D2.4
EeB technologies for building envelope and space of healthcare buildings

State-of-the-art review of architectural solutions

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Streamer - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems.
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Produced by	T2.2 Task Leader: Ipostudio Architetti srl (IAA)
Main author	Roberto Di Giulio (IAA)
Co-authors	Beatrice Turillazzi (AOC), Stefan Dehlin (NCC), Magnus Osbäk (NCC), Piotr Dymarski (MOW), Anna Rokicka (MOW), Thierry Juif (BOU), Jan-Peter Pols (DWA), René Waggeveld (DWA), Stefan van Nederpelt (DJG), Steven Burrows (ARU), Giacomo Bizzarri (BEQ), Roberto Traversari (TNO)
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Reviewed by	Thomas Liebich (AEC) and Martjan den Hoed (DJG)
Approved by	Freek Bomhof (TNO)
Dissemination	PU

Colophon

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Abstract

The Deliverable deals with the State-of-the-art review of architectural solutions (i.e. building envelope and spatial design) for energy-efficient healthcare buildings.

The Deliverable focuses on the identification of technologies and environmental design criteria that are feasible to implement and to benchmark necessary energy performance standards for energy savings in healthcare districts. The data collected show the updated State of the Art of the EeB solutions for building space and envelope: each chapter identifies strategies and opportunities for a significant energy reduction, both considering technical - related to the envelope - and spatial issues.

The choice has been made considering the suitability of a specific technology in healthcare buildings. The focus is both on new construction and retrofit actions: recommendations may be applicable to hospitals undergoing complete renovation, partial renovation, addition, remodeling, and modernization projects.

Regarding the methodology, the EeB technologies for building envelope and space in hospitals were searched, selected and briefly described. The resulting preliminary list of the state of the art of technologies was then reviewed and a selection of the most appropriate technologies was done and described more in detail.

The following step was to deepen each listed solution (57 at the beginning then reduced to 45) according to a common list of topics; the distribution of the work among partners was done on the basis of the knowledge and expertise stated by each involved partner.

Concerning the section related to the building layout, it was agreed that the Bouwcollege layers (i.e. the categories of space used in STREAMER) could be used also regarding the energy consumption.

Finally, the technical numerical parameters describing each solution was collected, listed and described in a table.

The report is organized in three main parts:

1. Design solutions of EeB space and layout (chapter 2);
2. Technical solutions of EeB envelope (chapter 3);
3. Parameters (chapter 4).

The first one classifies the building space and layout and presents the building space using two-pages forms, whereas the building layout is described through free-form text.

The second one classifies the envelope technologies (both façades and top closures) and presents each of them via the same two-pages forms.

The last part gathers the parameters defined in each technical and space solutions and presents them in a table.

Publishable executive summary

This report deals with the State-of-the-art review of architectural solutions (i.e. building envelope and spatial design) for energy-efficient healthcare buildings.

The Deliverable focuses on the identification of technologies and environmental design criteria that are feasible to implement and to benchmark necessary energy performance standards for energy savings in healthcare districts. **The data collected show the updated State of the Art of the EeB solutions for building space and envelope**: each chapter identifies strategies and opportunities for a significant energy reduction, both considering technical - related to the envelope - and spatial issues.

The choice has been made considering the suitability of a specific technology in healthcare buildings. **The focus is both on new construction and retrofit actions**: recommendations may be applicable to hospitals undergoing complete renovation, partial renovation, addition, remodeling, and modernization projects.

With the introduction of the Energy Performance Building Decree (2002/91/CE, recast 2010/31/UE) buildings are forced to respect minimum standards of energy performance: this leads to the control of two fundamental factors of the energy balance, envelope and plants. For this reason, in the last decade the building envelope has gradually developed into a dynamic and active bounding surface, able to gear its performance to the changes of the environmental conditions, as it integrates a great deal of working functional devices. Insulation, natural light and ventilation are the most important factors that have to be considered when a performing envelope is designed. Moreover, a dynamic envelope can provide active or passive energy from renewable sources in order to achieve the highest indoor comfort by restricting the use of air conditioning units and artificial lights. About the above mentioned issues, the most efficient technical solutions for the envelope are based on the fundamental principles of the sustainable architecture: thermal insulation, heat gaining by collecting and storing solar energy in winter, use of passive cooling and natural ventilation in summer, maximum natural daylighting, reduction of heat losses and thermal bridges, use of systems with low environmental impact such as dry technologies, use of renewable energy. To fulfill these performance, the potentialities of dynamic systems such as ventilated façades, double skin glass façades and solar shadings is very high and has been increased in the last years. This is substantial for healthcare districts, where the design strategies have to combine energy - saving with the comfort of the occupant (long term patients, medical staff).

The report is organized in three main parts:

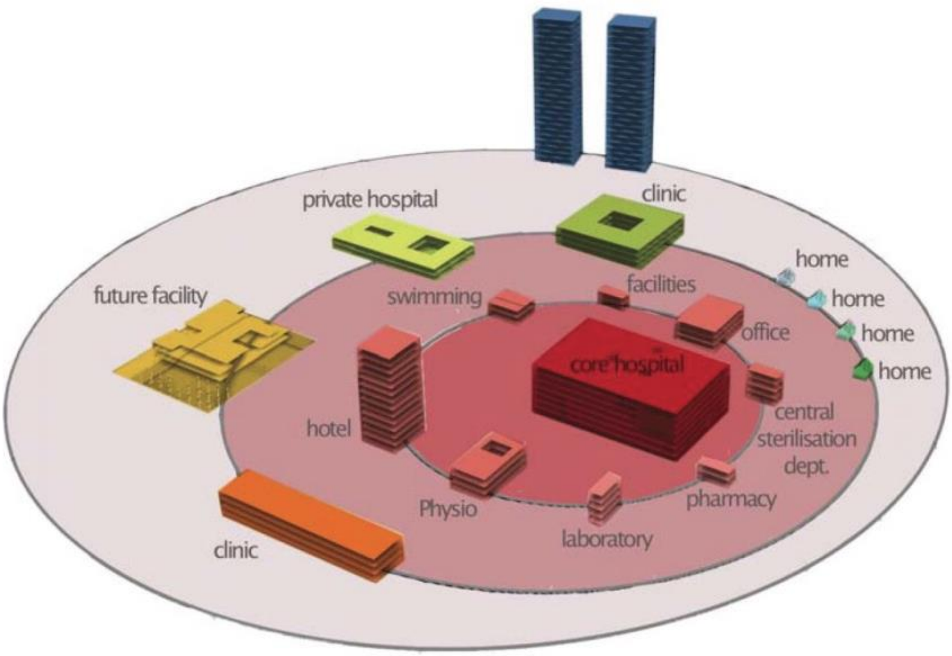
1. Design solutions of EeB space and layout (chapter 2);
2. Technical solutions of EeB envelope (chapter 3);
3. Parameters (chapter 4).

The section “**Design solutions**” analyses the most indicative factors that influences an environmental design, considering:

- design solutions for building space (morphology, orientation, number of stories);
- issues related to building layout.

The factors related to building space, as an example, can be helpful in identifying where in the façade windows can be located to enhance the indoor environment for occupants and the passive solar gains to improve the energy balance. At the first stage of the design, the prediction of solar extent is recommended to assess the exposure of intended glazing locations and the resulting penetration of solar rays into the building spaces. Anyway, this requires more detailed weather/climate/natural resources analysis usually quantifies true frequency of occurrence potential for natural ventilation for cooling, daylighting, heat recover. Building configuration strategies may be implemented during the design process of new buildings - and in retrofitting interventions as well - by considering possible modifies in the morphology (e.g. closure of balconies, to improve S/V ratio) and to optimize the envelope performance in relation to the orientation.

Regarding the layout solutions, it was agreed to use the layer approach from the former Bouwcollege as base for the Streamer project, even if, given the fact that the layers of the Building Differentiation model of Hospitals are not clearly defined (as far as it concerns the functions they include), energy is not part of the model and the energy demand of the different layers is not available. This approach is used as a very global and rough estimation of the energy use of a hospital and applied in the first phase of a design. In this approach the effect of specific measures related to energy consumption is not visible. For this reason a more detailed approach is recommended. Thus, the report describes a labelling system with labels that add semantic information to functions and subsequently to rooms that accommodate that function (see also deliverable D1.1). Information that can be added should be useful during the design process and operational phase and should have a relation with the energy demand. Within these labels a number of levels can be defined . Using these labels and levels most of the requirements related to a specific function (and thus the related rooms in hospitals) can be defined. With a combination of the building physics and the labels, the energy demand of a room, and at a higher level the building block, can be calculated.



The envelope (**Technical solutions**) is characterized by the opaque components and fenestration. Improvements should be considered for reduced thermal transmittance (i.e., U-factors), use of thermal mass, and control of solar heat gains.

The choice of the practicable strategies of intervention on the vertical envelope has been done considering the improvement of performance that a specific solution can achieve, by the following classification:

- improving of thermal and acoustic performance (External thermal insulating systems);
- improving of ventilation, passive cooling, thermal inertia (Ventilate façades);
- improving of overshadow, daylight control (Solar shadings);
- improving of heat gain, solar cooling (Passive solar energy systems);
- renewable energy use, autonomous energy production (Active solar energy systems);
- improving performances of fenestration, (glass envelope, windows with high-performing glass).

Horizontal envelope technologies have been firstly classified considering the roof typology (plan/slope), that is a fundamental factor that influences the energy performance; then, the improvement of energy performance has been classified as follows:

- improving of ventilation, passive cooling, (microvented, single/double ventilation layers);
- improving of thermal and acoustic performance (thermal insulation);
- improving of thermal inertia and waterproof (green roofs);
- renewable energy use, autonomous energy production (Active solar energy systems).

It is clear that a solution can fulfil different performance: in this case the most representative performance (driven–performance) was considered. Moreover, **some solutions have been simplified due to specific executive practices and climate conditions of the different European Countries**.

It is not reasonable to consider each design strategy for each climate, anyway it has to be considered that some fundamental principles are common (e.g. energy storage, renewable energy use): the suitability of one technology in comparison to another in relation to hot (Mediterranean) climate or to cold (Nord-Europe climate) has been highlighted in the forms. At the same time, some technologies are more suitable for retrofit actions than for a new building. As an example, traditional external thermal insulation composite systems (ETICS) is a very common technology for improving thermal insulation in retrofit actions, in comparison to the same system using polycarbonate or aerogel panels, that requires a bigger initial investment and more complex actions. The compatibility with refurbishment actions/new construction was reported in each form. The critical assessment on the state of the Art for EeB technologies can be helpful in highlighting how envelope technical solutions can be chosen to meet MEP solutions (see Task 2.1, Deliverable 2.1) in terms of energy requirements. By considering that the major energy conservation measures for hospitals are related to envelope, lighting and HVAC, this approach is useful to collect and identify the role of a specific system in the overall design strategy.

The last section lists and describes the **parameters** that measures the energy performance. This is helpful in describing the energy performance of each technology considering a standard value and the range between this is accepted (with reference to European standard, mentioned in the table).

Parameters were listed and described according to the following classification:

A Geometrical parameter

  A1 Building parameter

B Physical parameter

  B1 Heat Transfer Phenomena

    i General

    ii Opaque elements

    iii Transparent elements

  B2 Thermal conduction phenomena

  B3 Thermal Convection Phenomena

  B4 Radiation Phenomena

C Technological parameters

  C1 General

  C2 Ventilation plants

  C3 Photovoltaic Systems

  C4 Solar Low Temperature Thermal Collectors

Regarding the **methodology**, the EeB technologies for building envelope and space in hospitals were searched, selected and briefly described. The resulting preliminary list of the state of the art of technologies was then reviewed and a selection of the most appropriate technologies was done and described more in detail.

The following step was to deepen each listed solution (57 at the beginning then reduced to 45) according to a common list of topics; the distribution of the work among partners was done on the basis of the knowledge and expertise stated by each involved partner.

Concerning the section related to the building layout, it was agreed that the Bouwcollege layers (i.e. the categories of space used in STREAMER) could be used also regarding the energy consumption.

Finally, the technical numerical parameters describing each solution was collected, listed and described in a table.

The **forms** describing the solutions are made according to the following frame and contents:

<u>Description</u>

- brief description of the design criteria,
- how the solution works,
- design for best result,
- usability in healthcare districts,
- key properties.

<u>References</u>

Scientific publications and web sites are listed in order to improve the knowledge of those aspects not deepened in the description.

<u>Figure</u>

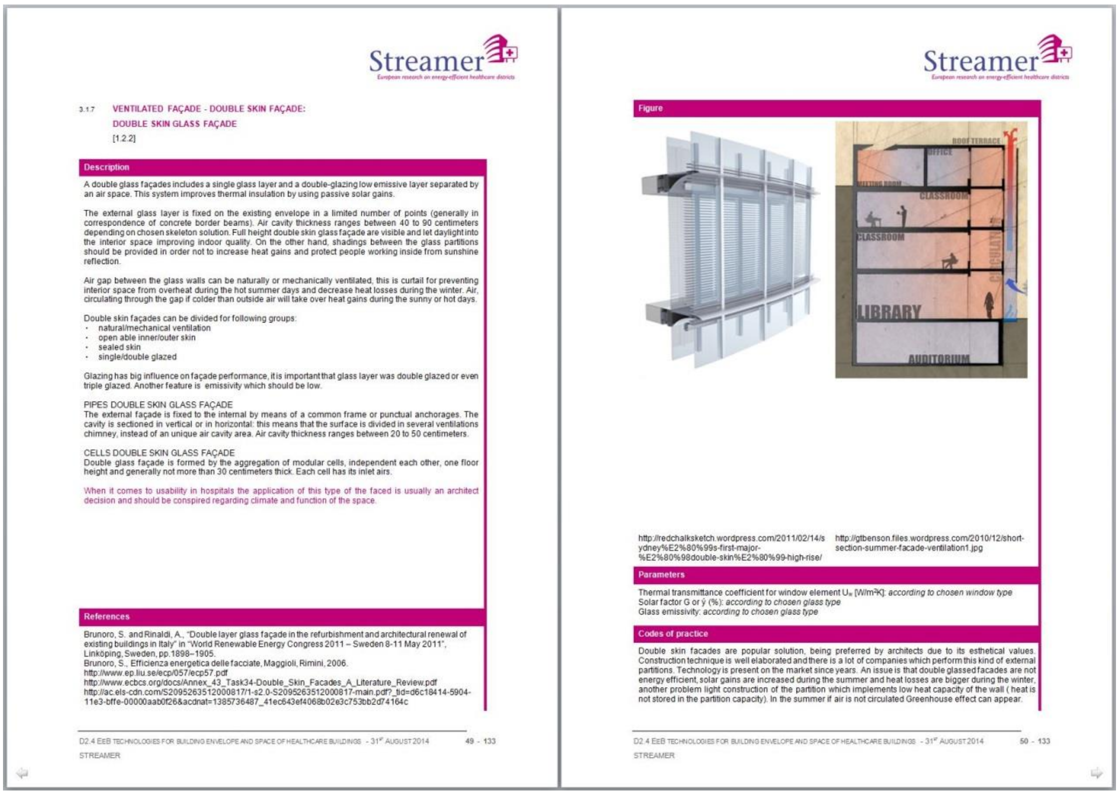
(Included sources)

Parameters

- technical numerical parameters.

Codes of practice

- method of installation,
- special precautions,
- construction for best result.



Regarding the **relationship with other WPs** of the research project, the report is strictly connected with Task 1.1 “Typology models of healthcare districts”, D1.1 “Taxonomy of healthcare districts focusing on EeB morphology and features” due to their cross topic “building layout” (see paragraph 1.1) and Task 3.1 “EeB performance indicators”, D3.1 “Building-oriented EeB KPIs of newly designed and retrofitted buildings” due to their cross topic “parameters” (see chapter 4).

Results achieved will provide inputs and will be applied in the work to be carried out in Tasks 7.1/7.2/7.3/7.4: classification and selected parameters will be tested on the Demonstration Projects.

Other outcomes related to this work will give inputs to WP3, WP5, WP6.

A strong relationship with a cross European project - **Green@Hospital** - is also highlighted. The questionnaire analysis carried out in the four Green@Hospital pilot hospitals is a valuable reference for Streamer WP1, WP2, WP3 and WP7. Concerning the WP2, the reference suggests that a selection - focusing on the feasibility of data retrieval - of the parameters resulting from the D2.1 and D2.4 State-of-the-Art, may be appropriate and worthwhile due to its easier collection during the survey on the pilot sites and its easier implementation during the creation of BIM tool.

In **conclusion**, this Deliverable can provide some indications for achieving energy savings goals by using architectural and technical solutions (envelope and space) that are feasible, operationally workable, and otherwise readily achievable. These recommendation should be meshed with data and inputs related to MEP system in order to reach the best energy saving performances.

