the depth of the room should not exceed twice the height of the window, when the window goes from the ceiling and down.



Placing the window

The top of the window decides how far the light enters the room. By raising the top of the window the level of light increases. The level of light will not rise if the window is extended downwards, it will only increase the level of light right by the window. For estimations and calculations concerning the connection between window areas, height/depth relationships, choice of glass and daylight factor please see the publication "Energi og Arkitektur" (see "References" for download).

Roof -and ceiling light gives more daylight than side light, partly because a larger part of the room receives direct skylight, and partly because the amount of vertical light is 3 times bigger than horizontal light.

Choice of glass

The choice of glass greatly influences the amount of light that enters the room, after the geometry of the facades is set. It is important to choose windows with a high light transmittance (LT-value) and good colour rendering, i.e. the Ra-index should be as high as possible.

The choice of glass also affects the heat loss (U-value) and the heat contribution from the sun through the window (g-value) - factors that need to be considered closely when choosing glass.

Sunlight

In the planning phase it is important to be observant of the orientation of the light inlets and if they answer to the purpose of the room. The height of the sun, and the need for sun screening due to glare or heat should also be taken into consideration. The orbit of the sun can be seen in a solar path diagram or can be read in computer programs - see fact sheet 8 on solar shading

References

www.ebst.dk/br08.dk

www.at.dk

www.sbi.dk/arkitektur/beredygtig/arkitektur-og-energi

www.gaisma.com

SBi-anvisning 196

Danish Building Regulations, section 6 is about daylight

Arbejdstilsynet. Requirements for i.e. daylight

Link to »Energi & Arkitektur«

Sundiagrams from the world. In English

»Indeklimahandbogen«



photo: Kirsten Sander,
KS architects

07. ARTIFICIAL LIGHTING

What is important?

Artificial lighting is a supplement to daylight, i.e. when the daylight is inadequate artificial lights are turned on. The lighting system should create a satisfactory visual environment with good conditions for vision. To achieve such an environment the following factors should be considered:

- Strength of lights
- Distribution of lights
- Glare
- Colour rendering
- Adjustments

Requirements?

The requirements for artificial lighting are described in the Danish standard “DS 700 - Artificial lighting in workrooms”, and standards specifically for hospitals and dental clinics are also available (DS 703 and DS 705 respectively). For typical workstations the requirements for lighting strengths are:

- 50 lux in hall areas.
- 200 lux normal lighting.
- 500 lux in extensive reading and writing conditions.

In addition, the glare index for the lighting system must not exceed 20, and the Ra-index (see later) must be minimum 80.

Glare index

Used for artificial lighting. A method of predicting the presence of discomfort due to luminance step. Expressed in numeral values. Typical requirements are max. 20 and preferably 16.

Ra-index

The Ra-index is used to describe the ability of the light source to render colours. The Ra-index is a number between 0-100 where 100 is daylight.

What to do?

Lighting strength and light distribution

The same light distribution in two different rooms does not necessarily give the same experience of the rooms. What we see is the reflection from the surfaces in the room (surface luminance). Therefore, the materials and the colours greatly affect the experienced light. It is easiest to create good lighting conditions in rooms with bright surfaces, as bright surroundings reduce the risk of glare and “dark holes” and ensure an efficient use and distribution of the light.

Distribution of light between the working object (e.g. a piece of paper), working area (e.g. a desk), and the surroundings (e.g. the room) should be 10:3:1.

Glare

Glare can be direct glare, where the light source shines directly into the eyes, or indirect glare, where the light source is reflected from a shiny surface into the eyes. Unpleasant glare comes from unprotected lighting fixtures. Reduced sight glare arises from strong direct sunlight (when you exit a tunnel and get the sunlight directly in the face). Glare can be avoided by using bright colours in the room, by using protected fixtures and by avoiding placing fixtures right above workstations.

Colour rendering

Artificial lighting renders the colours poorer than daylight, as they do not hold the full colour register. The ability to render colours is described in the colour rendering index, the Ra-index.

Incandescent bulbs is the type of artificial lights with the highest colour rendering with Ra=99. Energy saving bulbs and compact fluorescent lights has colour renderings of about 80-89. In commercial buildings the colour rendering must be over 80.

Light sources

It is also important to notice the energy efficiency of the light sources, i.e. how much light is sent out from the light source compared with the energy/heat it emits. Daylight is the "light source" with the highest energy efficiency, and today no light sources match daylight. In the future LED-lighting will probably reach an energy efficiency of 150 lumen/W, in which case LED-lighting would match daylight in regard to energy efficiency.

Regulation

Regulation of a lighting system can happen through on/off switches, time regulation (by clock), motion regulation (motion sensor) or light regulation (light sensor). The lighting system should also be divided into zones. On daylight regulation it would be typical to divide the system in rows parallel to the window facade.

The most efficient regulation is through daylight regulation where the ceiling lighting is adjusted automatically according to the entered daylight. 50% of the energy consumption for lighting can be saved through daylight regulation.

5 important things

- Light distribution in a room should be 10:3:1 (working object/working area/surroundings).
- Avoid glare.
- Use light regulation - Daylight regulation is the most energy saving.
- Ra-index must be minimum 80 and higher dependent of working task.
- Energy efficiency of light sources should be as high as possible - daylight is the best "light source".

Energy efficiency for selected light

Source		
Daylight	140-160	lumen/W
LED-lighting	70-80	lumen/W
Metal halogen	65-85	lumen/W
Compact fluorescent light	35-93	lumen/W
Halogen glow lamps	12-27	lumen/W
Incandescent bulbs	10-20	lumen/W

References

- www.faba.dk Programme to calculate artificial lighting systems.
- www.lysteknisk.dk Lysteknisk Selskab. Homepage with information regarding light.

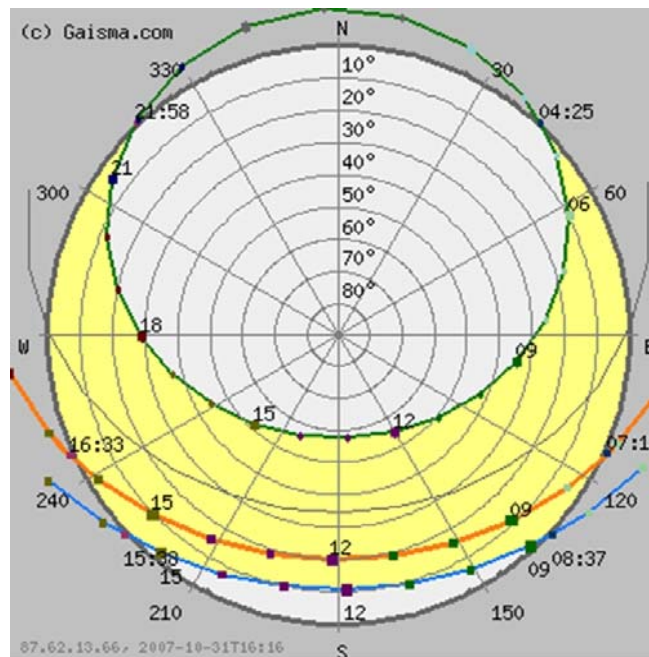
08. SOLAR SHADING

What is it?

Solar shading is used for screening the direct sunlight, in order to either reduce the heat load or to avoid glare from the windows. External solar shading is most efficient in terms of reducing heat radiation, as the rays of the sun will not pass through the windows. Internal solar shading has limited effect as heat screenings, but work well as glare screenings.

What is important?

Besides screening for the sunlight, solar shading also screens the skylight, which is important for the general level of daylight in the room. This means that if the skylight is permanently screened, the general level of light in the room is reduced. It can be appropriate to work with flexible solar shading in the Nordic countries, as these countries only experience few hours with sunlight, and flexible solar shading allow as much daylight into the room as possible during overcast periods. The most efficient solar shading will only just cover the orbit of the sun.



What to do?