The individual components of the envelope building design are highly integrated and impact the energy savings of the whole system, so an overview of possible usable strategies can give the clearest picture of how they can meet the needed requirements in a whole-building energy use

List of acronyms and abbreviation

AHU: Air Handling Unit
ATES: Aquifer Thermal Energy Storage
BEM: Building Energy Modeling
BIM: Building Information Modeling
BMS: Building Management System
BIPV: Building Integrated PV
BSI: British Standard Institution
CdTe: Cadmium Telluride
CFD: Computational Fluid Dynamics
CIGS: Copper Indium Gallium Selenide
COP: Coefficient Of Performance
CPC: Compound Parabolic Collectors
CT: Computed Tomography
D. LGS.: Decreto Legislativo (Legislative Decree)
EDRA: Forintek Envelope Drying Rate Analysis
EP: Energy Performance Index
EPS: Extracellular Polymeric Substances
ETC: Evacuated Tube Collectors
ETICS: External Thermal Insulation Composite System
FPC: Flat Plate Collectors
GFA: Gross Floor Area
GHG: GreenHouse Gas
HVAC: Heating, Ventilation and Air Conditioning
ICT: Information and Communication Technology
IG: Insulated Glazing
ISO: International Organization for Standardization
KPI: Key Performance Indicator
LFR: Linear Fresnel Reflector
Low E: Low Emissivity or Low thermal Emissivity
MEP: Mechanical, Electrical and Plumbing technologies
MRI: Magnetic Resonance Imaging
PCM: Phase-Changing Material
PUR: Polyurethane
PV: Photovoltaics
PVT: PV Thermal
ROI: Return On Investment
S: Surface Area
SCADA: Supervisory Control And Data Acquisition
TCO: Transparent Conductive Oxide

TIM: Transparent Insulation Material

UNI: Ente Nazionale Italiano di Unificazione (Italian National Body for Standardization)

UPVC: Unplasticized Polyvinylchloride

UV: Ultra Violet

V: Volume

VFD: Variable-Frequency Drives

VL: Ventilation

XPS: Expandable Polystyrene

Symbols and acronyms of parameters are not listed here (see paragraph 4)

Definitions

Layers approach (Bouwcollege)

This approach (relevant for new hospitals or existing ones subject to significant renovation) divides the function package of an hospital into four layers (a layer = a building block).

Each of these layers (Hot floor, Hotel, Office, Industry) has its own properties profile as regards specificity, investment costs, growth/downsizing requirements, and marketability of the property.

Hot Floor refers to capital intensive high-tech functions that are unique to the hospital; *Hotel* refers to patient accommodations; *Office* refers to outpatient units, accounting, management and training functions, *Industry* refers to laboratories, kitchen, etc.

Labels approach

This approach develops a labelling system with labels that add semantic information to functions and subsequently to rooms that accommodate that function. Information that can be added should be useful during the design process and operational phase and should have a relation with the energy demand (temperature level, ventilation demand and air tightness, insulation between rooms, medical equipment, time of use, etc.).

Building morphology

It is the building shape expressed by the surface area to volume (S/V) ratio (the three dimensional extrapolation of the perimeter to area ratio): the compactness of a building is one of the fundamental parameters affecting the energy consumption of a construction.

Building orientation

Design for orientation is a fundamental step to ensure that buildings work with the passage of the sun across the sky. Knowledge of sun paths for any site is fundamental in design building facades to let in light and passive solar gain, as well as reducing glare and overheating to the building interior. It is important to remember that the position of the sun in the sky is dynamic, changing according to time of day, time of year and the site's latitude. (John Brennan: Senior Lecturer, Edinburgh School of Architecture and Landscape Architecture)

Vertical envelope (façades)

The vertical outer skin of a building. As the interface between interior space and exterior environment, a building's skin plays a crucial role in heat and light exchange. Its performance in that role affects occupant comfort and productivity, energy use and running costs (ARUP).

Horizontal envelope (roof)

The horizontal outer skin of a building: it comprehends the covering and the framing or structure which supports the covering itself. As the interface between interior space and exterior environment, a building's skin plays a crucial role in heat and light exchange. Its performance in that role affects occupant comfort and productivity, energy use and running costs (ARUP).

Pitched roof

It is a roof made up of two angled pieces which meet in the middle, with gables at either end. The pitch of both sides of the roof is generally the same, although sometimes they may be pitched at different angles. A single pitched roof is a roof made of one flat segment installed at an angle. The angle of the pitch varies considerably, depending on the size of the building and the size of the segments.

Flat roof

British Standard BS 6229:2003 (Flat roofs with continuously supported coverings. Code of practice) defines a flat roof as "having a pitch less than 10° (22,22%) to the horizontal". Italian UNI 8627:2013 (Sistemi di copertura) defines a flat roof as having a pitch less than 1% (0,45°) and a sub-horizontal roof as having a pitch between 1% (0,45°) and 5% (0,9°).

Contents

1. Introduction and scope

The Deliverable deals with the State-of-the-art review of architectural solutions (i.e. building envelope and spatial design) for energy-efficient healthcare buildings.

It is the first report of the Task 2.2 “EeB solutions for building space and envelope”.

According to the DoW, this task connects the EeB technologies and measures with design optimisation of the building space/ interior layout and the building envelope. For this purpose, this task establishes the most effective relationship between building design and user workflow processes. The design approach is based on the principles of the Layer Model (Bouwcollege) by TNO to analyse the workflow based on 4 functional types of space, i.e. ‘hot floor (e.g. operation rooms and laboratories), hotel (e.g. patient rooms), office (e.g. workspaces), and factory (e.g. technical rooms)’.

Another concept, namely Health Flow Engineering (reference: Deerns), will be examined in the following deliverables of the Task due to its less relevance with the scope of this report. Indeed, this is an approach to alternate the traditional way of breaking the design effort into sub-questions to be handled by several separately working engineers, architects and designers one after the other. The focal point in this concept is the description of the medical processes that will be used as a dynamic communication tool between the community of medical staff, technicians and other stakeholders.

The report is organized in three main parts:

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The last part gathers the parameters defined in each technical and space solutions and presents them in a table.

Some topics are not deepened as they are not directly relevant for the purpose of the report. Thus they will be investigated in the following deliverables.

The Deliverable focuses on the identification of technologies and environmental design criteria that are feasible to implement and to benchmark necessary energy performance standards for energy savings in healthcare districts. **The data collected show the updated State of the Art of the EeB solutions for building space and envelope**: each chapter identifies strategies and opportunities for a significant energy reduction, both considering technical - related to the envelope - and spatial issues.

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The section "**Design solutions**" analyses the most indicative factors that influences an environmental design, by considering:

- design solutions for building space (morphology, orientation, number of stories);
- issues related to building layout.

The building space factors, as an example, can be helpful in identifying where in the façade windows can be located to enhance the indoor environment for occupants and the passive solar gains to improve the energy balance. At the first stage of the design, the prediction of solar extent is recommended to assess the exposure of intended glazing locations and the resulting penetration of solar rays into the building spaces. Anyway, this requires more detailed weather/climate/natural resources analysis usually quantifies true frequency of occurrence potential for natural ventilation for cooling, daylighting, heat recover. Building configuration strategies may be implemented during the design process of new buildings - and in retrofitting interventions as well - by considering possible modifies in the morphology (e.g. closure of balconies, to improve S/V ratio) and to optimize the envelope performance in relation to the orientation.

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The envelope (**Technical solutions**) is characterized by the opaque components and fenestration. Improvements should be considered for reduced thermal transmittance (i.e., U-factors), use of thermal mass, and control of solar heat gains.

The choice of the practicable strategies of intervention on the vertical envelope has been done considering the improvement of performance that a specific solution can achieve, by the following classification:

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Horizontal envelope technologies have been firstly classified considering the roof typology (plan/slope), that is a fundamental factor that influences the energy performance; then, the improvement of energy performance has been classified as follows:

- improving of ventilation, passive cooling, (microvented, single/double ventilation layers);
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It is clear that a solution can fulfil different performance: in this case the most representative performance (driven–performance) was considered. Moreover, **some solutions have been simplified due to specific executive practices and climate conditions of the different European Countries**.

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The last section lists and describes the **parameters** that measures the energy performance. This is helpful in describing the energy performance of each technology considering a standard value and the range between this is accepted (with reference to European standard, mentioned in the table).

1.1 Frame and contents of the forms

Each form describes the solution according to the following fields:

Description

- brief description of the design criteria,
- how the solution works,
- design for best result,
- usability in healthcare districts (written in fuchsia),
- key properties.

References

Scientific publications and web sites are listed in order to improve the knowledge of those aspects not deepened in the description.

Figure

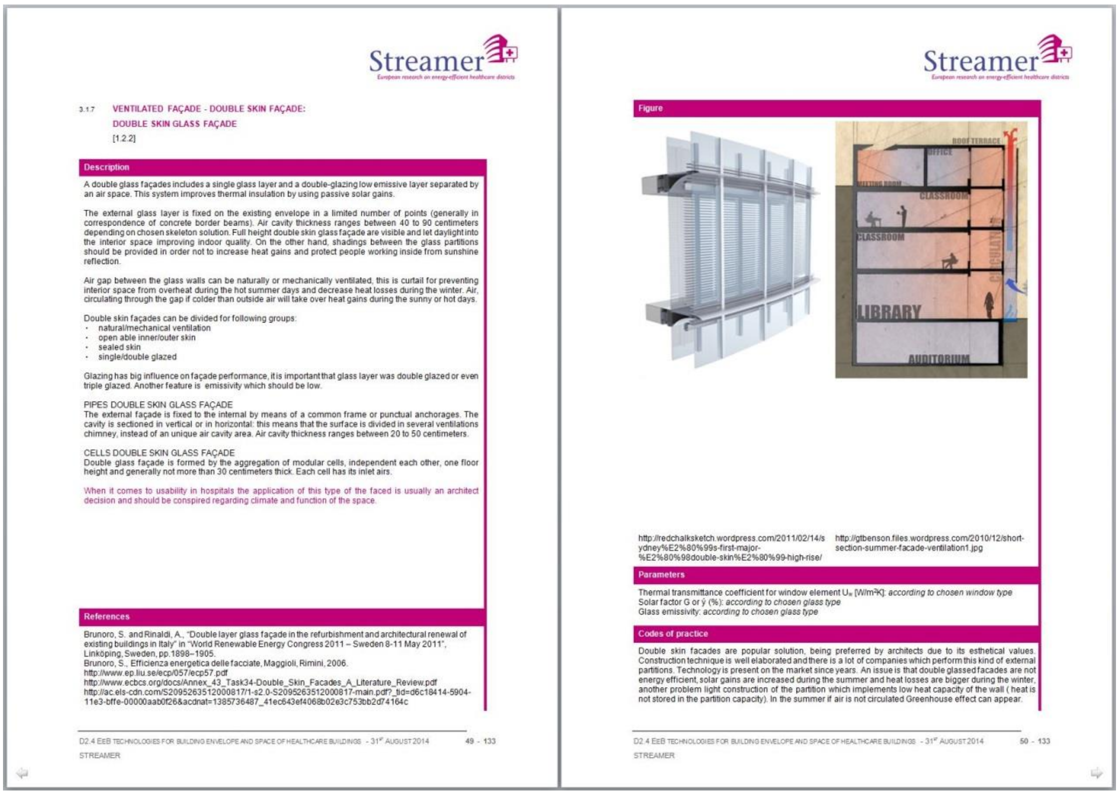
(Included sources)

Parameters

- technical numerical parameters.

Codes of practice

- method of installation,
- special precautions,
- construction for best result.



3.1.7 VENTILATED FAÇADE - DOUBLE SKIN FAÇADE: DOUBLE SKIN GLASS FAÇADE

[1.2.2]

Description

A double glass façades includes a single glass layer and a double-glazing low emissive layer separated by an air space. This system improves thermal insulation by using passive solar gains.

The external glass layer is fixed on the existing envelope in a limited number of points (generally in correspondence of concrete border beams). Air cavity thickness ranges between 40 to 90 centimeters depending on chosen skeleton solution. Full height double skin glass façade are visible and let daylight into the interior space improving indoor quality. On the other hand, shadings between the glass partitions should be provided in order not to increase heat gains and protect people working inside from sunshine reflection.

Air gap between the glass walls can be naturally or mechanically ventilated, this is curtail for preventing interior space from overheat during the hot summer days and decrease heat losses during the winter. Air, circulating through the gap if colder than outside air will take over heat gains during the sunny or hot days.

Double skin façades can be divided for following groups:

- natural/mechanical ventilation
- open able inner/outer skin
- sealed skin
- single/double glazed

Glazing has big influence on façade performance, it is important that glass layer was double glazed or even triple glazed. Another feature is emissivity which should be low.

PIPES DOUBLE SKIN GLASS FAÇADE
The external façade is fixed to the internal by means of a common frame or punctual anchorages. The cavity is sectioned in vertical or in horizontal: this means that the surface is divided in several ventilations chimney, instead of an unique air cavity area. Air cavity thickness ranges between 20 to 50 centimeters.

CELLS DOUBLE SKIN GLASS FAÇADE
Double glass façade is formed by the aggregation of modular cells, independent each other, one floor height and generally not more than 30 centimeters thick. Each cell has its inlet airs.

When it comes to usability in hospitals the application of this type of the faced is usually an architect decision and should be conspired regarding climate and function of the space.

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Figure

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http://gtbenson.files.wordpress.com/2010/12/short-section-summer-facade-ventilation1.jpg

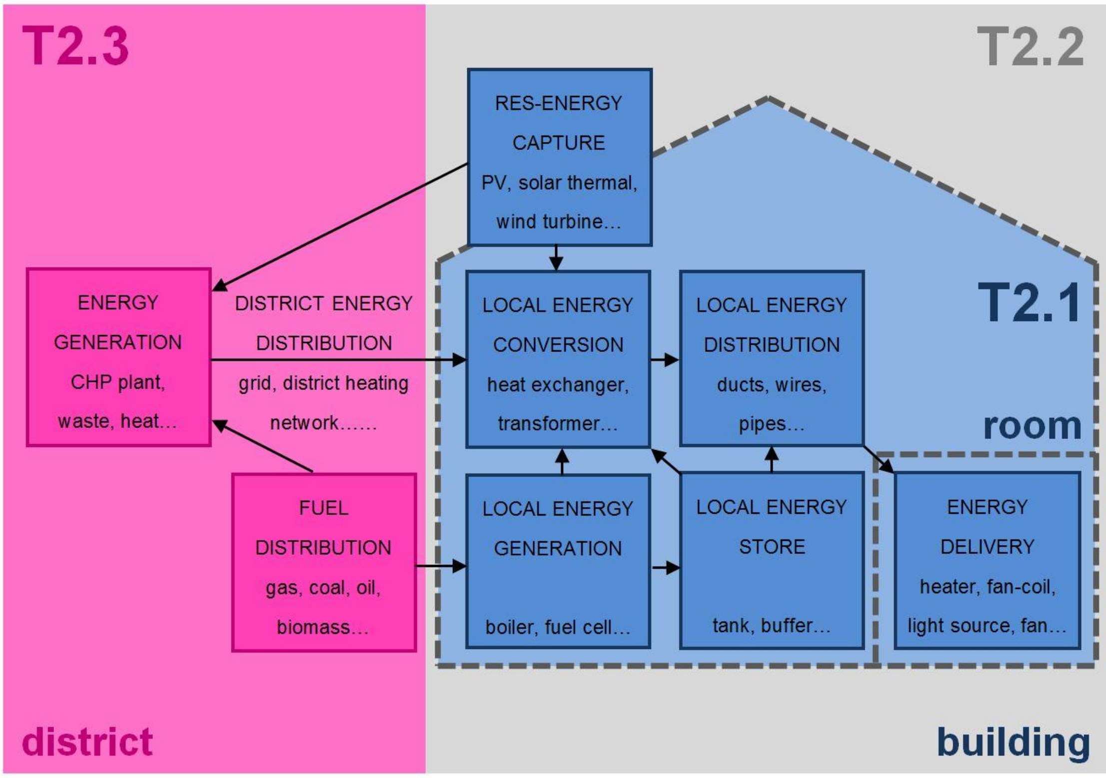
Parameters

Thermal transmittance coefficient for window element U_w [W/m²K]: *according to chosen window type*
Solar factor G or ŷ (%): *according to chosen glass type*
Glass emissivity: *according to chosen glass type*

Codes of practice

Double skin facades are popular solution, being preferred by architects due to its esthetical values. Construction technique is well elaborated and there is a lot of companies which perform this kind of external partitions. Technology is present on the market since years. An issue is that double glassed facades are not energy efficient, solar gains are increased during the summer and heat losses are bigger during the winter, another problem light construction of the partition which implements low heat capacity of the wall (heat is not stored in the partition capacity). In the summer if air is not circulated Greenhouse effect can appear.

1.2 Scopes of tasks in WP2 and relationship with other WPs



T2.1 and T2.3 efficiency supply side

4 sets of parameters (production, conversion, distribution, delivery)

T2.2 efficiency demand side

1 set of parameters

The report is strictly connected with:

- Task 1.1 “Typology models of healthcare districts”, D1.1 “Taxonomy of healthcare districts focusing on EeB morphology and features” due to their cross topic “building layout” (see paragraph 1.1);
- Task 3.1 “EeB performance indicators”, D3.1 “Building-oriented EeB KPIs of newly designed and retrofitted buildings” due to their cross topic “parameters” (see chapter 4).

Results achieved will provide inputs and will be applied in the work to be carried out in Tasks 7.1/7.2/7.3/7.4: classification and selected parameters will be tested on the Demonstration Projects. Other outcomes related to this work will give inputs to WP3, WP5, WP6.

1.3 Relationship with Green@Hospital

The main relationship between the Streamer Deliverable D2.4 (D2.1 as well) and the Green@Hospital research project regards the energy analysis aiming to identify and develop modifications that will reduce the energy use and/or cost of operating an healthcare building, as shown in Deliverable D2.1 “Standard energy audit procedure” and in Deliverable D2.2 “Building Management System” (WP2 Pilot’s solution set data analysis). According to the reports, the first steps to follow to make an energy analysis are the collection and the analysis of the historical energy uses/requirements (first step) and the study of the building and its operational characteristics (second step).

The first step regards the survey and the description of:

- Type of building, principal uses and areas;
- Energy Utilization Index (EUI): (annual energy use) kWh/m2 per year;
- Cost index: €/m^2 per year;
- Breakdown of various spaces within the building by function, hours of use, and area;
- Determine if efficiency may be affected by building functions that differ from the original functional intent of the building;
- Determine if any maintenance problems or practices may affect efficiency;
- Comparison of energy and cost indices of the building with one or more databases.

The second step regards the description and analysis of the energy-using systems of the building, including:

- Envelope;
- Lighting;
- HVAC;
- Domestic hot water;
- BMS;
- SCADA;
- ICT;
- Laundry;
- Food preparation;
- Conveying systems;
- Other systems.

As underlined, both the space/lay-out and the envelope of the healthcare buildings are characteristics to be collected during the audit, due to their relevance from an energy consumption point of view.

The energy audits carried out in the Green@Hospital pilot hospitals, in fact, were conducted differentiating functional areas and collecting the building(s) shell characteristics according to the following list:

- Total exposed above-grade wall area (m^2);
- Glazing area (% of exposed wall area);
- Roof area (m^2);
- Floor surface area exposed to outdoor conditions (m^2);
- Above-grade wall area common with other conditioned building (m^2);
- Total heated floor area (m^2);
- Materials and components.

The questionnaire analysis carried out in the four Green@Hospital pilot hospitals is a valuable reference for Streamer WP1, WP2, WP3 and WP7. Concerning the WP2, the reference suggests that a selection - focusing on the feasibility of data retrieval - of the parameters resulting from the D2.1 and D2.4 State-of-the-Art, may be appropriate and worthwhile due to its easier collection during the survey on the pilot sites and its easier implementation during the creation of BIM tool.

1.4 Classification of EeB envelope and space solutions

EeB envelope and EeB space/layout have to be listed in two separate lists according to their corresponding technical and “design” characteristics:

Design solutions:

- considerations related to building layout,
- design solutions for building space.

Technical solutions:

- vertical envelope (façades),
- horizontal envelope (top closures).

LIST OF THE DESIGN SOLUTIONS

0 | LAY-OUT			paragraph	partner
		Building lay-out and Semantic labels approach	2.1	TNO
1 | SPACE			**paragraph**	**partner**
1.1	**MORPHOLOGY**			
	1.1.1	Surface and volume ratio (S/V)	2.2.1	IAA
1.2	**ORIENTATION**			
	1.2.1	Solar gains	2.2.2	IAA
	1.2.2	Daylighting	2.2.3	IAA
1.3	**NUMBER OF STORIES**			
	1.3.1	Number of stories	2.2.4	IAA

LIST OF THE TECHNICAL SOLUTIONS

1 | VERTICAL ENVELOPE		paragraph	partner
1.1	**EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM (ETICS)**		
1.1.1	Traditional External Thermal Insulation Composite System	3.1.1	NCC
	Light colour of the outside wall	3.1.2	NCC
1.1.2	Polycarbonate insulation material	3.1.3	NCC
	Aerogel (highly insulated windows with aerogel)	3.1.4	NCC
1.2	**VENTILATED FAÇADES**		
1.2.1	Opaque ventilated façades	3.1.5	MOW
	Ventilated façades with PCM	3.1.6	MOW
1.2.2	Double skin glass façade	3.1.7	MOW
1.2.3	Hybrid façades (wall/glass)	3.1.8	MOW
	Integrated façades hybrid system	3.1.9	MOW
1.3	**SOLAR SHADING**		
1.3.1	External solar shadings	3.1.10	NCC-BOU
1.3.2	Internal curtains and venetian blind	3.1.11	BOU
1.4	**PASSIVE SOLAR ENERGY SYSTEM**		
1.4.1	Solar greenhouse	3.1.12	BOU
	Solar wall ®	3.1.13	BOU
	Solar chimney or ventilation chimney	3.1.14	DWA
	Green Wall	3.1.15	IAA
1.5	**ACTIVE SOLAR ENERGY SYSTEM**		
1.5.1	Photovoltaic panels	3.1.16	DWA
1.5.2	Solar collectors	3.1.17	DWA
1.5.3	Transparent PV overhangs	3.1.18	DWA
1.6	**HIGH EFFICIENCY WINDOWS**		
1.6.1	High efficiency windows (with solar films)	3.1.19	MOW
	High efficiency windows (with low-e/argon filled)	3.1.20	MOW

2 | HORIZONTAL ENVELOPE			paragraph	partner
2.1	**PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE**			
	2.1.1	Microvented	3.2.1	IAA
	2.1.2	Microvented insulated	3.2.2	IAA
	2.1.3	Vented (single ventilation layer)	3.2.3	IAA
	2.1.4	Vented (double ventilation layer)	3.2.4	IAA
	2.1.5	Insulated and vented (single ventilation layer)	3.2.5	IAA
	2.1.6	Insulated and vented (double ventilation layer)	3.2.6	IAA
2.2	**PITCHED ROOF WITH CONTINUOUS WATERPROOF SURFACE**			
	2.2.1	Insulated	3.2.7	DJG
	2.2.2	Vented (single ventilation layer)	3.2.8	DJG
		Vented (attic roof)	3.2.9	DJG
	2.2.3	Insulated and vented (single ventilation layer)	3.2.10	DJG
2.3	**FLAT ROOF**			
	2.3.1	Insulated	3.2.11	ARU
	2.3.2	Vented double roof	3.2.12	ARU
	2.3.3	Insulated and vented	3.2.13	ARU
	2.3.4	Green roof	3.2.14	ARU
	2.3.5	Cool roof	3.2.15	ARU
ACTIVE SOLAR ENERGY SYSTEM				
a	a.1	Photovoltaic panels on top	3.2.16	BEQ
	a.2	Integrated photovoltaic panels	3.2.17	BEQ
	a.3	Photovoltaic panels built in	3.2.18	BEQ
	a.4	Photovoltaic waterproof panels	3.2.19	BEQ
b	b.1	Solar collectors	3.2.20	BEQ
STRUCTURE				
A		Massive structure	3.2.21	BEQ
B		Light structure	3.2.22	BEQ

2. Design solutions of EeB space and layout

This section concerns the:

- considerations related to building layout (paragraph 2.1);
- design solutions for building space (paragraph 2.2).

2.1 Building layout and semantic labels approach

Building layout

At the start of the project the layer approach from the former Bouwcollege (Building Differentiation of Hospitals, Netherlands Board for Healthcare Institutions, ISBN/EAN 978-90-8517-095-2) seemed to be a good base for the Streamer project.

This approach divides the functions according to the specific building requirements into four accommodation typologies (building types), referred to as "layers". The approach is based on categorization of functions setting similar requirements for the built environment, for the purpose of optimizing the property. As a result of a differentiated constructional approach, part of the property can be realized on arm's length conditions, which is favorable as an established construction approach can be used for a specific type of building and designs can be adjusted more specifically to the regulations governing the relevant typology. Another advantage of construction on arm's length conditions is that, should the profitability be jeopardized in the future, parts of the building can be disposed of.

The first layer, the **hot floor**, comprises the high-tech, capital intensive functions that are specific for hospitals. The **hotel** comprises all functions for accommodation of patients. The functions for diagnostics and simple examinations and treatments are accommodated in the **office**. Logically, the office also accommodates the office facilities, such as staff accommodation, accounting and management. Last but not least, **industry** accommodates all medical supporting and facilitating functions.

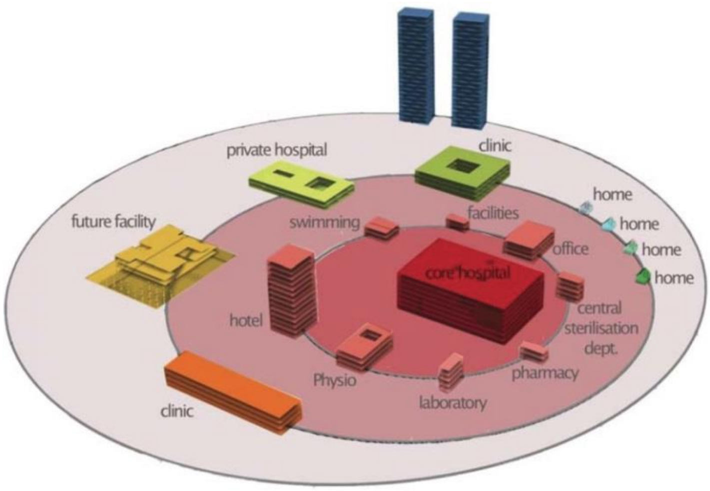


Figure 1. Extreme building differentiation model.

During a closer study of this layer approach some difficulties were encountered related to energy, the objective of the Streamer project. In the layer approach the different layers are not defined in detail, variation of functions within the layers is possible. The different layers are defined on a building typology level. Within these typologies (the four layers) a variation of functions is possible, depending on the degree to which the model is implemented: the monolith hospital with no or hardly any constructional differentiation as one extreme (no layers) and the most far-reaching model as regards to differentiation as the other extreme (Figure 1). So it is not perfectly clear what functions are within a specific layer (e.g. office, hot floor, etc.). The layer approach can be used to develop accommodation models that can provide the hospitals with optimum support relating to

1. specificity,
2. costs (investment and maintenance,
3. flexibility and
4. marketability of the different buildings.

The layer approach can be used as a thinking model and has its main advantage if different building qualities are used for the different layers. Which function belongs to each of the four layers depends to a great extent on the structural lay-out of the building section as a whole. So the model does not prescribe which functions belong in each of the layers. Or in other words: you can assign layers to different functions , but if you subsequently build the hospital as a monolith or if the hospital is already built as a monolith (or as a building with one constructional layout) the use of layers doesn't result in a more effective, cheaper, flexible or marketable building.

Reducing the energy consumption was not the aim when developing the layer approach nor part of any of its analyses. However, it offers an appealing way of looking at the functionality of spaces within a hospital, and intuitively there might be a meaningful relation between a layer and its energy consumption: the hot floor will use much more energy than the office layer.

The energy consumption of a building is based on

1. the building physics like insulation quality, orientation, glass surface etc. and
2. the way the building is used e.g. type of used medical equipment, time frame in which the room is used, additional requirements for the indoor air quality (above the requirements for a normal office), etc.

In general it can be stated that for the energy consumption caused by the building physics the floor area is the first determining factor given the same building physical quality of the outside walls, windows and ceiling. This means that the smaller the floor area the lower the energy consumption. So compact buildings have the lowest energy demand caused by the building physics.

The second determining factor is the temperature differences within the building can cause energy flows though inside walls. For example if the design set point of one room is at 26°C and the adjacent set point of the room is at 20°C a huge energy flow will occur. So in the design of the lay out, temperature differences between adjacent rooms shall be taken into consideration. The design temperatures of the different rooms have of cause a direct relation to the type of use but are important in an early stage of the design of the new building or refurbishment plans.

The most important factor for the final energy consumption is the user behavior and the function(s)/activities in the building. All consumed electric power (e.g. lighting, medical equipment, computers, etc.), will be transformed into a heat load in that building/room and can cause an additional cooling demand or reduce the heat demand of the building.

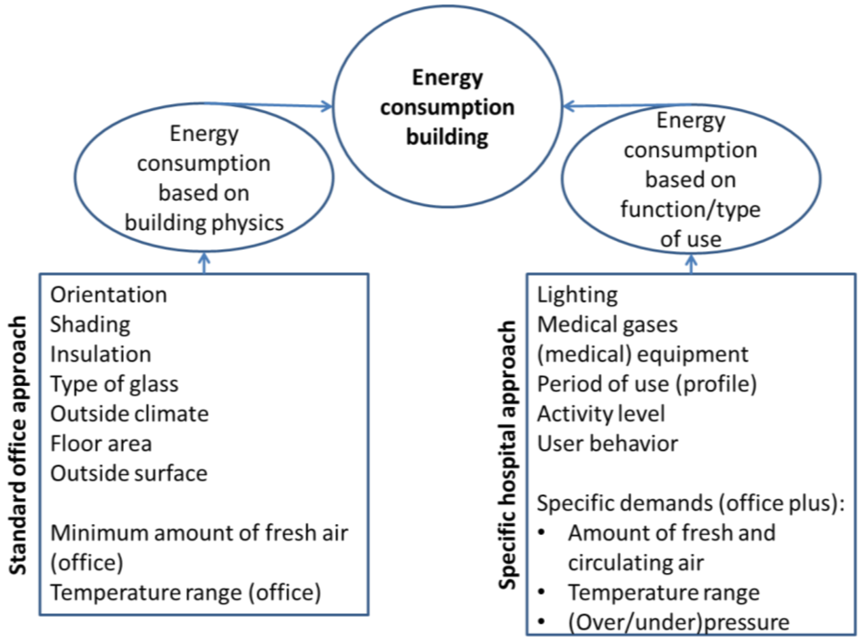


Figure 2. Decomposition of the energy demand.

The baseline for the energy consumption caused by the building physics are more or less the same as the energy consumption of an average office (Figure 2). The minimum requirements are given in the national building acts and Occupational Health and Safety Act of the member states. For the Netherlands these minimum requirements for an office building are given in Table 1. The average operational time of offices are Monday until Friday from 8:00 to 18:00 (30%).

Requirement	Value	Unit
Indoor temperature	20-26	°C (ARBO)
Ventilation	≥ 23,4	m^3/h.person (Bouwbesluit)
Lighting level	≥ 400	Lux (ARBO)
Insulation value wall	≥ 3,5	m^2.K/W (Bouwbesluit)
Insulation value window	≤ 2.2	W/m^2.K (Bouwbesluit)

Table 1. Minimum requirements for an office building in the Netherlands.

Based on these assumptions it can be argued that the different building typologies (layers model) have an energy consumption as stated in Table 2. This table is based on the extreme building differentiation model (only the functions with a medical relation are positioned in the most expensive building, the hot floor).

Type of building	Remarks	Energy profile
Office	The outpatients clinic has the same energy profile. In some cases the operational time is increased.	According to a normal office Average yearly energy use Dutch offices: Gas: 18 m^3 per m² GFA (n=76) Electricity: 83 kWh per m² GFA (n=115)[1]
Hotel		According to a normal office but 24*7
Hot floor		According to a normal office increased with the additional ventilation
Industry	MRI, CT, radiography department, Laboratories, (production) pharmacy, mortuary, etc.	
		Average yearly energy use Dutch hospitals: Gas: 33 m3 per m² GFA (n=11) Electricity: 103 kWh per m² GFA (n=19)2

Table 2. Extrapolation from office to hospital building.

Specific energy demands for the different layers is not available. The only available information is the total energy consumption of hospitals. In some cases the energy demand per m^2 is available, but a common discussion is which part of the floor area of the hospital is used for this calculation.

To make a good estimation of the energy demand for each type of room the function/ activity level should be known (design parameter). The function of that room/activities in that room determine the equipment that is used (semantic information) and the time the room is used so giving a good estimation of the energy demand for medical equipment. If also the energy demand resulting from the building physics is known, this bottom up approach (sum of the energy demands of the rooms is the energy demand of the building (block) can be useful determining the energy demand and effect of measured taken (Figure 3).

[1] SenterNovem: Energy data Buildings of Public Utilities 2008, August 2009
[2] SenterNovem: Energy data Buildings of Public Utilities 2008, August 2009

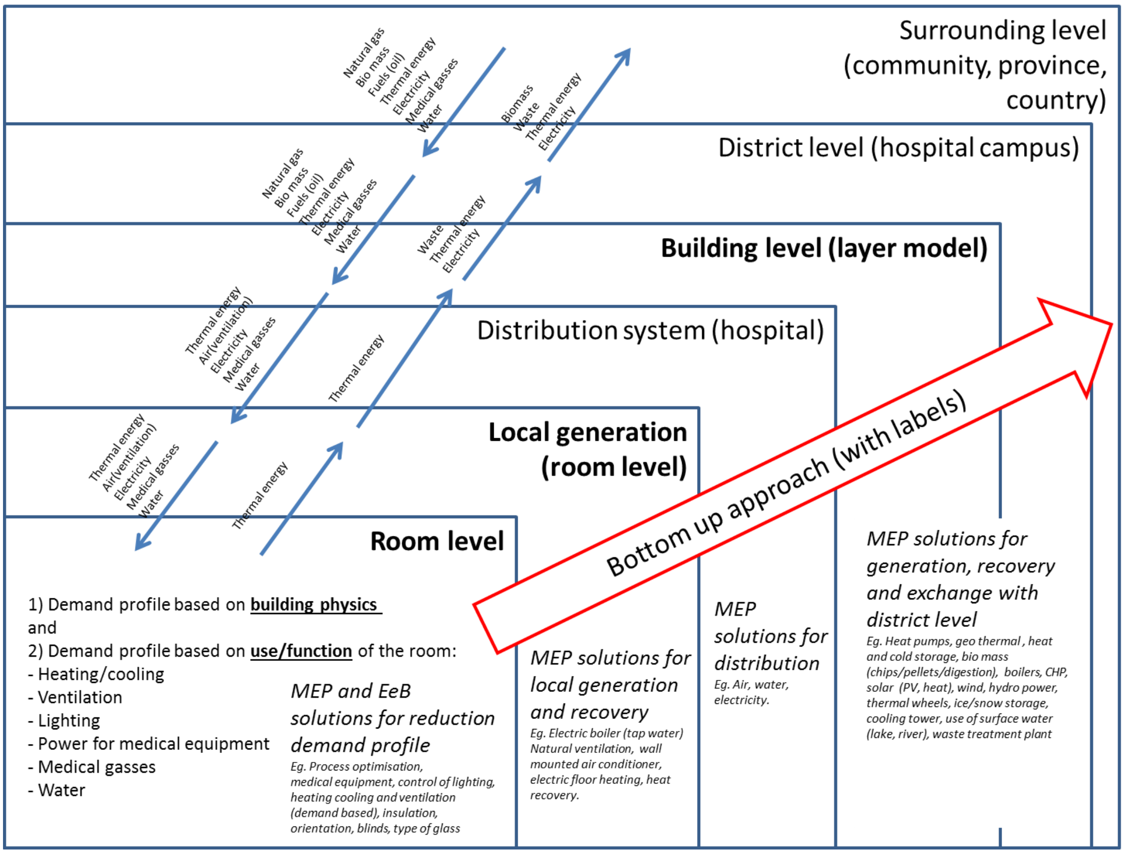


Figure 3. Energy flows and bottom up approach.