Solar shading should be planned carefully. First of all, the purpose of the solar shading must be determined. Is it for heat reduction or for glare? What other requirements are present? Is there a request of free field of vision? Is it wind sensitive etc.?

It is important to consider the height of the sun when planning solar shading. The position of sunlight on the sky is dependent on the location on earth and time of day and year. The orbit of the sun can be seen in a sun path diagram or can be read in computer programmes. See www.gaisma.com for further information on sun path diagrams.

The height of the sun is e.g. used to determine whether the shading should be vertical or horizontal. When the sun is positioned high in the sky horizontal shading is the most effective, while vertical shading works better when the sun is positioned low in the sky.

The height of the sun is also used for working out regulation strategies for the shading, e.g. how much the lamellas on the blinds should tilt in order to screen for the direct sunlight.

The regulation can be operated manually or automatically and with or without user control. The advantages of automatic regulation are that the screening is regulated according to the intensity of the sun on the facade and that the lamellas will adjust according to the height of the sun, resulting in optimal shading.

The disadvantage is that rapidly changing weather can make the screens shuttle. If the screenings are user controlled, the shuttling can be avoided by overriding the screening.

Summary

The chart below shows the advantages and disadvantages of various solar shading types. Notice that variations may occur depending on the regulation strategy and the climatic conditions.

Type	Heat screening	Glare	Daylight-access	Field of vision	Regulation	Wind sensitive
Awnings	++	÷	+	+	+	Yes
Projections	++	÷	÷	+	÷	No
External blinds	+++	+	+	÷	+	Yes
Internal blinds	÷	+	+	÷	+	No
External screen	++	+	+	÷	+	Yes
Internal screen	÷	+	+	÷	+	No
Shutter	+++	÷	+	+	+	Yes
Solar shading glass	+	÷÷	÷	+	÷	No

09. FIRE ISSUES

What is important?

Fire precautions should be dealt with early on in the design phase, as it can fix the design and greatly influence the strategy for sustainable design. With the introduction of functional based fire demands it is possible to design larger and more connected rooms, but this also involves increased demands for the fire strategy in the building.

What to do?

It is important to address the local authorities early on, as the fire inspector can request documentation for fire design, which should include:

- The use and design of the building
- Placement of the building
- Escape routes
- Active- and passive fire precautions
- Fire extinction possibilities for the rescue party

It is important to include the fire authorities early on to establish whether there are specific demands to the fire strategy in the building.

How to do it?

The “Eksempelsamling om brandsikring af byggeri”, focuses on the decisions in the Danish building regulation chapter 5 and it shows how to comply with the regulation. The examples only include traditional buildings and can not directly be used in more complex buildings.

When dealing with more complex buildings there will often be demands for fire design through 3D-analyses. Examples of how to carry out a fire design is illustrated in the publication “Information om brandteknisk dimensionering”.

Fire ventilation

- Installed to ensure personal safety, prevent spreading of fire or secure parts of the building
- Demands for fire ventilation can increase the potential for natural comfort ventilation.
- Openings can be used for fire ventilation as well as for comfort ventilation.

The publications “Eksempelsamling om brandsikring af byggeri” and “Information om brandteknisk dimensionering” can be downloaded from the homepage of “Erhvervs- og Byggestyrelsens”, see references.

Smoke ventilation

- Smoke ventilation is installed to ensure the extinction areas of the rescue party and is therefore activated only by them.
- Smoke ventilation is typically installed above escape routes.
- Smoke ventilation has normally no influence on the potential for natural ventilation.

5 important things

- The functional based fire demands are firstly about personal safety
- Functional based fire demands offers flexibility and the possibility of having larger rooms/volume, but increased demands for fire strategy is needed.
- Demands for fire ventilation can increase potential for natural comfort ventilation.
- Demands for sprinklers can reduce the potential for natural comfort ventilation (sprinklers will cool down the smoke and reduce the thermal buoyancy) and thus cause demands for mechanical smoke ventilation.
- Double facades can be problematic due to the spreading of fire and smoke.

References

- | | |
|--|--|
| www.ebst.dk/publikationer/eksempelsamling_om_brandsikring_af_byggeri/index.htm#download | Erhvervs- og Boligstyrelsen. Link to download of "Eksempelsamling om brandsikring af byggeri" |
| www.ebst.dk/publikationer/rapporter/brandteknisk_dimensionering/index.htm | Erhvervs- og Boligstyrelsen. Link to download of "Information om brandteknisk dimensionering". |
| www.ebst.dk/br08.dk | Erhvervs- og Boligstyrelsen. Link to bygningsreglementet BR08 |
| www.dbi-net.dk | DBI - Dansk Brand- og sikringsteknisk Institut. |

10. THERMAL COMFORT

What is it?

Design of a good thermal indoor climate deals with the thermal comfort of the users of the building. This means that they feel comfortable in relation to their experienced temperature. As the figure shows, there are many factors influencing the experienced temperature and therefore many conditions which have to be considered during the design of the thermal indoor climate.

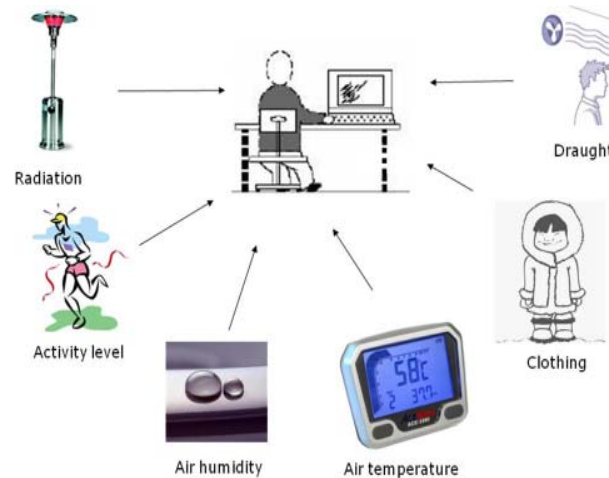
As a result of the requirements for the thermal indoor climate, the heating- and cooling demand in the building is determined.

What are the requirements?

The requirements for the thermal indoor climate in Denmark are stated in "DS 474 -Code for Thermal Indoor Climate". The code prescribes that the experienced temperature in the occupied zone has to be within the following intervals, where it can be expected, that 80 % of the users are satisfied with the thermal indoor climate:

- Winter: 20-24 °C
- Summer: 23-26 °C

In periods, where the outdoor temperature or other conditions are extreme and go beyond the design preconditions, it can be allowed that the requirements for the experienced temperature are exceeded.



The air humidity only has a small influence on the perception of thermal comfort and it is therefore not necessary to make special requirements regarding the air humidity. The recommended interval for the relative air humidity is therefore also relatively large and is between 30-70 %.

Draught, radiation, activity level and clothing. Apart from the influence on the experienced temperature, special demands to these parameters are made. These are dependent on various factors and will not be explained here. Reference is made to "DS 474 - Code for Thermal Indoor Climate" for further information.

Thus the following recommended values for exceeding the temperature intervals on hot days with light summer clothing and sedentary work are set up:

- Max. 100 hours above 26 °C
- Max. 25 hours above 27 °C

The recommended values for the exceeding are valid for the time of occupancy during a typical year, and are values which can be determined by using the simulation programme BSim.

5 important things to reduce the energy demand

- It is the users of a building that have comfort requirements and not the building itself. Therefore focus should be on the users and their activities when designing for the thermal indoor climate (situations can occur where specific demands are made independent of the users in e.g. the process industry, on museums, and for storage of vulnerable materials).
- Zoning in areas with the same thermal comfort requirements (the experienced temperature).
- Zoning in areas with the same time of occupancy and user pattern.
- Focus on the contribution from the passive solar heating: avoid it in areas with risk of high temperatures and make use of it in areas with a heating demand.
- Minimise the internal heat load (persons, devices and lighting) in areas with risk of high temperatures.