Given the fact that the layers of the Building Differentiation model of Hospitals are not clearly defined (as far as it concerns the functions they include), energy was not part of the model and the energy demand of the different layers is not available. This approach can only be used as a very global and rough estimation of the energy use of a hospital and can only be used in the first phase of a design. In this approach the effect of specific measures (clever positioning of functions in the building, refurbishment (changing function within the building), user behavior, period of use, energy efficient (medical) equipment, etc.) related to energy consumption will not be visible.

Semantic labels approach

With regard to the energy performance of hospitals a more detailed approach seems to be necessary. Although it is conceivable that average energy demands for the different layers can be derived, the results will only be meaningful if a hospital is actually built with the layers approach as guiding principle. If this is not the case, the layer typology could be sort of reverse-engineered by assessing the functions of each space, and determine if they can be grouped together in such a way that one can speak of a ‘layer’. Such an analysis starts with looking at the typology of each room.

The proposal is to develop a labelling system with labels that add semantic information to functions and subsequently to rooms that accommodate that function (see also deliverable D1.1). Information that can be added should be useful during the design process and operational phase and should have a relation with the energy demand (temperature level, ventilation demand and air tightness, insulation between rooms, medical equipment, time of use, etc.).

Labels that carry implicitly a lot of semantic information and have a relation to the energy demand can be:

I. Hygienic classes (has a relation with amount of ventilation, air tightness, cleaning, materials),
II. Accessibility (has a relation with the position in the hospital, safety/protective/security device),
III. Equipment (has a relation with the type of function, high electric power needed, medical gases, ICT data points),
IV. Construction (has a relation with floor strength, shielding against radiation, floor height, air tightness),
V. User profile (has a relation with the type of use).

Within these labels a number of levels can be defined (Table 3). Using these labels and levels most of the requirements related to a specific function (and thus the related rooms in hospitals) can be defined. With a combination of the building physics and the labels (giving information on the required properties: hygienic class, equipment and user profile) the energy demand of a room, and at a higher level the building block, can be calculated.

Label	Level
Hygienic classes (has a relation with amount of ventilation, air tightness, cleaning, materials)	· H1 (corridor, reception, toilet, etc.) · H2 (office, bath room, etc.) · H3 (patient room, examination room, treatment room, etc.) · H4 (operating room, insulation room, etc.) > additional air tightness and ventilation extra ductwork is necessary · H5 (laboratory, production pharmacy, etc.) > additional air tightness ventilation extra ductwork is necessary
Accessibility (has a relation with the position in the hospital, safety/protective/security device)	· A1 (Public) · A2 (Patients, visitors and staff) · A3 (Patients and staff · A4 (All staff members) · A5 (Specific staff members)
Equipment (has a relation with the type of function, high electric power needed, medical gasses,, ICT data points)	· EQ1 (Office level) · EQ2 (EQ1 and medical gases) · EQ3 (EQ1 and extra electric power) · EQ4 (EQ1 and extra ICT data points) · EQ5 (EQ2, EQ3 and EQ4) · EQ6 (High electrical safety) · EQ7 (special equipment)

Label	Level
Construction (has a relation with floor strength, shielding against radiation, floor height, air tightness)	• C1 (Office level) • C2 (Office level with extra floor strength) • C3 (Office level with extra floor height) • C4 (C2 and C3) • C5 (Accessible from the outside with heavy load) • C6 (Shielding against radiation) • C7 (high level of air tightness)
User profile (has a relation with the type of use)	• U1 (Monday to Friday from 8:00 – 18:00) • U2 (U1 extended till 20:00) • U3 (U1 with emergency function outside this timeslot) • U4 (24*7)

Table 3. Proposal for semantic labels and levels.

The labels within the BIM also give design teams the possibility to detect conflicting/incompatible interests in an early design phase and during plans for refurbishment. E.g. a room to accommodate a function with a high hygienic class (additional air tightness and ventilation) with a high equipment level in a public zone (A1) with a low hygienic class (H1) and low equipment level. This means that the installation and building construction should be very specific for one room in a more general area resulting in an inefficient situation from this point of view. So there should be a very good reason for doing this. The same situation can be encountered during refurbishment/relocation functions (Figure 3).

A first step is to define the labels and add levels to the labels. Based on this structure a database shall be established with the relation between health care functions, the KPI's and these label structure which is applicable for the European hospitals. Semantic rules can be added to this database to enrich the information. Semantic information linked to the labels (levels) can be that for a room with a high hygienic class:

- a higher amount of fresh air is needed,
- special filtration of air is necessary,
- air tightness of the room is important,
- a cleaning protocol is necessary,
- that details of the construction shall provide possibilities for easy cleaning,
- materials shall be used that can resist cleaning agents,
- this room should be close to other rooms with the same technical specifications,
- power plugs shall be of a certain quality,
- national regulation should be taken into account,
- special clothing should be used,
- etc.

This database can be used in different phases of the design in the BIM structure to help design teams.

All the labels to be defined shall comply with the following demands:

1. Expose the difference between function/activity and the requirements for the room,
2. Add information that can be used during the design process,
3. Carry more semantic information that one parameter (e.g. shall be more than only m^2, height, etc.),
4. To be used within Europe and create a standard for hospital design and refurbishment based on user requirements for functions/activities in hospitals.

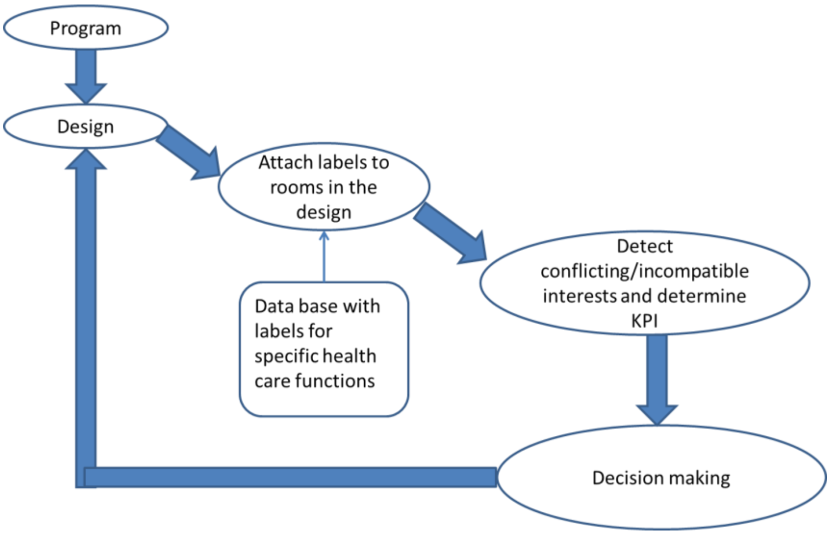


Figure 4. Design process

2.2 Building space

1 Building space
1.1 Morphology
1.2 Orientation
1.3 Number of stories

List of the Technologies

categories		name	paragraph
1.1	1.1.1	Surface and volume ratio (S/V)	2.2.1
1.2	1.2.1	Solar gains	2.2.2
	1.2.2	Daylighting	2.2.3
1.3	1.3.1	Number of stories	2.2.4

2.2.1 MORPHOLOGY:

SURFACE AND VOLUME RATIO (S/V)

[1.1.1]

Description

The S/V ratio express the compactness of a building and it is one of the fundamental parameters to calculate the energy efficiency of a construction.

S is the SURFACE AREA (m^2) that borders the heated volume V to the outside, or to a not - heated zone (e.g. car park, basement).

V is the gross VOLUME (m^3) of the heated zones defined by the surfaces border.

The three dimensional extrapolation of the perimeter to area ratio (S/V) is an important factor in determining heat loss and solar gain. The shape of a building has a fundamental impact on the day lighting potential, on the building's transfer characteristics, and on its overall energy use. The greater the surface area the more the heat gain/loss through it. So small S/V ratios imply minimum heat gain and minimum heat loss.

To minimize the losses and gains through a building envelope a compact shape is desirable: the most compact orthogonal building would then be a cube. This configuration, however, has to be compared to the correct daylighting and natural ventilation comfort. A compact building that optimizes daylighting and ventilation would be elongated (rectangular shape) so that more of the building area is closer to the perimeter. While this may appear to worst the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed daylighting system will more than compensate for the increased fabric losses.

In hot-dry climates, the S/V ratio should be as low as possible as this would minimize heat gains. 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. In these climates, the use of courtyards and inner spaces is favorable for the overheating reduction. In cold-dry climates also S/V ratios should be as low as possible to minimize heat losses.

The compactness of a building is fundamental in the building energy needs calculation. In most of the European countries, the primary energy demand (EP) for heating per square meter of useful internal area of a building, in kWh/m^2 per year is expressed depending on the ratio area/volume (form factor).

Anyway, the S/V ratio cannot be considered as the only indicator of thermal behavior of a building, but has to be evaluated in relation to the climatic zone, orientation and solar gains, especially in buildings with complex plans and heights.

This factor is one of the most important that influences the environmental design. Applied to hospitals, by comparing two typologies of block (tall and low) it can be said that a tall and thin building has a more favorable S/V ratio, anyway a more horizontal, and thinner courtyard configuration offers more potential for cross views, daylight, and natural ventilation.

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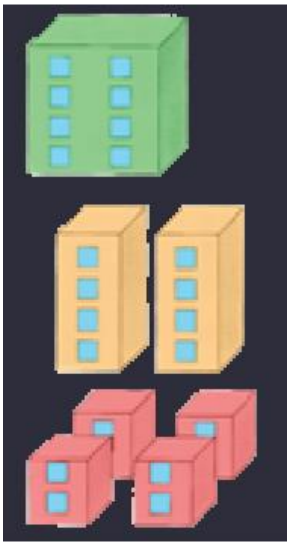
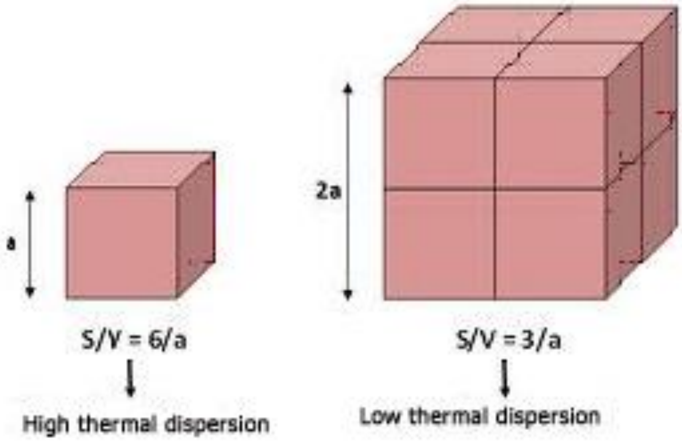
http://www.new-learn.info/packages/clear/thermal/buildings/configuration/surcafeareato_vol_ratio.html
http://www.newlearn.info/packages/clear/thermal/buildings/configuration/images/formthermalperformance.pdf
D. LGS. 311/06
UNI/TS 11300

Figure





Buildings have the same volume but different surfaces.

In the first case:
S= 864 m2 V= 1728 mc S/V = 0,5

In the second case:
S= 1008 m2 V= 1728 mc S/V = 0,65

In the third case
S= 1728 m2 V= 1728 mc S/V = 1

Minimum surface area reduces heat transfer.
Increased area, greater heat transfer.

Source: CasaClima

Parameters

S/V index (%)
In Italy 0,2 and 0,9 are the maximum and minimum range between which primary energy demand of a building is classified.
In other Countries (e.g. MInergie or Breem standard) the S/V volume is expressed in typology of building (e.g. single house, multifamily, etc.)
Outdoor Air Speed/Wind direction and intensity (m/s)

Codes of practice

In a building, the more complex and extended is the surface, the more unfavorable the S/V ratio. In cold climates the use of lodges and cavities may be unfavorable to the overall energy balance. Anyway, building morphology cannot be considered without climatic zone and orientation.

2.2.2 ORIENTATION:

SOLAR GAINS

[1.2.1]

Description

The building orientation is fundamental in the building design as it determines the amount of radiation it receives on each surface. The solar radiation incident on a building is one of the fundamental factors that influence heat transfer through the building envelope. The orientation of a building/room has an effect on its heat and cool load, as the thermal exchange through walls and roofs varies a lot depending on their orientation: anyway solar gains are an important member of the thermal balance equation, besides the thermal transmittance of the envelope.

Solar gains are fundamental in the energy balance, the design for best result is to have some solar heat gain in winter, when the sun is low on the horizon and the favorable energy intake (at 44 ° North Latitude December 21th , the winter solstice, the sun has a height of about 23° above the horizon) this means that the south side receives the maximum luminance, this favor south orientation and maximize solar gain in winter season (e.g. greenhouse effect).

While in the North Latitudes, temperatures do not exceed 25 degrees, in the South latitudes (Mediterranean countries) the summer is characterized by hot climate, so overheating has to be avoided.

In the summer the sun is high (at the 21th of June, the summer solstice, sun is about 70° above the horizon) with strong inclination on vertical surfaces which are better protected from direct solar exposure. Anyway, the energy intake is unfavorable and causes overheating accounts. In this latitude, solar heat gain on the east and west side can be particularly troublesome as its maximum intensity coincides with the hottest part of the day.

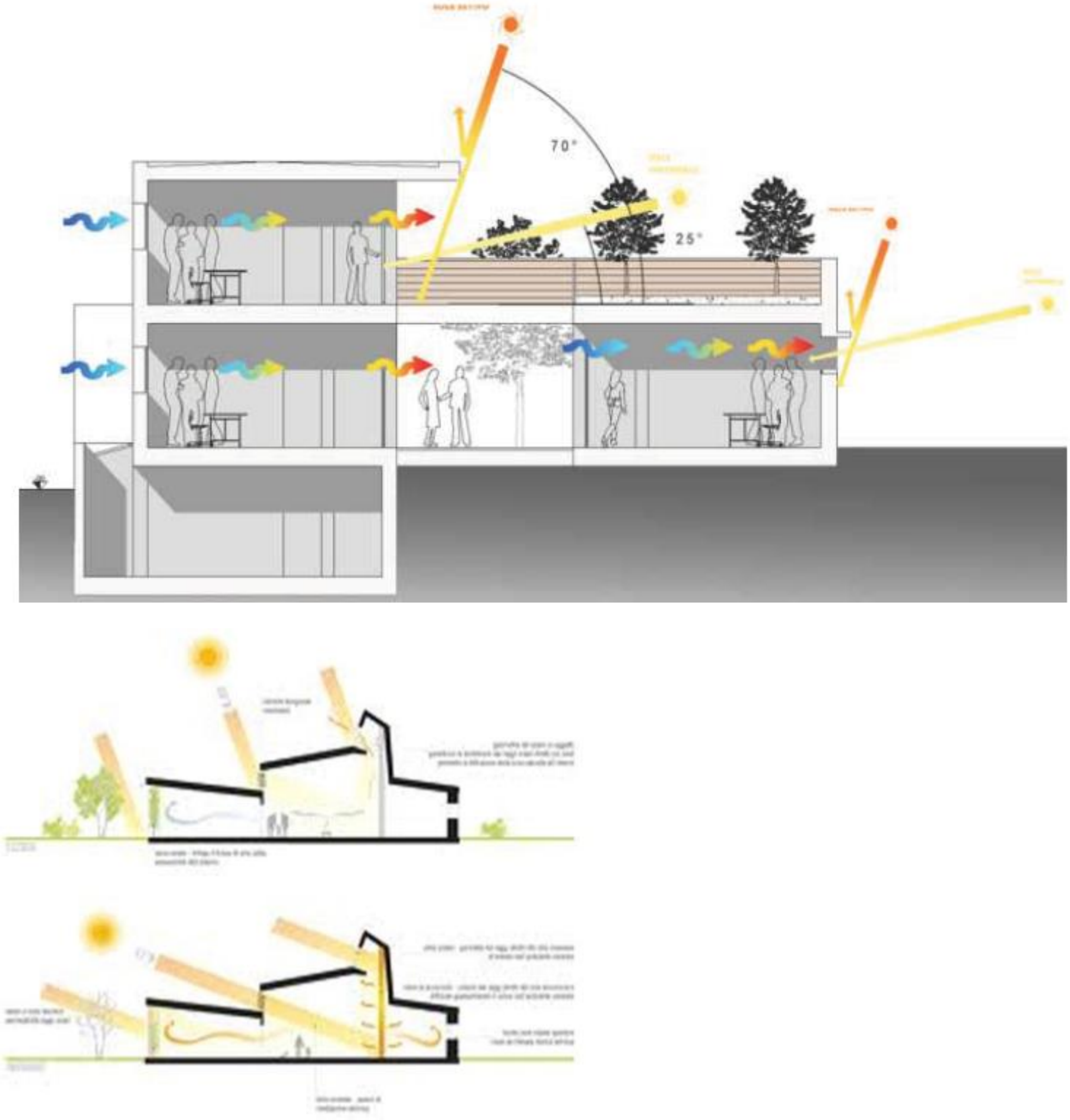
To optimize the building shape without considering the orientation can produce relevant errors in terms of solar gains and indoor comfort. A very compact shape may not be optimum if, for instance, it is needed to favor the exposure of walls to winds (e.g. natural cooling) as well as the solar radiation exclusion (e.g. the mitigation of solar gains during the summer season with the use of cavity spaces). The orientation of the building as well as the relative dimensions of opaque/transparent surfaces facing different directions would have to be considered.

This factor is fundamental in the healthcare districts design. The orientation of the rooms directly impacts its energy performance and affects the impact of daylight on patient healing. This is due primarily to the orientation of the fenestration and the glazing’s exposure to light and solar heat gain.

References

http://www.new-learn.info/packages/clear/thermal/buildings/configuration/building_orientation.html
D. LGS. 311/06
UNI/TS 11300

Figure



Source: silvia.brunoro@unife.it

Parameters

Heat gain (MJ/m^2)
Solar elevation angle (degree)
U value (W/m^{2}K)
Overall energy balance (Ep) [Kwh/m^{2}a]
Outdoor Air Speed/Wind direction and intensity (m/s)

Codes of practice

Less compact forms increase a building’s solar gain potential, but they also may magnify the influence of outdoor climate fluctuations. Greater surface/volume ratios increase conductive and convective heat transfer through the opaque building envelope, and the potential for massive radiant solar heat gains via unshaded glazing. Therefore, it is critical to assess the solar gain characteristics of the building form in combination with the shading of all glazing surfaces and the heat transfer characteristics of the building envelope in order to optimize overall building energy and daylighting performance.

2.2.3 ORIENTATION: DAYLIGHTING

[1.2.2]

Description

Daylight is fundamental for the building comfort, as it contributes to an energy-efficient, healthy, and productive environment. The controlled admission of natural light, direct and diffuse sunlight into a building is fundamental to reduce electric lighting and saving energy.

The daylight factor is the ratio of internal light level to external light level and is defined as follows: DF = (Ei/Eo) x 100% where, Ei = illuminance due to daylight at a point on the indoors working plane, Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky.

Daylighting strategies dictate the building's morphology (shape and form), and their successful integration into the design from structural, mechanical, electrical, and architectural standpoints. In order to be effective, the building design must consider the geographic and climatic conditions particular to the project's site. For example, eastern and western exposures are difficult to shade, so an effective building form for daylighting is one that minimizes the amount of fenestration at these exposures and maximizes fenestration at north and south exposures.

An integrated design approach that involves decisions about the building form, siting, climate, building components (such as windows and skylights), lighting controls, and lighting design criteria is needed.
With a proper building design, daylighting can translate into energy savings, thus reducing operating and investment costs such as reduce electricity use and peak electrical demand for lighting, cooling energy and cooling loads. Fenestration is responsive to the site-specific solar exposure and patterns, they have to be controlled in shape and dimension and effective shading devices have to be designed to minimize solar radiation gains during peak cooling times.

High levels of light (even on overcast days) can be bright enough to cause glare. Solar shadings and high-performance glazing are used to meet lighting design criteria, block solar radiation, and minimize thermal transmission gains (summer) and losses (winter). For an optimum indoor comfort, the façade should be designed to allow high levels of light, but only a limited amount of direct light.

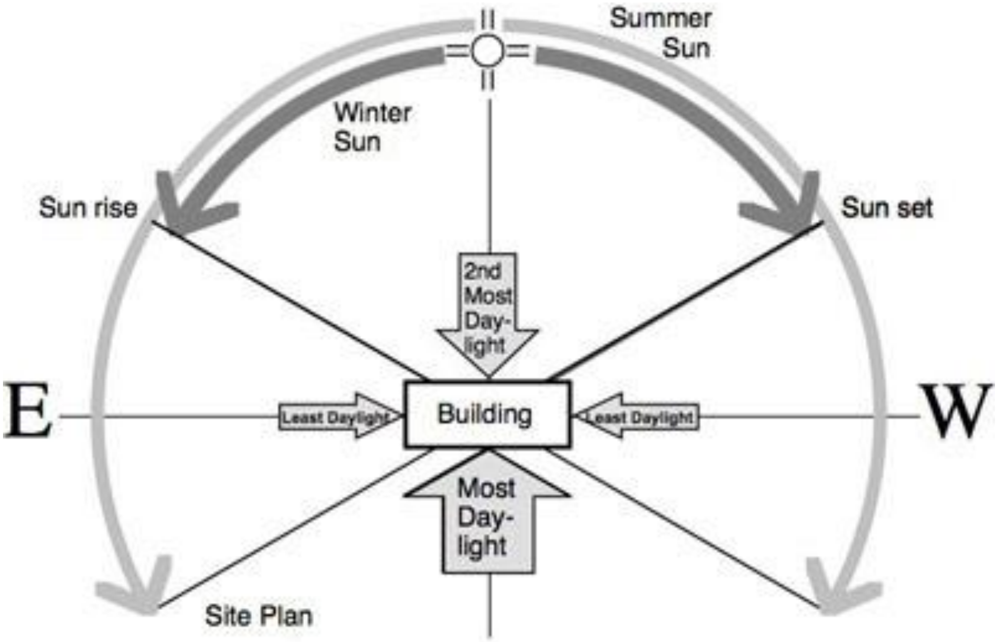
A good daylighting solution requires the simultaneous examination of the building configuration and internal space planning so as to maximize the amount of normally occupied space that has access to daylight for ambient illumination. This analysis must also include an assessment of the space's ability to maintain heat gain criteria for minimizing cooling energy and maximizing the potential for solar heating during cold periods.

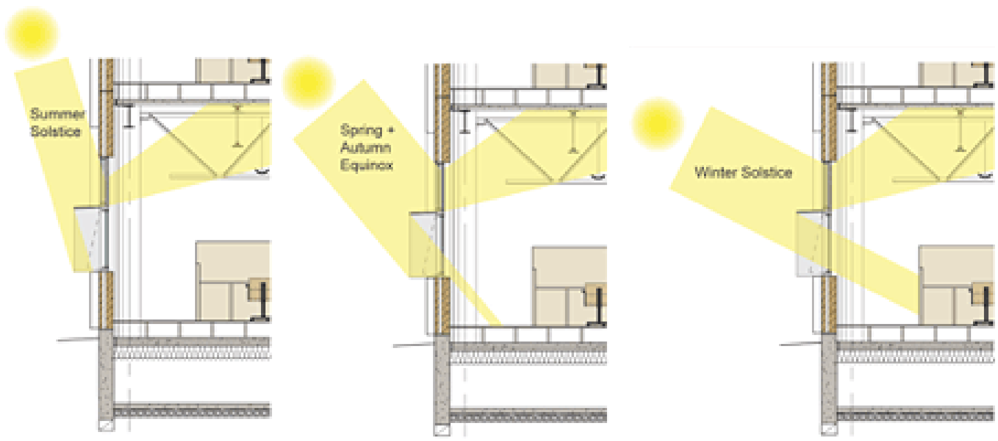
This factor is crucial in the healthcare districts design. This involves the psychological aspect of who is forced to live in a room for long periods. Robust amounts of daylight are needed as natural light helps humans to maintain their natural circadian rhythms and reduces illness and stress.

References

http://www.wbdg.org/resources/daylighting.php
D. LGS. 311/06

Figure





Source: http://www.wbdg.org

Parameters

Shading percentage (%)
Daylight factor (%). In most of the European Countries, the Daylight factor parameter is defined by local regulation (Health & Safety Adviser).
Shadow range simulation at 10.00, 13.00 and 16.00 of 25 of June and July
Shadow range simulation at 13.00 and 15.00 of 25 of July
Outdoor Air Speed/Wind direction and intensity (m/s)

Codes of practice

Particular attention is given to daylighting while designing a building when the aim is to maximize visual comfort or to reduce energy use. Improving daylighting, energy savings can be achieved from the reduced use of artificial (electric) lighting or from passive solar heating or cooling. Moreover, in the Mediterranean Countries, the daylighting control is fundamental in the summer season. As an example, in Italy, windows that are south and west oriented have to respect a minimum shading percentage to avoid summer daylighting and overheating. Almost the 50% of the transparent surface has to be shaded by means of external devices (fixed or moveable). Use of fixed (balconies, lodges) or moveable shadings (curtains).

2.2.4 NUMBER OF STORIES:

NUMBER OF STORIES

[1.3.1]

Description

The number of stories in a building may affect energy performance.

Generally, as the number of stories of a building increases, some aspects of the design become more complicated. For instance, the requirements for structural performance and durability/design life may affect choice of envelope components, the viability of exposed thermal mass, and the amount of area that may be used for fenestration.

Tall buildings tend to be thinner and have greater daylighting access due to a higher ratio of perimeter wall area to floor area. If an increased amount of space with access to natural daylight or ventilation is preferred, this have to be carefully check to avoid solar gains when not necessary.

Large block buildings are generally shorter, in this case the depth of the building has to be controlled.
Short and deep buildings may have inner spaces far from the perimeter and lack of natural light. Designers can introduce daylight via the roof area, thus providing top-light via skylights and atriums.

Anyway, any consideration on a building height has to be carefully related with the climatic inputs of the area and with the orientation itself.

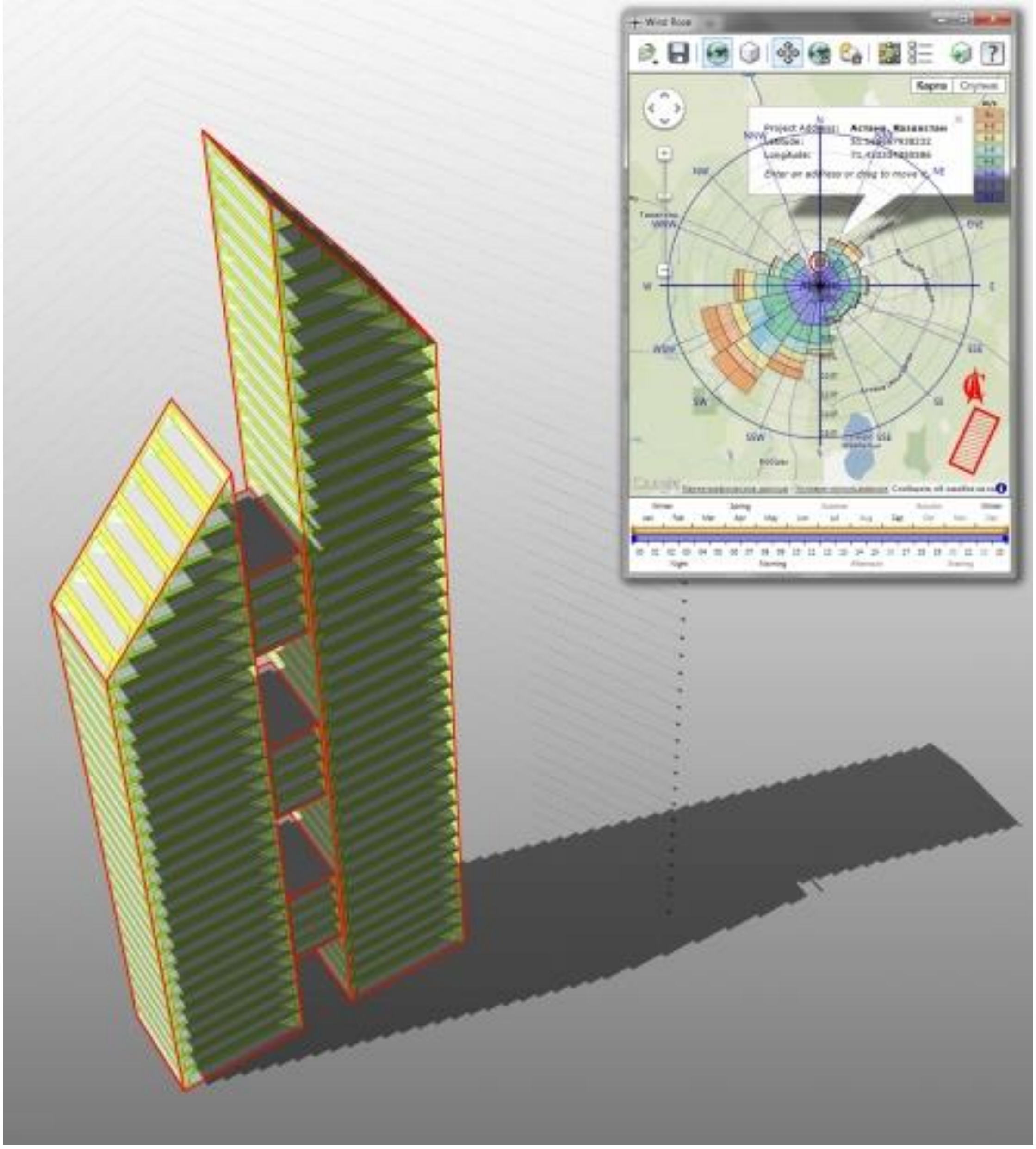
Moreover, tall buildings have elevators with large energy-consuming motors but intermittent energy use. Large buildings require frequent vertical trips and should consider the use of variable-frequency drives (VFDs) on the motors and controls to stage the travel of elevators and reduce redundant trips in response to a call button.

This factor is largely applicable in healthcare districts. Tall Hospitals generally tend to be thinner and have greater daylighting access due to a higher ratio of perimeter wall area to floor area. In these cases the solar gains load has to be controlled, moreover the vertical connections (elevators, staircases) has to be carefully designed as becomes the critical point of the design.

References

ASHRAE, Advanced energy design guide for large hospitals (50%), Updated May 10, 2012.

Figure



Source: http://sustainabilityworkshop.autodesk.com/sites/default/files/styles/large/public/gallery-inserted-images/4-2-chelyabinsk-susu-alik_ustyuzhanin-iteration3.jpg?itok=AqE--RLH

Parameters

Floor height (m)
Outdoor Air Speed/Wind direction and intensity (m/s)

Codes of practice

This topic cannot be considered by itself but has to be carefully evaluated in relationship with: site selection, climatic factors, orientation, surface/ratio volume.

3. Technical solutions of EeB envelope

This section considers the:

- vertical envelope (façades) - paragraph 3.1,
- horizontal envelope (top closures) - paragraph 3.2.

3.1 Vertical envelope (façades)

1.1 External Thermal Insulation Composite System (ETICS)	1.2 Ventilated façades	1.3 Solar shading	1.4 Passive solar energy system	1.5 Active solar energy system	1.6 High efficiency windows (double or triple glass with coatings, tinted and/or gas filled)
1.1.1 Traditional External Thermal Insulation Composite System	1.2.1 Opaque Ventilated façades	1.3.1 External solar shadings	1.4.1 Solar greenhouse	1.5.1 Photovoltaic panels	1.6.1. Double – triple glazing with solar films
1.1.2 Transparent Insulation Materials (TIM)	1.2.2 Double skin glass façades	1.3.2 Internal solar shadings		1.5.2 Solar collectors	1.6.2 Double – triple glazing with Low – E glass
	1.2.3 Hybrid façades (wall/glass)			1.5.3 Mixed systems	

List of the Technologies

categories		name	paragraph
1.1	1.1.1	TRADITIONAL EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM	3.1.1
		LIGHT COLOUR OF THE OUTSIDE WALL	3.1.2
	1.1.2	POLYCARBONATE INSULATION MATERIAL	3.1.3
		AEROGEL (HIGHLY INSULATED WINDOWS WITH AEROGEL)	3.1.4
1.2	1.2.1	OPAQUE VENTILATED FAÇADES	3.1.5
		VENTILATED FAÇADES WITH PCM	3.1.6
	1.2.2	DOUBLE SKIN GLASS FAÇADE	3.1.7
	1.2.3	HYBRID FAÇADES (WALL/GLASS)	3.1.8
		INTEGRATED FAÇADES HYBRID SYSTEM	3.1.9
1.3	1.3.1	EXTERNAL SOLAR SHADINGS	3.1.10
	1.3.2	INTERNAL CURTAINS AND VENETIAN BLIND	3.1.11
1.4	1.4.1	SOLAR GREENHOUSE	3.1.12
		SOLAR WALL ®	3.1.13
		SOLAR CHIMNEY OR VENTILATION CHIMNEY	3.1.14
		GREEN WALL	3.1.15
1.5	1.5.1	PHOTOVOLTAIC PANELS	3.1.16
	1.5.2	SOLAR COLLECTORS	3.1.17
	1.5.3	TRANSPARENT PV OVERHANGS	3.1.18
1.6	1.6.1	HIGH EFFICIENCY WINDOWS (WITH SOLAR FILMS)	3.1.19
		HIGH EFFICIENCY WINDOWS (WITH LOW-E/ARGON FILLED)	3.1.20

3.1.1 **ETICS - TRADITIONAL EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM: TRADITIONAL EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM**

[1.1.1]

Description

ETICS is a highly effective technical solution for improving thermal insulation (U value) in walls. The system consists of an external covering with insulating panels, fixed to the existing surfaces through wedges and binders, then armed with special nets and completed with a thin layer of plaster.