References

www.bvgnet.dk

Byggecentrum from where
"DS 474 - Code for Thermal Indoor Climate" can be bought.

www.sbi.dk/indeklima/simulerin

BSim - Calculation of thermal indoor climate and energy use for operation of the building

SBI-anvisning 196 "Indeklimahandbogen" (Indoor climate)

II. AIR QUALITY

What is it?

As for the thermal indoor climate, it is not the building but the users who have requirements to the air quality.

Therefore it is important that the focus is on the users when designing for the air quality.

Air quality principally consists of 3 parameters:

- Appropriate CO₂-level
- Low content of pollution from particles and degassing from materials
- Appropriate air humidity

Air quality can e.g. be simulated with software like BSim and as a result the demand for fresh air supply is determined. The fresh air demand is defined in l/s (litre/second) or air change per hour (h⁻¹). An air change of 1 h⁻¹ means that the air volume in a room is changed during one hour.

What are the requirements?

When breathing we exhale carbon dioxide - also called CO₂. If fresh air is not supplied to the occupied zone the CO₂ content in the air will rise.

Increased CO₂ concentrations can result in lack of concentration and symptoms as headache and dizziness can arise. CO₂ is therefore an important design parameter, when designing for the air quality.

The requirements for the CO₂ concentration are among other things dependent of the ventilation type:

- Mechanical ventilation: CO₂ < 1000 ppm
- Natural ventilation: CO₂ < 1000 ppm (mean)
CO₂ < 1500 ppm (max)

Pollution from particles and degassing

There are no specific maximum requirements to the pollution from particles and degassing from materials as it is a very complex area and very difficult to clarify. However, it is important to have focus on these parameters as research has shown that they have an influence on the pronounced increase of asthma and allergy which have been seen the last 10-20 years.

The external pollution is an important parameter as it has a large influence on the need for filtering of the outdoor air before it is supplied to the occupied zone. An increased demand for filtering will increase the demand for energy and at the same time reduces the possibilities for the use of natural ventilation.

Over time dust particles will be formed internally in the building and these particles have to be removed by regular cleaning. Especially for mechanical ventilation systems it is important that a regular replacement of the filters and cleaning of the duct system are made in order to keep the air quality supplied to the occupied zone optimal. By easy access for service and maintenance and by minimizing the amount of ventilation ducts, the risk of insufficient maintenance can be reduced.

Air humidity

The air humidity is affected by a number of factors as sweat, air humidity in the outdoor air, moisture load from cleaning, cooking and plants plus a relatively large contribution from respiratory air. The air humidity usually only has a small influence on the human perception of the air quality, and therefore the recommended interval for the relative air humidity is also relatively large and is between 30-70 %. Above this limit one could feel the air as damp and sultry - the clothes will stick to the body. Below this level some may experience symptoms as dry mucous membranes and dry skin.

However, the air humidity can have large influence on the moisture accumulation in building materials and thereby formation of mould fungus. The air humidity is therefore an important design parameter especially in buildings with an increased moisture production.

5 important things to reduce the energy demand

- The users have requirements regarding the air quality and not the building itself. Thus it is important to focus on the users and their occupancy of use pattern in the design of the air quality (there can be situations where specific demands are made independent of the users e.g. in the process industry, laboratories etc.).
- Choose environmentally friendly materials and surface treatments. Hereby the degassing from the building materials can be minimised, the demand for fresh air supply can be reduced and energy is saved.
- Zoning in areas with the same requirements to the air quality.
- Zoning in areas with the same occupancy and use pattern.
- Focus on the internal loads from occupants when there are large internal loads due to occupants, the CO₂ concentration is increased and the demand for supply of fresh air is increased.

CO₂ concentration

- CO₂ concentration is measured in ppm (parts per million).
- The unit ppm means that if for instance there are 1000 CO₂ molecules in a volume with 1 million molecules the the CO₂ concentration is 1000 ppm - that is 1000 'parts per' 1 million.

References

www.sbi.dk/indeklima

SBI. Home page with good information about the parameters of indoor climate and links to good publications. Especially the book

www.sbi.dk/indeklima/simulerin

BSim -Calculation of the air quality and energy

SBI-anvisning 196 "Indeklimahandbogen" (Indoor Climate)

12. THE BUILDING ENVELOPE

What is it?

The building envelope consists of the outer walls, the ground floor, the roof, and the windows and is a very important parameter regarding building sustainability, as a large part of the heat loss is through the building envelope.

How does it work?

The heat loss through the building envelope is determined by the U-value and linear heat losses of the building envelope.

U-value

The U-value expresses how much heat is transported through one m² of the construction at a temperature difference of one degree between the inner and the outer side of the construction. The lower the U-value, the better the insulating property. The unit for U-value is W/m² K (K=Kelvin-degrees) and is a result of the thermal conductivity and the thickness of a material. The U-value is therefore improved by both choosing a material with a low thermal conductivity (good insulating property) and by increasing the thickness of the material.

The total U-value for windows is a result of many factors (see figure), and thus it is important to make sure that you are given the **total** U-value for the **whole** window. The centre U-value for the window can be low, but as especially the U-value for the frame/case typically is higher than the U-value for the pane, the total U-value will be higher.

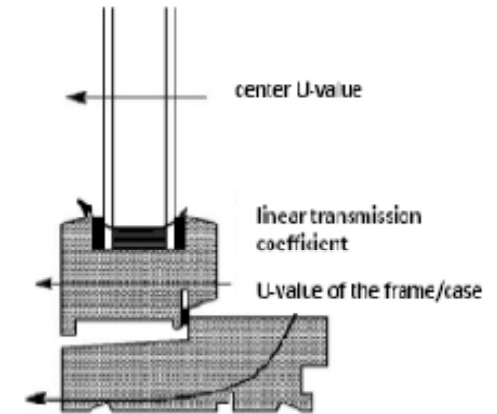
Other factors influencing the total U-value for a window is the ratio between the area of the frame/case and the pane, and whether the window can be opened. A window, which cannot be opened and has a small frame/case will have the lowest total U-value. Typical **total** U-values for windows for low energy buildings should be 0.8-1.2 W/m² K.

Linear loss

The linear loss - colloquially called heat bridges - is an expression for the energy loss through joints at windows, foundations etc. Linear losses is measured in W/mK and is thus an expression for the extra heat loss e.g. around a window or along the foundation due to a reduced insulation thickness or use of materials with a higher thermal conductivity. By the introduction of the new energy regulations, the demands on the linear losses are tighten up in the building codes. It is important to focus on the linear losses in the design phase, when the construction details are drawn, but also in the construction phase. Without focus, the linear losses can result in large heat losses and increased risk of moisture accumulation and e.g. formation mould fungus.

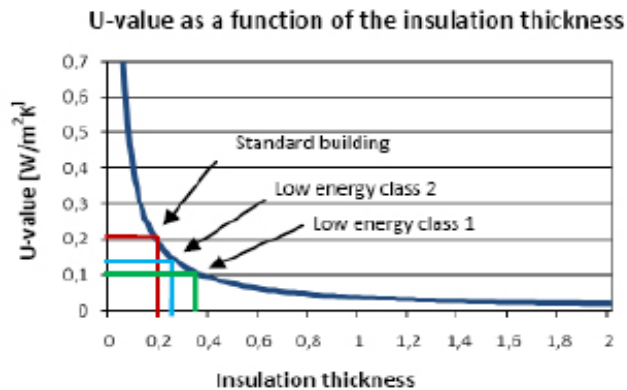
What can be used?

To decrease the heat loss through roof, outer walls and ground floor, a material with a low thermal conductivity (as insulation) should be selected. As all insulation materials



consist of approximately 90% air (it is still-air that insulates), the thermal conductivity is almost equal for the typical insulation materials.

The thickness of the insulation has on the other hand large influence on the total U-value. As seen on the figure, the U-value decreases when the insulation thickness is increased. The largest effect is seen for the first 0.2 metres. Hereafter the curve flattens off, and in practice, no one uses insulation thicker than 0.5 metres. Recommended insulation thicknesses are shown for houses that respectively meet the standard requirements, the requirements to low energy class 2, and the requirements to low energy class 1 in the Danish building code.



Vacuum insulation

A material that insulates better than traditional insulation is vacuum insulation. Vacuum insulation is made of a fine-grained material placed in vacuum by a surrounding sealed foil. Experiments show that it is possible to achieve a thermal conductivity that is almost a factor 10 better than traditional insulation. Hence, the same insulating property can be achieved with a considerably smaller insulation thickness. However, there are big challenges in the use of vacuum insulation, as it is very vulnerable to perforations, the insulation panels are to be produced in the exact size (cannot be trimmed on the spot), and finally the price is relatively high. For more information on vacuum insulation, please see the references.

Double glass facades

Double glass facades are typically built up with a single layer glass pane outermost and a 2-layer low energy glass pane innermost. With the tightened requirements to the

heat loss, a construction with a 3-layer energy glass pane innermost is also widely used. Advantages and disadvantages for double glass facades can be seen below:

Advantages:

- Lower U-value for the glass areas result in possibilities for a larger glass area.
- Larger glass area gives better outlook and more daylight.
- The more expensive low energy pane is protected against wind and weather.
- Increased potential for natural ventilation in the space between the glasses.
- Possible solar shading can be placed in the space between the glasses. The shading is protected and the heat contribution from the sun is minimised and can be ventilated away.
- Good sound insulation.

Disadvantages:

- Increased risk of glare.
- Increased glass area can imply necessity of solar shading towards East, West, and South.
- Makes traditional venting difficult.
- Double glass area to maintain and clean.

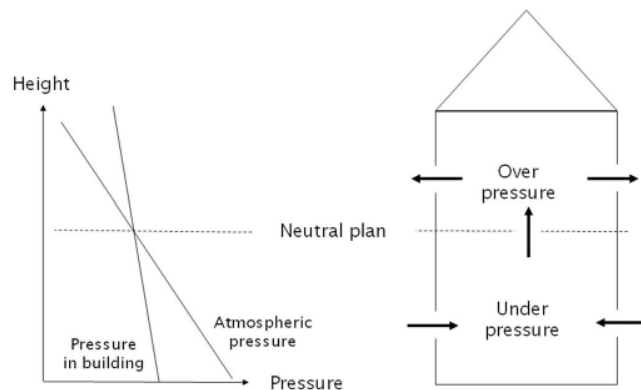
References

www.sbi.dk/bvggeteknik/bvgningsfsvik	SBI. A very informative home page with links to publications about thermal insulation and alternative insulation
www.vip-bau.ch	Home page about vacuum insulation. Information about the physics behind, reports from the latest research and links to manufacturers etc. In German and English.
www.bvg.dtu.dk/Forskning/hentned.a	DTU Byg. Homepage with possibility of download of publications from research results on subjects within the building envelope
www.rockwool.dk	Rockwool. Information about everything within traditional insulation plus mini encyclopaedia.
www.varme-vinduer.dk	Good homepage about windows

13. NATURAL VENTILATION

What is it?

Natural ventilation is characterised by using the natural driving forces to supply fresh air and remove the amount of polluted air, which is necessary to maintain a good thermal indoor climate and a good indoor air quality. Hence, no energy is used to operate ventilators and typically no ventilation ducts are necessary. As natural ventilation solely is dependent on the natural driving forces, the design of the building is very important and natural ventilation therefore has to be considered in the early design phase.



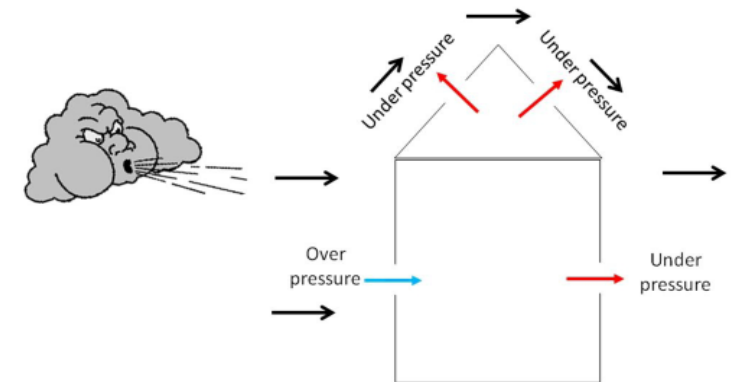
How does it work?

Thermal buoyancy

The thermal buoyancy, which makes warm air rising is used in natural ventilation - also called the chimney effect. In addition, the temperature difference between outside and inside is used. Due to the fact that warm air is lighter than cold air the temperature difference also implies a pressure difference between inside and outside. In the figure to the right there will thus be an under pressure in the bottom of the building and an over pressure in the top compared to outside. By placement of openings over and under the neutral plane (where the pressure difference is zero) it is possible to get air flowing in and out of the building.

Forces of the wind

Another factor that influences the natural ventilation is the forces of the wind. When the wind blows on a building, the velocity of the airflows around the building will create an over pressure on the front side and an under pressure over and on the backside of the building. Thus, natural ventilation will be a combination of both the thermal buoyancy and the forces of the wind and both factors have to be considered carefully when designing for natural ventilation.



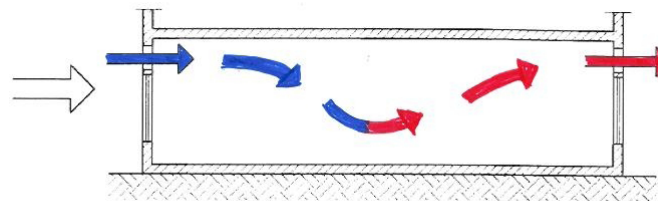
What to do?

As natural ventilation solely is dependent on the natural driving forces there will be a limit for how large air changes that can be obtained. Furthermore there will be variations over the day and night and over the year, and therefore it has to be ensured that a satisfying indoor climate can be maintained in the whole time of occupancy. In which cases natural ventilation can be chosen depends on a number of factors which have to be considered in the design phase. Therefore check lists have been developed about the use of natural ventilation. All the factors will not be mentioned here but some of the most important appear in the following scheme.

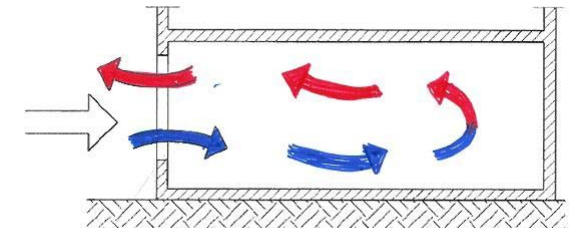
Openings

The placement, size and design of the openings will be essential for the total air change and for the airflows in the building. The thermal buoyancy can be increased by increasing the vertical distance between the inlet and outlet. This can be done by increasing the room height, open the building between the floors, establish vertical channels or ventilation chimneys, and also by using an atrium as chimney. In addition, it is important that the neutral plane is placed so high that sufficient fresh air is coming into all occupied zones. In buildings with more floors it often means that the opening area in the top has to be considerably larger than the total area of the inlets.

Natural ventilation can also be made by single sided ventilation or cross sided ventilation where the contribution from the wind is very important but where the thermal buoyancy also can contribute by an appropriate placement of the openings (e.g. more openings in different heights).



Cross sided ventilation:
Room depth up to 5 x room height



Single sided ventilation:
Room depth up to 2.5 x room height

If the fresh air is to be supplied without preheating, the optimal placement of the openings is as high as possible. Furthermore, the windows have to be pivot-hung and open inwards. Thus, the risk of draught is minimised, a better air dispersion and better possibility of night cooling is achieved. There is a possibility of placing the fresh air inlet at the floor, but in climates as the Danish, it will require preheating of the air.

5 important things

- Double facades - can help to increase the thermal buoyancy and function as a “chimney”.
- Energy use - is very low in summer, but has to be carefully considered in winter, as heat recovery at present is no possibility and the energy use for heating will therefore be relatively high.
- Hybrid ventilation - natural ventilation can be supported with ventilators to increase the driving force
- Indoor climate - Natural ventilation induces the experienced indoor climate and the user satisfaction
- Suspended ceilings - an advantage to avoid suspended ceilings where night cooling is considered.