External layer overlapped on the wall improves global thermal transmittance, reduces thermal heat loss and thermal bridges and help to maintain required indoor conditions. System is easy to apply and available on the market since 50 years. There are a wide range of thermal isolative components such as Styrofoam, mineral wool, expanded polystyrene foam. Depending on the kind of material, the thermal conductivity (λ value) can vary from 0,003 to 0,045 Wm^2/K. The global thermal transmittance (U value) of the envelope depends on the ETICS thickness.

The application of ETICS became in the last ten years a popular measure to improve the energy performance and the weather resistance of façades in the building stock.

In an existent building, in the most cases, wall transmittance is higher than the minimum requested, for example, by Italian national standards: an addicted layer (e.g. 12 cm of extruded polystyrene insulation layer) can improve global thermal transmittance and, consequently, reduce the building global energy need.

Improving the building envelope by adding a 10-12 cm of thermal insulation layer can reduce the U value of a wall of about one third, this can be considered as a very good result for the global energy efficiency of the building: if we consider the global energy performance (primary energy coefficient) we can say that a jump to one or two energetic class of (e.g. from G to D class) can be obtained by an ETICS intervention.

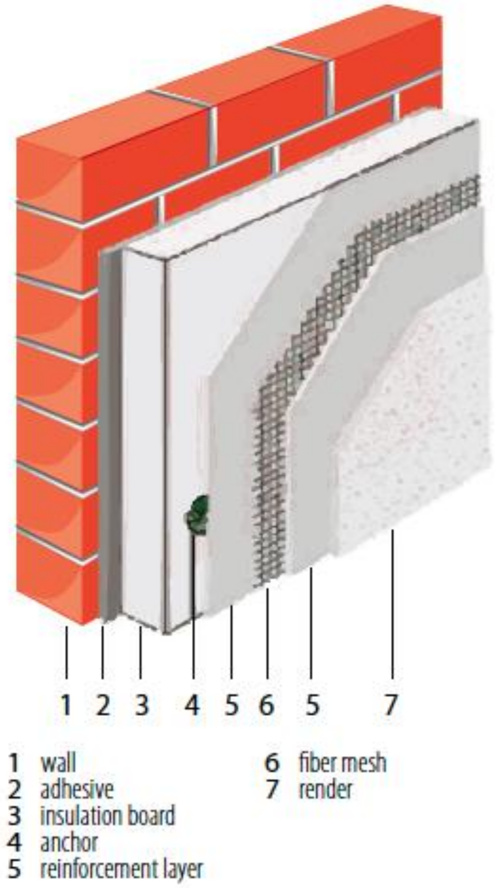
About the main risks of the device, even if it is frequently supposed that the small thickness of the exterior plaster and a smooth insulation material as substrate are possible causes for damage from mechanical impact, many experiences can demonstrate that the costs and frequency of maintenance for ETICS are less than those of traditional wall structures (e.g. traditional plaster replacement).

This technology is well known and generally used in European Countries, it can be easily applied to all type of Healthcare facilities.

References

http://www.mapei.com/public/AU/linedocument/qt_mapetherm_gb_bassa.pdf
UNI EN ISO 6496 and UNI EN ISO 13786:2008

Figure



Source:
http://ea-etics.eu/~run/views/etics/about-etics.html

Source :
STYROFOAM™ ETICS

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient for wall U_W [W/m^{2}K]
Periodic Thermal Transmittance YIE [W/m^{2}K]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]
Capacity of an opaque wall to phase shift and to mitigate the thermal flow over 24 hours

Codes of practice

The insulating panels covering is fixed to the existing surface through wedges and binders, then armed with special nets (plastic or glass fiber) and completed with a thin layer of plaster. When the wall is irregular, a thin plaster film is fundamental for planarity flaws. One of the most important precaution is to avoid thermal bridges in the correspondence of the fixing elements (that are diffused all over the surface). The use of "warm wedges" is recommended (e.g. plastic wedges, or in the case of metallic wedge, they have to be covered with insulating material).

3.1.2 ETICS - TRADITIONAL EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM: LIGHT COLOUR OF THE OUTSIDE WALL

[1.1.1]

Description

Creating a building shell that is massive and well insulated can effectively address conduction gains and losses, but it is critical to also take into account radiant solar gains. By comparison, in the warmer months, in a hot and humid climate, almost all of the cooling load coming from the wall and roof area can be attributed to radiant heat gain. When solar radiation strikes a surface, a certain percentage of radiation is reflected away, and the balance is absorbed. When this occurs, it heats up that material, and the material reradiates downward. The low-emissivity properties of the surface material stop this radiant process.

By addressing this problem it is possible to decrease the cooling load significantly. Heat radiation can be reduced by using light coloured coating with high reflectance.

Some reflectance values for common exterior wall surfaces

Surface	Emmisivity or Absorptivity		Reflectivity
	(Low temperature radiation)	(Solar radiation)	(Solar radiation)
Aluminium, bright	0.05	0.20	0.80
Asbestos cement, new	0.95	0.60	0.40
Asbestos cement, aged	0.95	0.75	0.25
Asphalt pavement	0.95	0.90	0.10
Brass and copper, dull	0.20	0.60	0.40
Brass and copper, polished	0.02	0.30	0.70
Brick, light puff	0.90	0.60	0.40
Brick, red rough	0.90	0.70	0.30
Cement, white portland	0.90	0.40	0.60
Concrete, uncoloured	0.90	0.65	0.35
Marble, white	0.95	0.45	0.55
Paint, Aluminium	0.55	0.50	0.50
Paint, white	0.90	0.30	0.70
Paint, brown, red, green	0.90	0.70	0.30
Paint, black	0.90	0.90	0.10
Paper, white	0.90	0.30	0.70
Slate, dark	0.90	0.90	0.10
Steel, galvanized new	0.25	0.55	0.45
Steel, galvanized weathered	0.25	0.70	0.30
Tiles, red clay	0.90	0.70	0.30
Tiles, uncoloured concrete	0.90	0.65	0.35

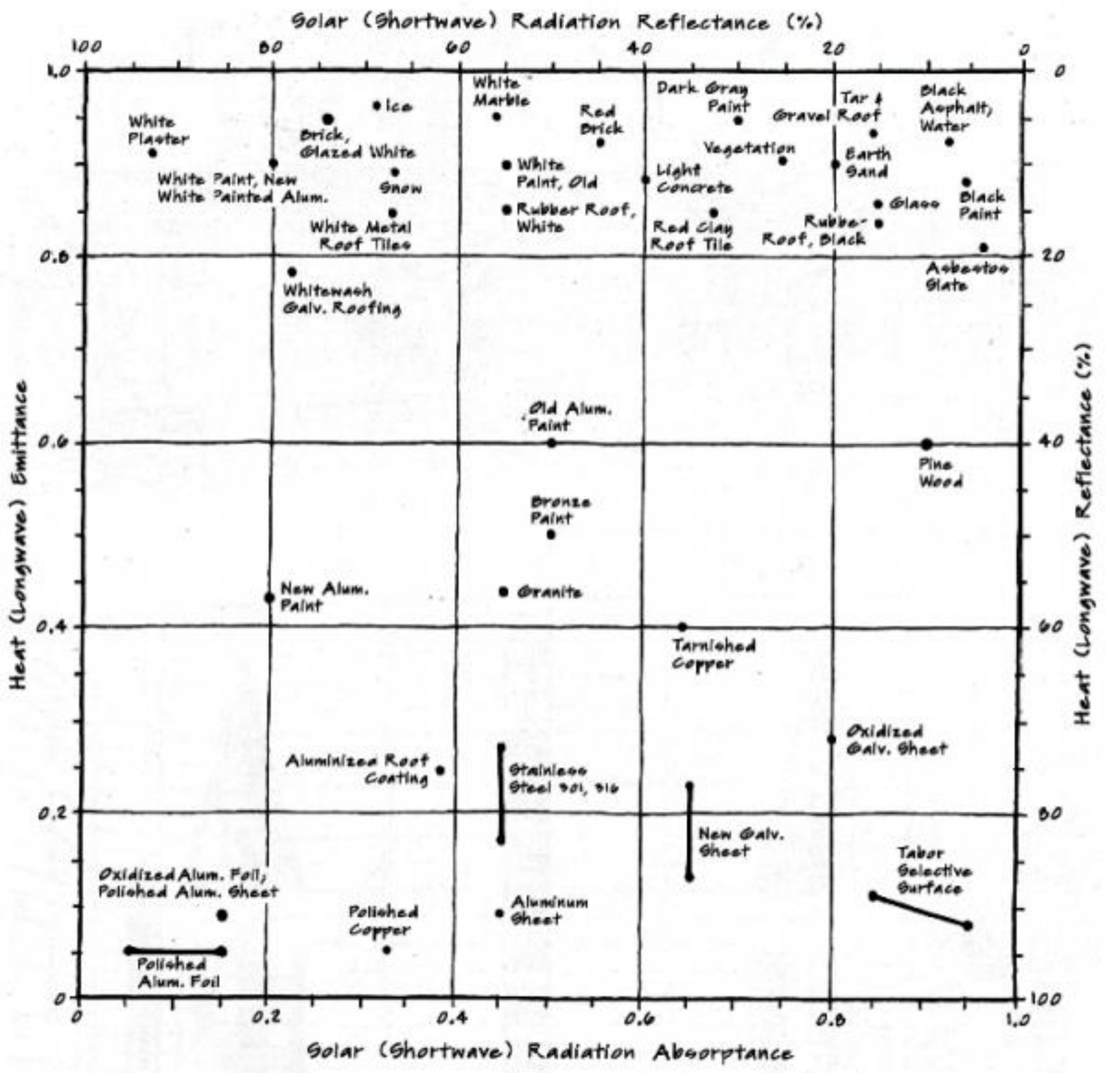
Complementary measures to reduce radiant heat gain through walls can e.g. be to add shades and vegetation, for example, trees and bushes, which allow solar gain in the winter but block light and heat in the summer.

The use of light colors for surface is diffused all over Europe and can be applied to all type of healthcare facilities.

References

Brown, G. Z. and DeKay, M. “Sun, Wind & Light: Architectural Design Strategies”, Wiley, New York, 2000.
http://mnre.gov.in/solar-energy/ch4.pdf

Figure



Solar Reflectance and absorption vs. heat reflection and emittance, for common materials.

Source: Brown, G. Z. and DeKay, M. “Sun, Wind & Light: Architectural Design Strategies”, Wiley, New York, 2000.

Parameters

Solar (short wave) Reflectance Index SRI [%]
Heat (long wave) Reflectance Index HRI [%]
Surface area [m^2]

Codes of practice

Choosing reflecting light colours of the external walls is a comparatively resource effective way to reduce the amount of heat entering the building and thus the cooling load. This is particularly important in areas where radiant barriers cannot practically be installed; there is a lack of natural shading, such as trees and bushes, and/or in a hot climate.

3.1.3 ETICS - TRANSPARENT INSULATION MATERIALS (TIM): POLYCARBONATE INSULATION MATERIAL

[1.1.2]

Description

Transparent Insulating Materials (TIMs) perform a similar function to opaque insulation, yet they have the ability to transmit daylight and solar energy, reducing the need for artificial light and heating. TIMs transmit heat, mainly through conduction and radiation, as convection is usually suppressed. It can be explained by that TIMs are transmitters of short wave radiation but barriers to long wave radiation. Short wave solar radiation passes through the transparent insulation whereas long wave heat radiation is insulated. Incident solar energy falling on the transparent insulation is reflected and re-reflected within the material and eventually falls on the absorber. In addition, transparent insulation materials also have increase thermal resistance due to conduction in comparison to standard glass.

The thermal and optical properties of TIMs depend on the material, its structure, thickness, quality and uniformity. Depending on the structure of a TIM, its arrangement can be classified as absorber perpendicular, absorber parallel, cavity or quasi-homogeneous (see figure).

TIMs typically consist of either glass or plastic arranged in a honeycomb, capillary or closed cell construction. Alternatively, granular or monolithic silica aerogel can be used to achieve higher insulation values.

TIMs glazing typically consists of glass or plastic capillaries or honeycomb structures sandwiched between two glass panes. These systems diffuse light well, while reducing glare and shadowing. Some commercial products, such as Okalux and Arel, glazing can exhibit low U-values with good solar and light transmittance. For example, 40-mm-thick Okalux capillary glazing, and 50-mm-thick Arel honeycomb glazing can achieve U-values of 1.36 W/m^2K, which is comparable to modern gas filled double glazing. Alternatively, 80- and 100-mm thick systems can achieve U-values of 0.8 W/m2 K, respectively, which is comparable to modern gas filled triple glazing units.

This technology is mainly applicable in Healthcare districts located Northern Countries, where the need of solar gain is fundamental in the energy balance of the building, while is not convenient in Mediterranean Countries where the reduction of overheating is the primary issue. In this case an integrated solar shading device is needed, that increases the cost of the system.

References

Brunoro, S., Efficienza energetica delle facciate, Maggioli, Rimini, 2006.
Dowson, M., “Novel retrofit technologies incorporating silica aerogel for lower energy buildings”, Brunel University School of Engineering and Design PhD Theses, 2012.
Lien, A.G., Hestnes, A.G., Aschehoug, “The use of transparent insulation in low energy dwellings in cold climates", in Solar Energy, January 1997.
Wong, I.L., Eames, P.C. and Perera, R.S., “A review of transparent insulation systems and the evaluation of payback period for building applications”, Solar Energy, Vol. 81, No. 9, 2007, pp. 1058-1071.
Hutchins, M. and Platzer, W.J. The thermal performance of advanced glazing materials, Renewable Energy, Volume 8, Isues 1-4, May-August, 1996, pp. 540-545.
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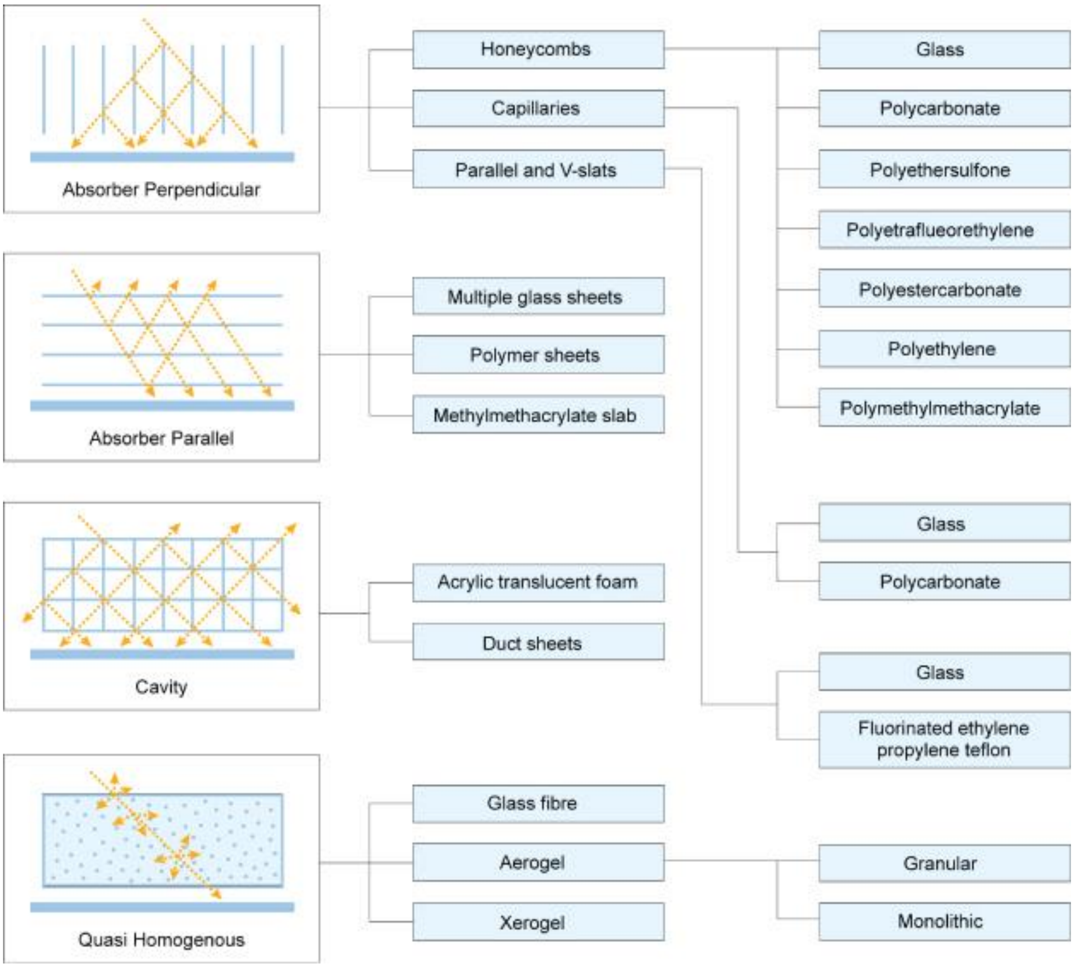
http://www.ciriaf.it/ft/File/Pubblicazioni/pdf/1560.pdf
UNI EN ISO 6496 and UNI EN ISO 10077

Figure



Source: Adapted from Wong, I.L., Eames, P.C. and Perera, R.S., "A review of transparent insulation systems and the evaluation of payback period for building applications", Solar Energy, Vol. 81, No. 9, 2007, pp. 1058-1071.

Parameters

Insulation material thickness d [m]
Thermal transmittance coefficient U_W [W/m2K]
Thermal conductivity coefficient λ [W/mK]
Solar factor G or ý (%) – the total percentage of energy, i.e. heat, that passes through the glass
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Transparent insulation is used in the housing industry as a passive solar feature. It is attached to the walls of houses for insulation and solar energy gains are transmitted to the house during the right ambient conditions. The walls of the house act as a thermal mass, absorbing the sunlight at the surface and converting it into heat which is slowly transmitted to the inside of the house. TIMs are also been used for windows, skylights, roofs and high-performance solar collectors.