References

www.sbi.dk/indeklima/naturlig-ventilation

SBi. Link to good literature about natural ventilation.

www.indeklimaportalen.dk

Indeklimaportalen. Parameters of the indoor climate including natural ventilation.

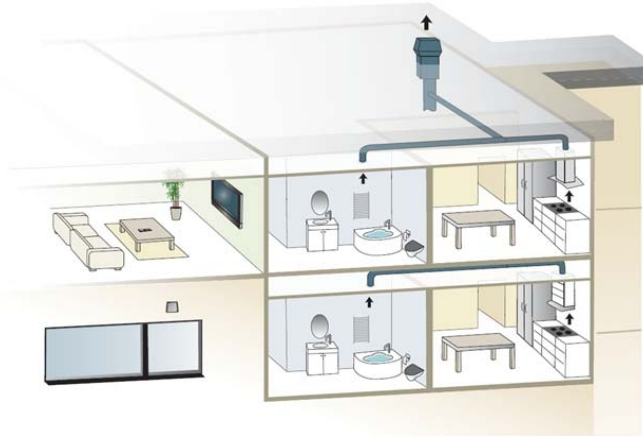
www.windowmaster.dk

Windowmaster. Manufacturer with good information, solutions and animations of the

14. MECHANICAL VENTILATION

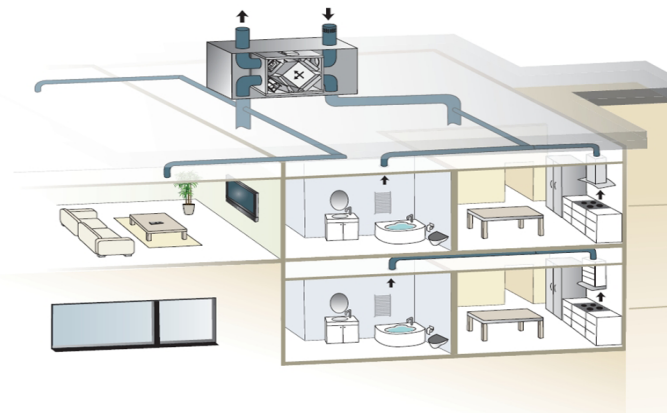
How does it work?

In mechanical ventilation the ventilation air is moved through ducts, filters and fixtures using fans run by electricity. Systems can be divided in exhaust ventilation and balanced ventilation.



Exhaust ventilation

The typical design in exhaust ventilation includes an exhaust-air fan located on the roof, sucking air from the individual rooms through a grid of ducts in the building. The air which is removed is replaced with incoming air, either through vents, leakages and windows facing the outdoor air. Because the incoming air is not pre-heated, there is a risk of drafts. Pure exhaust systems are typically installed in toilets, kitchens, bath-rooms, printer/copy rooms and as point-exhaust systems removing pollutants directly from the source (typically in industry).



Balanced ventilation

Balanced ventilation systems are the most typical lay-out of mechanical ventilation systems. Here the exhaust fan is supplemented with an inlet-air fan, creating a balance between the incoming air and the exhaust air. Due to the need to control both the incoming and outgoing air, two duct-work systems are needed. Balanced ventilation has the advantage of good possibilities for heat recovery from the exhaust air, hereby saving energy for preheating of the incoming air. Balanced ventilation can be used in almost all types of buildings and due to the need for heat recovery in low-energy buildings, this system has become almost standard in these buildings (e.g. passive houses).

In the case of balanced ventilation the incoming air can be distributed in the room in two different ways:

- **Mixing** - When using mixing as air distribution principle, the air is typically provided through fixtures below or in the ceiling with an airspeed which ensures that the incoming air is well mixed with the air in the room. Mixing is the most common form of air distribution.

- **Displacement ventilation** - Differs from mixing in several ways. The incoming air is provided near the floor with a slightly lower temperature (2-5 °C) than the room air temperature. Due to this lower temperature the inlet air will be distributed along the floor. As the inlet air is gradually heated, it will rise and displace the warmer and more polluted air. The polluted air will rise to the ceiling where the exhaust air will suck the polluted air out of the room. Displacement ventilation is especially relevant in rooms with high floor to ceiling height or when the air quality or acoustic requirements are crucial, such as in cantinas and theatres.

Controlling principles

The most common form of control is the CAV (Constant Air Volume), where the ventilation rate (m³ per hour) is kept at a constant level during operation hours. This strategy does not take into account variations in internal heat load, and can only be recommended in situations with a well-defined and constant demand. If designed for situations with varying loads, the system is typically designed for the worst case scenario and too much air will be provided most of the time, resulting in an unnecessary energy and potentially unsatisfying indoor climate. In a VAV (Variable Air Volume) strategy, the ventilation rate will vary according to the ventilation needs due to e.g. changing internal heat loads. This principle is also called demand-controlled ventilation. Hereby an optimal indoor climate can be ensured in the most energy efficient way, and this strategy is the preferred strategy for low-energy buildings, due to the high energy saving potential.

5 important issues

- Minimising the internal pollutants through the use of environmental sound materials without any emissions to the room air.
- Interior design ensuring that polluting equipment (copy, printers etc.) is located in separate rooms with exhaust-ventilation, maybe with heat-recovery, if feasible.
- Reduction of internal heat gains through the use of daylighting, efficient solar shading.
- Zoning of the building according to patterns of use, internal gains etc.
- Utilisation of VAV-controlled ventilation to match the variations in ventilation demand.
- Use balanced ventilation with heat recovery, when the heat balance of the building is benefiting from this.

Other issues

Using demand controlled exhaust-air ventilation using humidity as indicator for the ventilation needs in dwellings has proven to save around 40% of the energy consumption for heating and ventilation and at the same time improving the indoor climate.

The system maintains a base-ventilation rate in periods with no presence and no humidity added to the room air. Whenever users are adding humidity to the air or humidity is added from showers, cooking, cleaning, washing etc. the ventilation is substantially increased and ensures a quick and efficient removal of polluted air.

In the Danish building code this principle is still not included as a standard and accepted design, but experience has shown good possibilities for exemptions given the right arguments.

References

www.lindab.com

www.oeland.dk

www.exhausto.dk

Manufactures with technical information about mechanical ventilation and solution for ventilation systems. Also in English.

15. COOLING

What is it?

The experienced temperature has a high influence on the user's experience of indoor climate and therefore it can be necessary to cool buildings in periods where there is a risk of too high temperatures. The cooling demands in buildings are very dependent of the internal heat gains such as personal load, lighting and equipment, solar irradiation and outdoor temperature. Especially the internal heat load and the solar load are factors which can be largely controlled and minimised during the design phase. If the design team succeeds to minimise or even eliminate the cooling need, it will have a large influence on the total construction cost and the total energy use of the building. The energy use for cooling is one of the areas where the largest potentials for savings on the energy costs can be obtained through the use of an integrated design process.

How is it working?

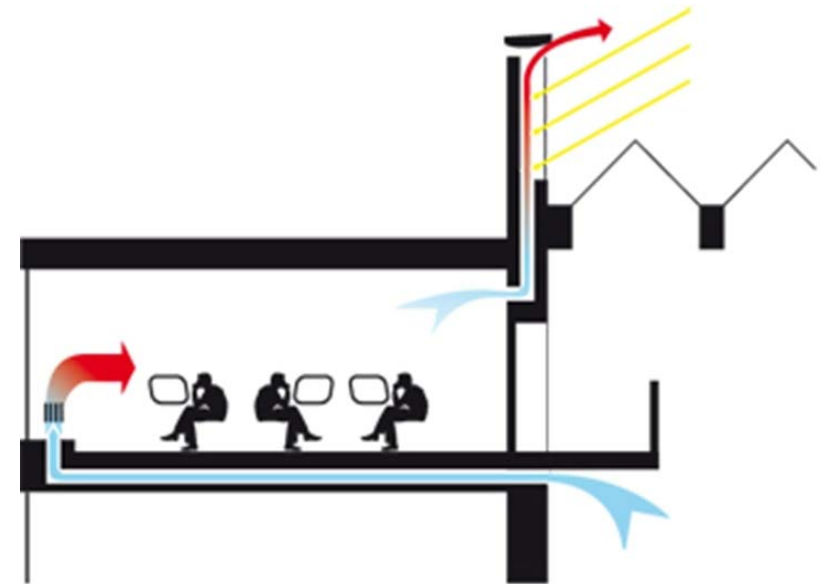
If cooling is unavoidable it is important, that the potential of using the most sustainable methods is being investigated first. The overview in the following shows the most sustainable ways of cooling, listed in sequence.

Passive cooling

Here the outdoor air is being used as a refrigerant typically in combination with natural ventilation.

Capacity can be increased through the use of night time cooling in combination with exposed thermal mass or to utilize buried channels, where the heat capacity of the surrounding earth will contribute to cool the incoming air during summertime and temperate the incoming air during winter time.

Another cost effective and energy efficient form of passive cooling is to use cool materials on the building envelope. Cool materials (paints, tiles, shingles etc.) can reject solar heat remaining cooler under the sun. This is due to their two main properties high solar reflectance and high infrared emittance. At building scale the use of cool materials results in lower energy consumption for cooling, improved thermal comfort and lower carbon footprint. These effects are far more important if the building is poorly or not insulated.



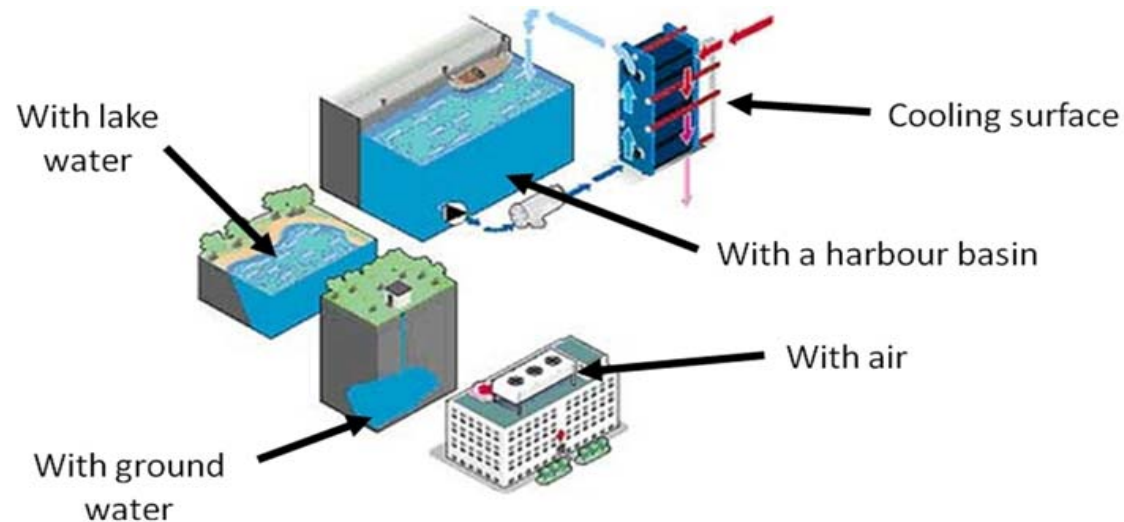
Using cool materials at large scale results in improving the urban microclimate by mitigating the heat island effect and its negative consequences. Passive cooling has a large potential but requires very careful design considerations. Passive cooling is not using energy to cool the air and therefore this principle is very energy friendly but since the control and the capacity is rather limited it is often necessary to combine passive cooling with active cooling for areas in the building, which have a high internal cooling demand.

Free cooling

Free cooling is a process where like, passive cooling, there is no extra energy needed to run the cooling process but instead the cooling capacity of cool outdoor air, groundwater, seawater, water from lakes etc. can be utilized directly. These cooling sources are not distributed directly to the building itself as is the case with the air for passive cooling, but they are transferred via a heat exchanger.

The advantages are the fact that the possibility for accurate control is large and that the energy consumption to run the system is very low compared to conventional cooling

system. The disadvantage is that the temperature span is rather limited due to the temperature of the cooling source and even if capacity being slightly larger than passive cooling, it can still be necessary to supplement free cooling with active cooling in areas in the building with high cooling demands.



Active cooling

Active cooling requires energy, typically to work the compressor. This system is usually considered the traditional solution, which can be used in almost all buildings and has a high accuracy of control and can be designed for large capacities, but the drawback is that this technology is also the absolutely most energy consuming cooling technology.

Absorption cooling

A more sustainable way of using active cooling is through the use of absorption cooling. One of the advantages is, that absorption cooling can be run using waste heat or solar energy. Hereby, the electricity consumption is replaced with a potentially “free” energy source, and this approach will reduce the total energy consumption and will lead to a lower emission of CO₂.

Sorption cooling

The principle of sorption cooling works the same way as evaporation of water on the human skin cools the skin. The cooling principle is especially useful in dry warm climates where the air can contain the water directly. This technology can also be combined with using solar energy and waste heat. The result is substantially lower energy consumption and less CO₂-emission.

5 important things

- Optimal building orientation
 - Reduce large glazed facades towards east, south and west for a Northern hemisphere
 - Ensure daylight availability for lighting and efficient solar shading
 - Location of rooms with high internal heat gains or demand for low temperature towards orientations with small solar gains
- Reduce all internal heat gains (anthropogenic loads, equipment, artificial lighting)
- Zoning of the building according to patterns of use and internal loads
 - Location of areas with high internal heat loads, such as server and printing rooms in separate rooms
- Apply external solar shading
- Make use of a daylight control system to minimize the heat load from the artificial lighting.

References

www.wemas.dk

EnOpSol. Manufacture working with sustainable optimisation of cooling systems. Also in English.

www.learn.londonmet.ac.uk/packages/clear/thermal/buildings/passive_system/passive_cooling/index.html

Information of passive cooling

www.esu.com.sg/pdf/Passive_Cooling_of_Building.pdf

A chapter on passive cooling by Mat Santamouris

www.keepcool.info/

Link to the KeepCool EU project on sustainable cooling

www.coolroofs.org/

The Cool Roof Rating Council (CRRC) is an organisation that provides info on cool roofs

www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products

A list of cool roof rated products by Energy Star

www.coolroofs-eu.eu/

Cool Roofs EU project site for the promotion of cool materials technology in the EU

<http://coolroofs-eu-crc.eu/>

EU Cool Roofs Council web site



Sun shading is important to avoid overheating in the building.

16. SOLAR HEATING

What is it?

The sun emits electromagnetic radiation at different wave lengths and it is an inexhaustible energy source, which annually supplies roughly 10.000 times the total energy consumption on earth. Solar heating is using the energy of the sun to produce heating. The principles for solar heating usage are simple. When the rays of the sun hit a material, part of them are absorbed and part of them are transformed into heat. There are two types of solar heat: passive and active.



What does it do?

Passive solar heat – In the process of passive solar the solar heat is stored in the absorption material and is primarily used for indoor heating through thermal conductance or heat radiation from the absorption material. In principle, solar heat utilization takes place in all buildings with windows, as part of the light through the window is absorbed in the floor and walls and transformed into heat. The energy input to the building can be optimized by varying the size, shape and orientation of the windows, and also by storing the absorbed energy in the construction for later use (large buildings/large thermal mass).