3.1.4 ETICS - TRANSPARENT INSULATION MATERIALS (TIM): AEROGEL (HIGHLY INSULATED WINDOWS WITH AEROGEL)

[1.1.2]

Description

Aerogels are synthetic low-density materials with unique physical properties. They are formed by removing the liquid from a gel under special drying conditions, bypassing the shrinkage and cracking experienced during ambient evaporation. This creates a solid three-dimensional nanoporous structure containing 80-99% air. Due to their high porosity, aerogels exhibit the lowest thermal conductivity of any solid, and at the same time, being transparent to light and solar radiation. Aerogels are often cited as a promising material for translucent insulation applications. They can be made from practically any material, although the most common form is silica aerogel which can be produced as granules or in solid (monolithic) tiles.

Transparent monolithic silica aerogel has the potential to achieve U-values as low as 0.1 W/m^2K. However, research and development into monolithic glazing is limited due to the high cost of production, long processing time and the difficulty of creating large uniform samples with complete transparency, thus aerogel has only been produced in small quantities and sizes, so only tile-sized samples have been used as windows for research purposes. For example, European manufacturers have produced double-glazed windows filled with small beads of aerogel and while the units have good insulating values, they are diffusing and do not provide a view.

Besides highly reduced heat transfer and energy savings benefits, windows with aerogel shows good characteristics in terms of no risk for inert gases to leak out, lighter than triple glazed window units, better sound insulation performance, and better light transmittance without low-e coatings. Characteristics that will make it possible to obtain bigger window space avoiding increase of energy demand for heating and cooling.

Aerogels can be produced as either opaque, translucent, or transparent materials, thus enabling a wide range of possible building applications, e.g. applied to a building's walls, attics, grounds and appliances.

No doubt, the aerogels represent a state-of-the-art thermal insulation solution, very promising with a high potential. The production costs are still quite high and the coming year's progress will show how far and extensive the aerogels can be applied in the building sector.

Aerogels is not new on the market, but its diffusion on a large scale until now was not affordable mainly due to the production cost. Anyway it can be very promising in case of hospitals usage as it helps to improve thermal comfort with low thickness, and it can be applied on internal or external surfaces in the renovation.

References

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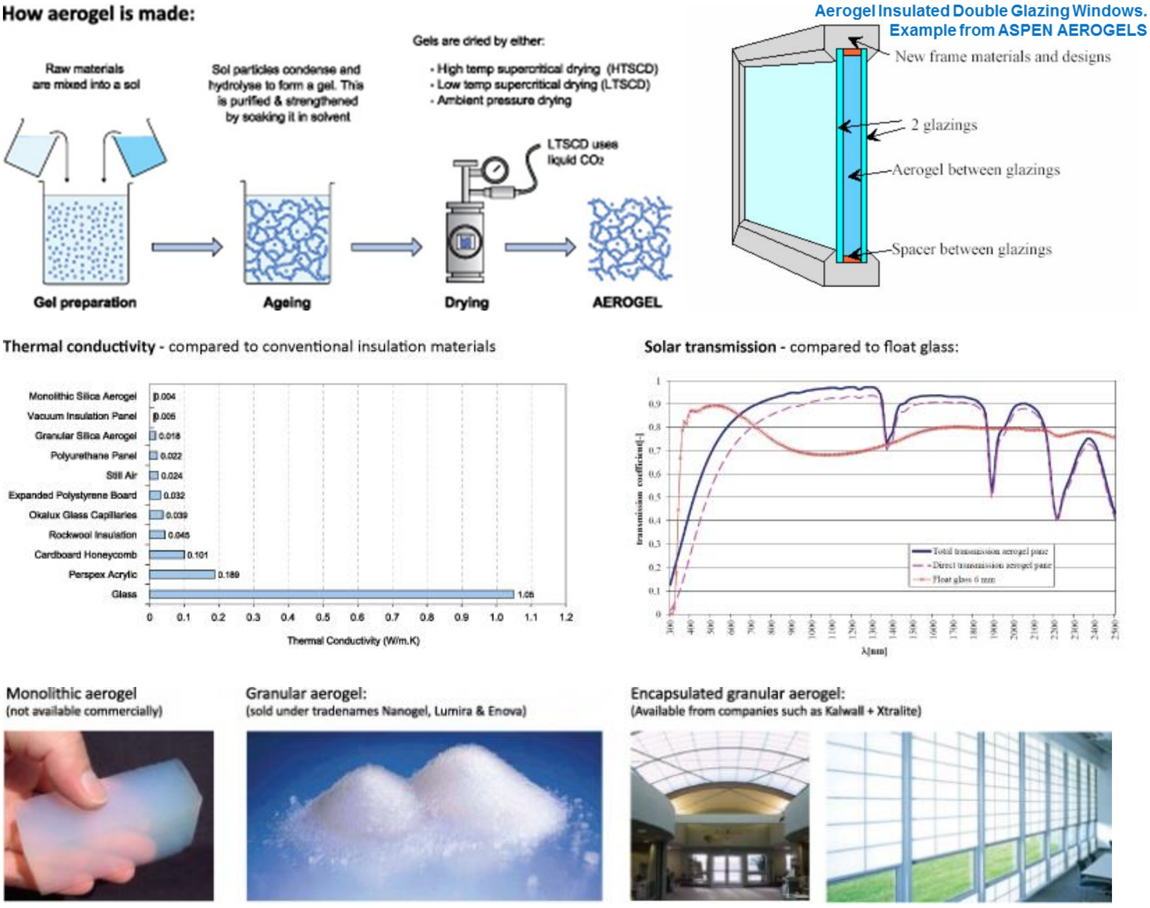
http://www.crbnet.it/file/pubblicazioni/pdf/1554.pdf
http://www.designingbuildings.co.uk
http://www.burohappold.com
http://www.commercialwindows.org
UNI EN ISO 10077

Figure



Source: Buro Happold - http://www.burohappold.com

Parameters

Thermal transmittance coefficient for window element U_W [W/m^{2}K]
Sound reduction index R [dB]
Solar factor G or ý (%)
Capacity of an opaque wall to phase shift and to mitigate the thermal flow over 24 hours
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Commercial products for the building sector include cavity insulation, glazing units and cladding systems containing granular aerogel, and translucent and opaque insulation boards, blankets and tensile roof membranes embedded with aerogel particles. Aerogel might find a future application as a component of a larger window system, such as spacers between insulating panes of glass, or in skylights or glass blocks – of course, depending on if it possible to reduce the high cost of production, the long processing time, the market situation and the difficulty of creating large uniform samples with complete transparency so to achieve sound business conditions. Potential development of retrofitting polycarbonate panels filled with aerogel granules to existing windows to improve their thermal performance.

3.1.5 VENTILATED FAÇADES - OPAQUE: OPAQUE VENTILATED FAÇADES

[1.2.1]

Description

Ventilated Facades consist of bear loading layer, insulation layer, air gap from 4-10 centimeters thick and external, finishing layer. External cladding is dry mounted usually by fixing it to the existing wall by steel structure.

Thick air cavity is located between the cladding and the insulating panels.

The natural air circulation is set up by so called "chimney effect" and helpfully reduces heat gains in the summer and the waste-water forming in the winter by removing it with air flowing through the gap.

Ventilated façade is an effective prevention from vapor condensation inside the wall and ensure high level of comfort inside the building. This solution can considerably reduce the total costs of air conditioning and prevent building from adverse moisture evaporation what can be a reason of mold growth on the internal walls surface. The Forintek Envelope Drying Rate Analysis (EDRA) study showed that "walls with cavities (vented and ventilated) dried faster than comparable panels without cavities (face-sealed). There was a substantial range in the drying rates: as much as three times higher drying rate for comparable walls with a ventilated cavity than for those without. Ventilation (top and bottom vents) resulted in marginally faster drying than vented (bottom vents) walls. The width of cavity was also important, and those walls with cavities of 19 millimeters dried faster than 10 millimeters." (1)

However air flow should be controlled during the winter in order not to overcool the partition.

Market offers a wide range of possibilities. Various kinds of materials for cladding are available and different steel structures can be used as well. Standard insulation layer thickness is from 10-15 centimeters and can be thicker if house is built in Passive House standard.

Thermal properties depend on used materials. Insulation type has the biggest influence on thermal transmittance coefficient. Layers should be design in a way which will ensure that thermal transmittance for the wall do not exceed, required in national standards, value.

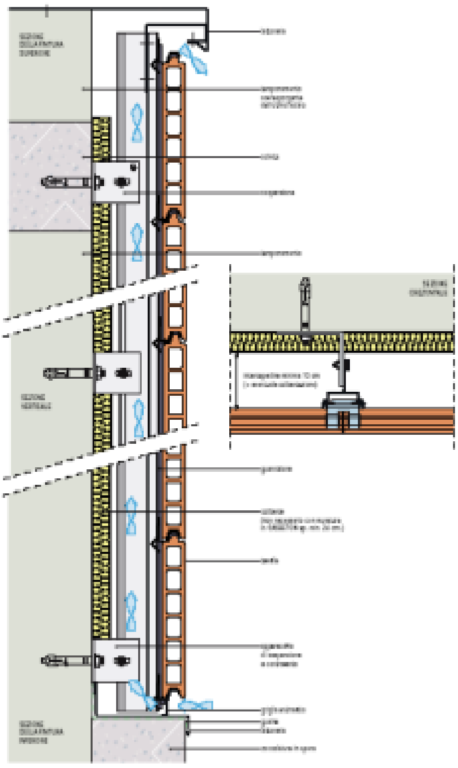
This technology can be applied to all type of Healthcare facilities is well known and used in European Countries.

(1)
Straube, J. and Finch, G. "Ventilated Wall Claddings: Review, Field Performance, and Hygrothermal Modeling", Research Report – 0906, 2009.

References

Brunoro, S., Efficienza energetica delle facciate, Maggioli, Rimini, 2006.
Brunoro, S., "Technical improvement of housing envelopes in Italy" in: Bragança, L., Wetzel, C., Buhagiar, V., Verhoef, L.G.W. (edited by), "COST C16 Improving the quality of existing urban building envelopes. Facades and roofs", Volume 5, IOS Press, Amsterdam, 2007, pp.69-82.
http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/OAA_En_aug10.pdf
http://gundog.lbl.gov/dirpubs/vent_facade.pdf

Figure



Typical ventilated opaque façade section.

http://gundog.lbl.gov/dirpubs/vent_facade.pdf

http://www.wido.com.pl/?act=155&id=168

Parameters

Thermal transmittance coefficient for wall U_w [W/m^{2}K] :0,15 to 0,30 W/m^{2}K
Air gap thickness [mm]: 4-10cm
Periodic Thermal Transmittance YiE < 0,12 W/m^{2}K
Capacity of an opaque wall to phase shift and to mitigate the thermal flow over 24 hours
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Cavity wall can be applied to retrofitted partitions and as well as in new build facilities. There is a lot possibilities of fulfilling cavity with insulation material such as mineral wool or polyurethane foams. Important is to perform well drainage so that moisture can be removed from the cavity. This solutions is popular in Great Britain where climate is humid. Code of practice can be found in British Standards BSI.

3.1.6 **VENTILATED FAÇADES - OPAQUE:**

VENTILATED FAÇADES WITH PCM

[1.2.1]

Description

Ventilated facades with PCM, if well designed, can efficiently reduce the overall HVAC energy consumption of buildings by absorbing part of the solar radiation during winter and preventing overheating during warm periods PCM in combination with the ventilated facade constructive system, can absorb solar radiation and reduce the heating load of the whole building. The Phase Changing Materials (PCM) can be used as an energy storage system especially for light construction walls with low thermal accumulation.
One of possible solution is MICRONAL® phase changing material which can be added to the plaster dry mixture.

This material has properties of phase changing from liquid to solid (solidification - exothermic phase change) and from solid to liquid (melting - endothermic process). Phase change point for this material is set from 21°C to 26°C what makes it applicable in hospital facilities. Heat is storage during the melting phase change and gave back to the room when indoor temperature falls down, under the melting point.

There is a possibility to put plaster layer on inside wall surface so that heat gains are absorbed by the finishing layer and later energy is transferred back to the room while indoor temperature falls under melting point.

PCM layer can help cooling in the summer and stabilize of the indoor temperature in the comfort zone.
According to manufacturer data 30kg of PCM material can storage 1kWh of energy.

Thermal conductivity according to DIN EN 12667 for 20,7 mm thick layer of plaster with PCM is

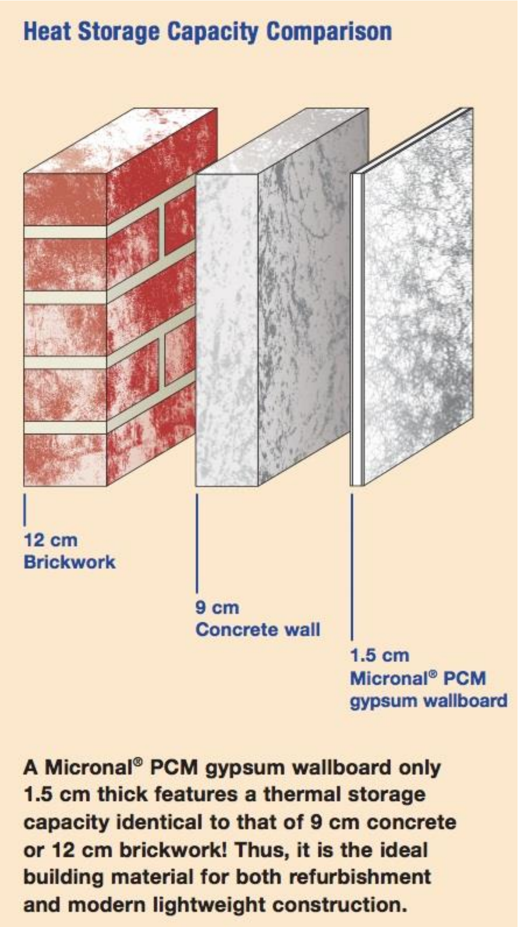
- for average temperature 8,2 °C - 0,472 W/(m*K)
- for average temperature 37,3 °C - 0,484 W/(m*K)

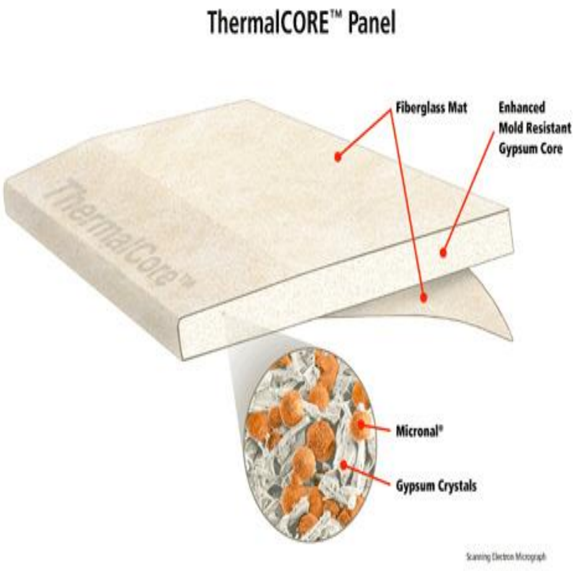
Solution is new on the market, seems to be very promising in case of hospitals usage as it helps to improve thermal comfort. Can be applied while renovation the interior and for new build facilities.

References

http://www.maisonpassive.be/IMG/pdf/Micronal_EN.pdf

Figure





http://www.treehugger.com/green-architecture/why-is-phase-changing-drywall-in-the-news-instead-of-in-the-home-depot.html

Parameters

Thermal transmittance coefficient for wall U_W: up to 0,25 W/m^{2}K
Air gap thickness : 4-10 cm
Melting point for PCM: 21°C- 26°C
Periodic Thermal Transmittance YiE < 0,12 W/m^{2}K
Capacity of an opaque wall to phase shift and to mitigate the thermal flow over 24 hours
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

PCM material is now being introduced to the marked however application of plaster with PCM is the same as in case of standard plaster. The layer of PMC material has to be calculated regarding room function (indoor temperature) and climate zone. Melting point has to be selected according to room inside air temperature. There is a big potential of this solution, and application in the hospital environment can influence reduction of size of the air conditioning system.

3.1.7 VENTILATED FAÇADE - DOUBLE SKIN FAÇADE: DOUBLE SKIN GLASS FAÇADE

[1.2.2]

Description

A double glass façades includes a single glass layer and a double-glazing low emissive layer separated by an air space. This system improves thermal insulation by using passive solar gains.

The external glass layer is fixed on the existing envelope in a limited number of points (generally in correspondence of concrete border beams). Air cavity thickness ranges between 40 to 90 centimeters depending on chosen skeleton solution. Full height double skin glass façade are visible and let daylight into the interior space improving indoor quality. On the other hand, shadings between the glass partitions should be provided in order not to increase heat gains and protect people working inside from sunshine reflection.

Air gap between the glass walls can be naturally or mechanically ventilated, this is curtail for preventing interior space from overheat during the hot summer days and decrease heat losses during the winter. Air, circulating through the gap if colder than outside air will take over heat gains during the sunny or hot days.

Double skin façades can be divided for following groups:

- natural/mechanical ventilation
- open able inner/outer skin
- sealed skin
- single/double glazed

Glazing has big influence on façade performance, it is important that glass layer was double glazed or even triple glazed. Another feature is emissivity which should be low.