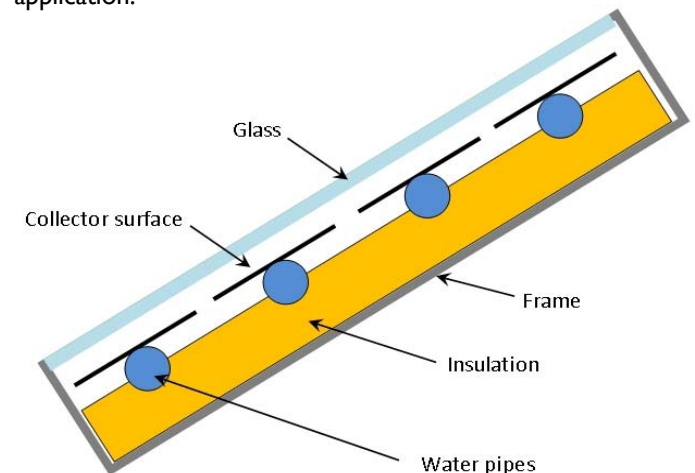
Active solar heating – The main components in an active solar heating system are the solar collector, which converts the solar energy into heat, the solar heating circuit, which transports the solar heat in liquid or gaseous state - usually driven by a circulation pump - and the storage, which can store the solar heat for later usage.

Vacuum tube solar collector

Solar collectors

The most common type of solar collector is the flat plate collector with a cover of glass. A black metal sheet (absorber) is heated by the sun and water pipes are connected to the sheet to transport the absorbed heat. The back of the solar collector is insulated to minimize the heat loss.

The vacuum tube solar collector consists of a number of cylindrical glass tubes connected at the top to a condenser/ heat exchanger unit. The vacuum in the glass tubes is used to minimize the heat loss, and because of the lower heat loss the vacuum tube solar collector often has a better efficiency at high temperatures compared to the flat plate collector. However, in Denmark the ratio between price and yield is poorer than for a flat plate collector at normal application.



How to use it?

There are many applications for an active solar heating system.

- Heating of domestic hot water in roughly all buildings. The size of a solar collector system depends on e.g. the hot water need and the pattern of use, but as a rule of thumb about 1-1,5 m² of solar
- collectors per person and a tank volume of about 50 liter per m² solar collector is necessary. This should enable that 60-70 % of the energy for heating domestic water is covered by the solar collector system.
- Combination systems, where the solar heating system is used for space heating as well. Combination systems are not common in Denmark, due to the fact that the need for space heating is biggest in times of less sunlight. However, it slowly gains footing as more and more homes have reduced heating needs at the same time as the heating comes from floor heating or other low temperature systems which suit the temperatures from a solar heating system well.
- Outdoor swimming pools, where the solar collector usually just consists of a black plastic absorber without covering layers or insulation etc. This system is cheap and has a high yield.
- Process heating in the manufacturing industry e.g. slaughterhouses, the dairy sector, for cleaning and drying processes, where the need for temperatures under 100 °C is present.

- Thermal solar power stations, where concentrated solar collectors heat liquid and convert it to steam, which in turn can be used to run a steam turbine and thus produce electricity.
- Solar cooling. Solar heat can also be used for cooling, usually through the application of the absorption cooling system. This system is gaining footing where the intensity of the sun and the need for cooling is high.

Yield in Denmark:

- Typically 350-550 kWh/m²/yr

- Vacuum panels up to 800 kWh/m²/yr

Economy?

The economy in a solar heating system depends on the energy it replaces and the construction and design of each specific system etc. Please see references, especially www.altomsolvarme.dk which gives an overview over yield and economy.

However, installation costs for medium-large systems are typically around 4.000 Dkr. per m² solar collector (excl. VAT).

5 important things

- Orientation should be southwest/southeast
- Slope between 45° and 60°.
- Reasonably free of shade
- A roof surface suitable for mounting and the life span of the roof material should correspond to the life span of the solar collector.
- Short distance to the tank/boiler room. Must be possible to carry pipes to the tank/boiler room.

References

www.solenergi.dk

Danish homepage about solar cells and solar heating

www.altomsolvarme.dk

Danish homepage about solar cells and solar heating, economy etc. Links to further information

www.ises.org

International Solar Energy Society

<http://www.eere.energy.gov/>

Energy Efficiency and Renewable Energy.

17. SOLAR CELLS

What is it?

The sun emits electromagnetic radiation at different wave lengths and it is an inexhaustible energy source, which annually supplies roughly 10.000 times the total energy consumption on earth. When using solar cells the energy of the sun is used for production of electricity. The basic material in most of the solar cells available is silicon – extracted from sand which is the most common element on earth. There are typically three types of solar cells:

- **Mono crystalline** are sliced from a single round silicon crystal. It has a uniform black-blue colour. The most efficient per unit area with an efficiency rate of 13-17%.
- **Poly crystalline** are silicon crystals melted together, cast directly in a mould. It has a shaded surface, often in blue colours. Has an efficiency rate of 12-14%. It comes in other colours too, but with reduced efficiency rates.
- **Amorphous** are thin film cells, where the cell does not have a crystalline structure. Silicon is vaporized on glass or foil or enclosed in flexible plastic. It can be black or dark brown. The cheapest type per m², but with an efficiency rate of only 5-9%.

How does it work?

A solar cell works by letting the silicon react with a material which results in a surplus of electrons on one side and a corresponding deficit of electrons on the other side. When sunlight hits the silicon electrons from the surplus side break free, and will migrate to the deficit side. However, the electrons are caught by the metal grid on the front of the solar cell. This is a much easier way than through the silicon. The metal grid is connected with the back of the solar cell enabling the migration of the electrons, which in turn creates a current without mechanical influence. This is a photoelectric or photovoltaic process.

A solar cell is the smallest building block in a solar cell system. The cells are electrically connected and put together in a solar cell module. These can be joined in units of desired levels of voltage and current. Solar cells come typically in sizes of ca. 10 x 10 cm to 15 x 15 cm. The area of a typical module is ca 0,5-2,5 m², but larger modules are also available.

Yield in Denmark:
- 80-129 kWh/m²/yr
- 100-150 W/m²
(poly og mono crystalline).

Application?

Solar cell systems are divided into two main categories; systems connected to the grid and stand-alone systems. In grid connected systems an inverter converts direct current into alternating current which is used locally in existing installations or exported to the grid. In stand-alone systems the current is usually stored in batteries to even the difference between production and consumption or used directly e.g. for pumps or ventilators.

Placement on roof surfaces

Two different systems are available when placing on roof surfaces. Integrated into the roof, i.e. they are mounted into the roof construction and thus replaces parts or all of the roofing (see picture), and built-ons. Built-ons on flat roofs often have modules mounted on stands which are fastened to the roof construction or they can be mounted on consoles which are secured with ballast. Solar cell systems can also be seen mounted in glass roofs or sky lights. This offers a visual effect, at the same time as the solar cells act as a sun screen.

Placement on/in facades

Solar cell systems can be placed on or in facades in several different ways.

- Integrated
- Built-on
- In glass facades
- In windows
- In parapets
- As sun screens

Economy?

Installation costs for solar cell systems vary a lot, due to the rapid development within the solar cell industry. It is very difficult to estimate the price on solar cell systems, and with varying electricity costs repayment periods are impossible to estimate. Please see references for up-to-date figures. Medium-to-large sized systems in Denmark calculate with prices in the area of 40 Dkr. per. installed effect (Watt) and a simple repayment period of 20 years.

5 important things

- Orientation must be between south west and south east.
- The optimal slope in Denmark is 37° from horizontal, but it is acceptable if solar cells are placed between 15° and 60° from horizontal.
- Solar cells are sensitive to shadows. Even small areas in shade reduce the yield significantly.
- Ensure good ventilation of the solar cell modules as yield decreases at high temperatures.
- Solar cells can be combined with solar collectors - called PV/T (Photovoltaic/Thermal). In a PV/T system both electricity and heat is produced, which results in a more efficient utilization of the incoming solar radiation. The system has a large potential in the future.

References

www.solenergi.dk	Danish homepage with information about solar cells and solar heating
www.ises.org	International Solar Energy Society
www.eere.energy.gov	Energy Efficiency and Renewable Energy.



18. WIND ENERGY

What is it?

Wind energy is typically defined as using the wind for electricity production from wind turbines, but wind energy can also be used for natural ventilation. This fact sheet will primarily focus on the production of electricity from wind turbines.

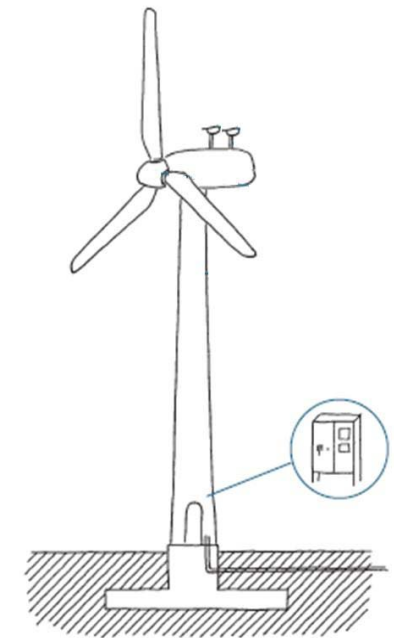
How does it work?

A wind turbine is a mechanical device, which converts the kinetic energy from the wind that passes through the wind turbine's rotor to electricity.

When a stream of air hits the wing from in front, the shape of the wing will cause the air molecules to move faster on the top of the wing than underneath. Higher speeds will result in longer distances between the air molecules and consequently a lower pressure, hereby creating an upward lift pulling the wing up. This principle makes airplanes take off and wind turbine wings spin. The turbine's wind vane points toward the wind direction as a weathercock. At wind speeds around 4 meters per second the rotor will start to turn slowly, primarily due to the pressure of the wind on the wings. As soon as the rotor starts spinning the aero dynamics around the wing profile will set in, which results in improved power and increased rotation speed.



The rotor is connected to a generator, which is placed in the turbine house. When the rotor reaches a certain speed the turbine generator will connect to the grid and will start producing electricity. The turbine will produce more and more electricity at higher wind speeds, and it will reach its maximum at wind speeds around 13-14 m/s. At higher wind speeds the wings will turn, resulting in a constant rotor speed. At wind speeds over 20-25 m/s (dependent of each turbine) the turbine will stop in order to avoid too heavy strains and subsequently collapses.



Application?

Electricity produced from wind turbines is typically exported to the grid and in Denmark 5,400 wind turbines produce just over 7 billion KWh, corresponding to about 20% of the total electricity consumption.

The amount of electricity produced depends on the location and the size of the turbine. Off-shore turbines generate more electricity than turbines on land due to the higher wind speeds on water. Size also matters, and the trend is now to install fewer, but larger turbines due to their improved efficiency.

The chart shows the energy production and the CO2 savings for different sizes of wind turbines.

Size of wind turbine	Production of kWh per year	CO2-savings, tonnes per year	CO2-savings in life span, tonnes
600 kW	1.380.000	1.076	21.520
1 MW	2.300.000	1.794	35.880
2,3 MW	5.290.000	4.126	82.520

With a total yield from wind turbines of just over 7 billion kWh it corresponds to an annually CO2 saving of about 5.5 million tonnes.

5 important things

- A wind turbine generates 80-120 more energy during its lifetime than being used to produce, maintain and scrap it. This corresponds to a repayment period in terms of energy of only 3 months!
- Other buildings must be located more than four times the total height of the turbine away.
- The sougning of a wind turbine has the same sound level as normal speech.
- Wind turbines displace CO2.
- Wind roses are used to get information about wind direction and wind speed for different locations (se references for wind roses in Denmark).

Other things

Another way of exploiting the wind is through wind cowls. Wind cowls are designed in a way that creates an increased driving force for natural ventilation, and most wind cowls are not dependent on the direction of the wind. This is an efficient way of saving electricity for ventilators.

References

www.dkvind.dk

Danmarks Vindmølleforening. Homepage with information on wind turbines. Also in English

www.folkecenter.net

Nordisk folkecenter for vedvarende energi. Homepage with information on sustainable energy and small wind turbines. Also in English

www.nova-air.dk/index-dk.htm

Nova-air's homepage on wind cowls.

www.dmi.dk/dmi/saadan_blaeser_det_i_danmark

DMI. Wind roses for different locations in Denmark.

19. EVALUATION OF THE DESIGN (TOOLS)

Software	Description	Link
A. Whole building analysis (energy and load calculation, renewable energies, green buildings)		
TRNSYS	energy simulation, load calculation, building performance, simulation, research, energy performance, renewable energy, emerging technology	http://sel.me.wisc.edu/trnsys/default.htm
DOE-2	Energy performance, design, retrofit, research, residential and commercial buildings	http://simulationresearch.lbl.gov/
Energy Plus	energy simulation, load calculation, building performance, simulation, energy performance, heat balance, mass balance	http://www.eere.energy.gov/buildings/energyplus/
ESP-r	Advanced calculation of thermal and visual indoor climate and energy consumption of the building.	http://www.esru.strath.ac.uk/
ECO-TECT	environmental design, environmental analysis, conceptual design, validation; solar control, overshadowing, thermal design and analysis, heating and cooling loads, prevailing winds, natural and artificial lighting, life cycle assessment, life cycle costing, scheduling, geometric and statistical acoustic analysis	http://www.squ1.com

Software	Description	Link
Energy-10	conceptual design, residential buildings, small commercial buildings	http://www.sbicouncil.org/store/e10.php
Bsim	Calculation of thermal indoor climate and energy consumption of the building.	http://www.sbi.dk/indeklima/simulering
BEAT2000	Tool for environmental evaluation of buildings, building parts and building materials.	http://www.sbi.dk/milio-og-energi/miljovurdering/edb-verktoj-beat
DesignBuilder	Building energy simulation, visualisation, CO2 emissions, solar shading, natural ventilation, daylighting, comfort studies, CFD, HVAC simulation, pre-design, early-stage design, building energy code compliance checking, OpenGL EnergyPlus interface, building stock modelling, hourly weather data, heating and cooling equipment sizing	http://www.designbuilder.co.uk
BEES	environmental performance, green buildings, life cycle assessment, life cycle costing, sustainable development	http://www.bfrl.nist.gov/oae/bees.html
ENVEST	sustainable design, green buildings, life cycle analysis, environmental impact analysis	http://www.bre.co.uk/envest

Software	Description	Link
B. Materials, components and systems		
WIS	Calculation of U-value, solar- and visual transmission of windows.	http://www.windat.org/
WINDOW	fenestration, thermal performance, solar optical characteristics, windows, glazing	http://windows.lbl.gov/software/window/window.html
FRAMEplus	windows, fenestration, framing, building components, thermal characteristics, optical characteristics	http://www.enermodal.com
Radiance	Advanced and very detailed simulation tool for calculation of daylight inside and outside buildings.	http://radsite.lbl.gov/radiance/HOME.html
Relux	Advanced simulation of daylight in and outside buildings.	http://www.relux.biz/
Sombrero 3.01	Solar shading, solar radiation, building geometry, solar systems	http://nesa1.uni-siegen.de/

Software	Description	Link
C. Ventilation, indoor air quality, fire		
CONTAM	Calculation of natural ventilation .	http://www.bfrl.nist.gov/IAQanalysis/
Fluent	CFD - calculation tool for complicated air flows.	http://www.fluent.com/
COMIS	multizone airflow, pollution transport	http://www-epb.lbl.gov/comis
FLOVENT	airflow, heat transfer, simulation, HVAC, ventilation	http://www.flovent.com
PHOENICS	computational fluid dynamics, air pollution, smoke and fire, air flow	http://www.ozemail.com.au/~acadsbsg

D. Codes and standards		
BeO6	Calculation program for documentation of the energy requirements in the Danish building code. The calculations are based on the method described in "Instruction 213 - Energy demand of buildings".	http://www.sbi.dk/milio-og-energi/energiberegning/anvisning-213-bvgningers-energibehov/
PHPP	Calculation for documentation of the requirements in the Passive House standard.	http://www.passiv.de/



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