PIPES DOUBLE SKIN GLASS FAÇADE
The external façade is fixed to the internal by means of a common frame or punctual anchorages. The cavity is sectioned in vertical or in horizontal: this means that the surface is divided in several ventilations chimney, instead of an unique air cavity area. Air cavity thickness ranges between 20 to 50 centimeters.

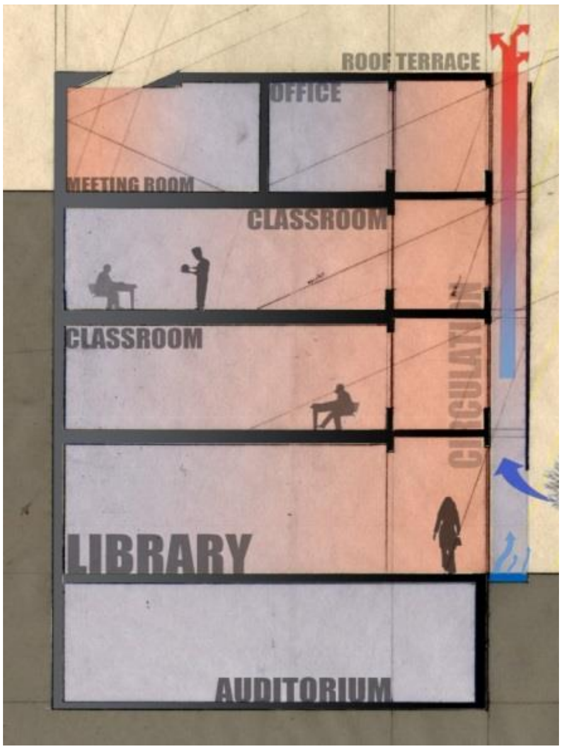
CELLS DOUBLE SKIN GLASS FAÇADE
Double glass façade is formed by the aggregation of modular cells, independent each other, one floor height and generally not more than 30 centimeters thick. Each cell has its inlet airs.

When it comes to usability in hospitals the application of this type of the faced is usually an architect decision and should be conspired regarding climate and function of the space.

References

Brunoro, S. and Rinaldi, A., “Double layer glass façade in the refurbishment and architectural renewal of existing buildings in Italy” in “World Renewable Energy Congress 2011 – Sweden 8-11 May 2011”, Linköping, Sweden, pp.1898–1905.
Brunoro, S., Efficienza energetica delle facciate, Maggioli, Rimini, 2006.
http://www.ep.liu.se/ecp/057/ecp57.pdf
http://www.ecbcs.org/docs/Annex_43_Task34-Double_Skin_Facades_A_Literature_Review.pdf
http://ac.els-cdn.com/S2095263512000817/1-s2.0-S2095263512000817-main.pdf?_tid=d6c18414-5904-11e3-bffe-00000aab0f26&acdnat=1385736487_41ec643ef4068b02e3c753bb2d74164c

Figure



http://redchalksketch.wordpress.com/2011/02/14/sydney%E2%80%99s-first-major-%E2%80%98double-skin%E2%80%99-high-rise/

http://gtbenson.files.wordpress.com/2010/12/short-section-summer-facade-ventilation1.jpg

Parameters

Thermal transmittance coefficient for window element U_w [W/m^{2}K]: *according to chosen window type*
Solar factor G or ý (%): *according to chosen glass type*
Glass emissivity: *according to chosen glass type*

Codes of practice

Double skin facades are popular solution, being preferred by architects due to its esthetical values. Construction technique is well elaborated and there is a lot of companies which perform this kind of external partitions. Technology is present on the market since years. An issue is that double glassed facades are not energy efficient, solar gains are increased during the summer and heat losses are bigger during the winter, another problem light construction of the partition which implements low heat capacity of the wall (heat is not stored in the partition capacity). In the summer if air is not circulated Greenhouse effect can appear.

3.1.8 VENTILATED FAÇADE - HYBRID FAÇADES (WALL/GLASS): HYBRID FAÇADES (WALL/GLASS)

[1.2.3]

Description

A Trombe Wall is an energy efficient solution design to absorb heat from the sun. Used heavy construction enables to store it in the masonry wall to be later radiated to the room during the night period. Wall consist of 10 to 14 centimeters thick masonry (it is good to cover its exterior surface with dark, heat-absorbing material) and a single or double layer of glass or opaque material. Air space is create between the external finishing layer and masonry wall. In this cavity air is being heated up what creates an air flow in the gap. Heat form the Sun is absorb in the masonry wall. It is recommended to use glass as an exterior finishing layer to increase solar gains. High transmission glass maximize solar gains to masonry wall.

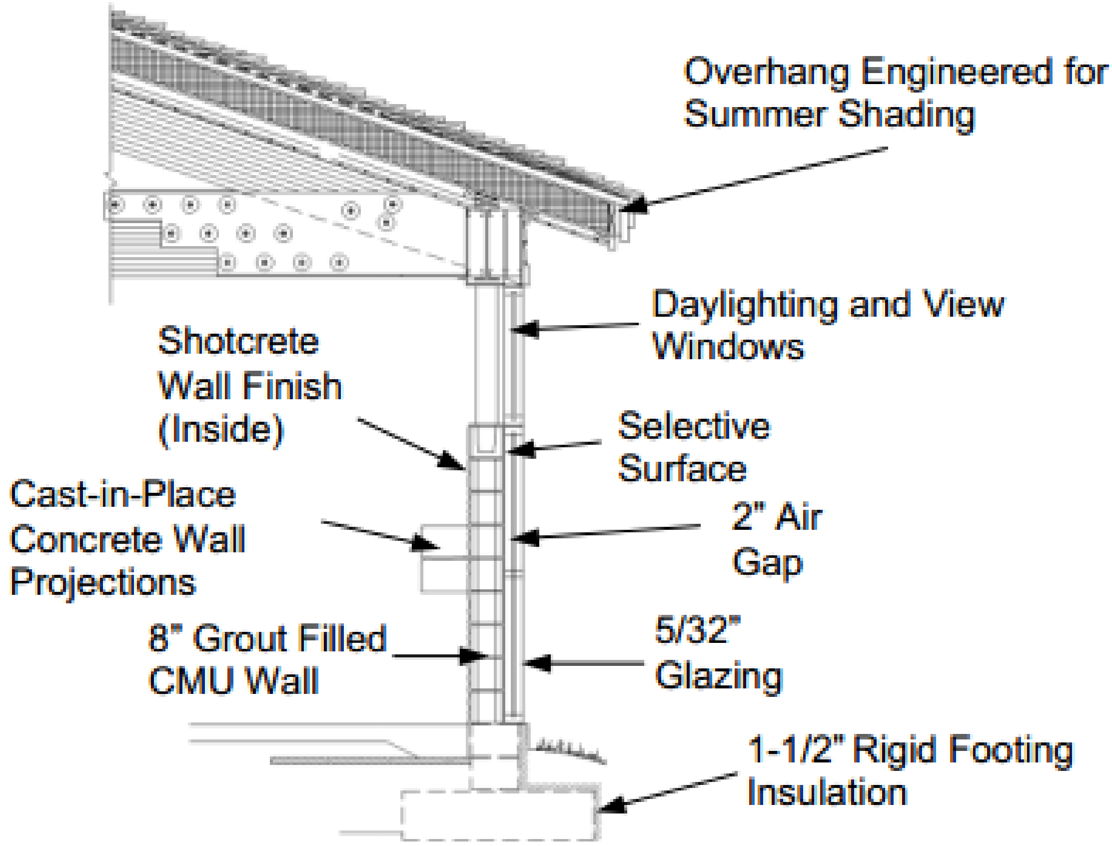
For 20cm Trombe Wall according to P. Torcellini and S. Pless study, were Trombe Wall have been tested in Colorado, USA, 20 centimeters wall, heat will take 8 to 10 hours to reach the interior building. Rooms receive slow heating for many hours after sun sets what influences reduction of energy for heating system.

For Hospital buildings this solution may find usage. Nevertheless it has to be remembered that this solution can be used as a supplement of conventional heating system and amount of storage energy should be taken into account while calculating the total energy demand for heating system so that smaller units could be installed.

References

Torcellini, P. and Pless, S., "Trombe Walls in Low-Energy Buildings: Practical Experiences", World renewable energy congress – VIII and Expo Denver Colorado NREL/CP-550-36277, 2004, pp.1-8.

Figure



http://www.nrel.gov/docs/fy04osti/36277.pdf

Parameters

Thermal transmittance coefficient U_W[W/m^{2}K]
Storage capacity [kJ/kg]

Codes of practice

Trombe wall, being a passive solar system, can be applied in hospital environment (office, communication halls, etc.). The technology is well known and easy in performance. There is a big potential in storage capacity anyway for hospital it has to be designed with special care regarding indoor conditions of the room.

3.1.9 VENTILATED FAÇADE - HYBRID FAÇADES (WALL/GLASS): INTEGRATED FAÇADES HYBRID SYSTEM

[1.2.3]

Description

Hybrid ventilation is a system which integrates natural ventilation with mechanical ventilation connecting benefits from both types of ventilation. This solutions can easily decrease the amount of power needed for electrically driven fans and provides possibility for users to control environment conditions in the room individually. In hospitals where indoor air quality is very important and air change rate have to be kept on required level hybrid systems are recommended.

This kind of ventilation enables to control air quality in the room individually, when people open the windows fresh air is delivered to the room and there is no need for mechanical system to turn on. When the windows are closed and sensors installed in the room detect that concentration of measured value (i.e. CO_2 level) is higher than set value mechanical ventilation is set on and air quality is kept on requested level. System enables to control CO_2 level and air temperature in the room by automatic opening and closing the windows. Can be integrated with shading (both interior and exterior) control what would decrease solar gains.

Mechanical ventilation can be realized by standard system with AHU, ventilation units installed in the façade directly or individually by mechanisms which opens and closed the windows automatically.

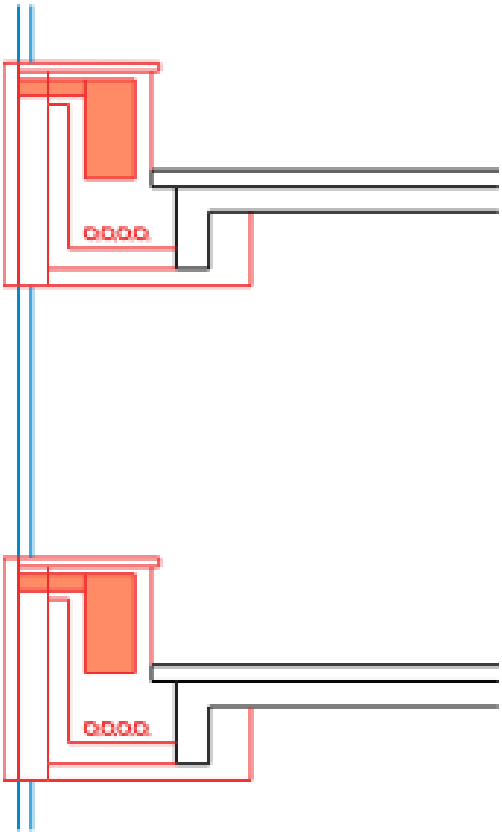
This solution is recommended for hospitals as it is energy efficient can bring energy savings is well designed.

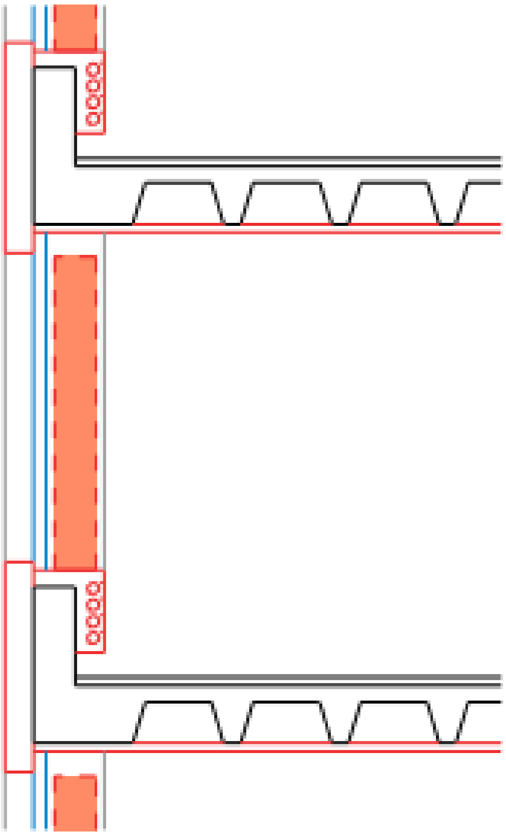
References

Gruner, M. (master candidate), “The Potential of Façade-Integrated Ventilation Systems in Nordic Climate, Advanced decentralised ventilation systems as sustainable alternative to conventional systems, 2012.
http://www.bine.info/fileadmin/content/Publikationen/Projekt-Infos/2010/Projektinfo_15-2010/11.pdf

Figure

New facade integrated hybrid system with automated windows





http://www.bine.info/fileadmin/content/Publikationen/Projekt-Infos/2010/Projektinfo_15-2010/11.pdf
Gruner, M. (master candidate), "The Potential of Façade-Integrated Ventilation Systems in Nordic Climate, Advanced decentralised ventilation systems as sustainable alternative to conventional systems, 2012.

Parameters

Thermal transmittance coefficient for window element U_w [W/m^2K]: *depending on used windows type*
Air change rate [m^3/h]: *depending on room requirements and chosen solution*
Air flow rate [m^3/h]

Codes of practice

System is new on the market. Technology requires good control system which will regulate the mechanical and natural ventilation by opening or closing the windows. Sensors should be suited to measure controlled parameter like CO_2 concentration in the room. It is good solution for keeping good air quality in the rooms especially in the Hotel part of the hospital. This can influence energy savings for mechanical veneration.

3.1.10 **SOLAR SHADINGS - EXTERNAL:**
EXTERNAL SOLAR SHADINGS
[1.3.1]

Description

Exterior shading devices are primarily used to control sunlight penetration to the interior of buildings.

A varied of shading configurations including materials such as aluminum, steel and wood, have been invented and put in the market, such as fixed, manual and automatic movable, internal and external shading device. Moveable louvers are the most effective energy efficiency shadings as they allow the incidence of the rays of sun during the winter (benefit for the overall thermal balance of the building) and protect against summer overheating.

Such shading devices are always attached on the mullion as a separate component of building envelop, but can also be achieved by disposition of the building floors to create overhands. Solar radiation enters the interior of buildings through direct beam penetration, sky diffuse and reflection from other surfaces.

As shown in the top figure following page, exterior shading device decrease direct beam penetration by projecting shadow on the window along the sunlit direction; sky diffuse radiation is also decreased because a portion of sky cannot be “seen” by the window. When designing shading devices for heat avoidance it will be important to also balance desired solar penetration during the heating months. Optimal design of exterior shading device needs to tradeoff the advantage during summer and disadvantage during winter, a simple approach is to consider two extreme solar positions.

Two basic types of exterior shading device are horizontal and vertical, varies combination of those creates many configurations to accommodate different envelop shapes and orientations (see figure: bottom left). Other external solar shading types include e.g. louver systems which are particularly effective in reducing air condition loads: Radiation from the sun is transmitted, absorbed and reflected by the louvers. As a result solar heat gain is prevented from passing into the building. If an operable system is chosen, the adjustable louvers will track the position of the sun increasing the systems shading effectiveness and further reducing glare, see figure bottom right following page.

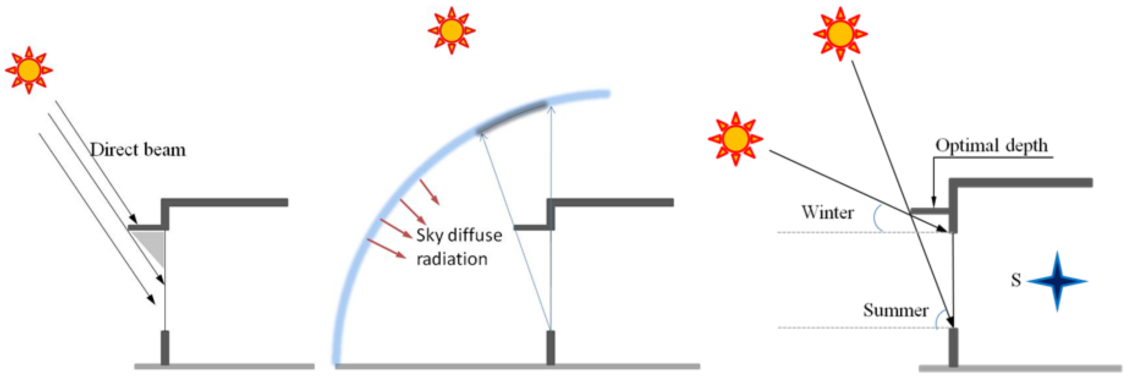
Example of tools used to assist shading design:
- DAYSIM daylighting analysis software that calculates the annual daylight availability in arbitrary buildings based on the RADIANCE backward ray tracer.
- EnergyPlus, IES-VE are comprehensive building simulation tools including shading and daylight analysis.
- Ecotect calculates daylight factors and luminance levels using radiance calculation engine.

This technology is recommended for energy savings (reduction of cooling loads) and it can be easily applied in the healthcare districts, both in the case of new and renovation actions, as in the most cases solar shadings can be independently installed on the external envelope with their proper structure (no need of relevant modifies).

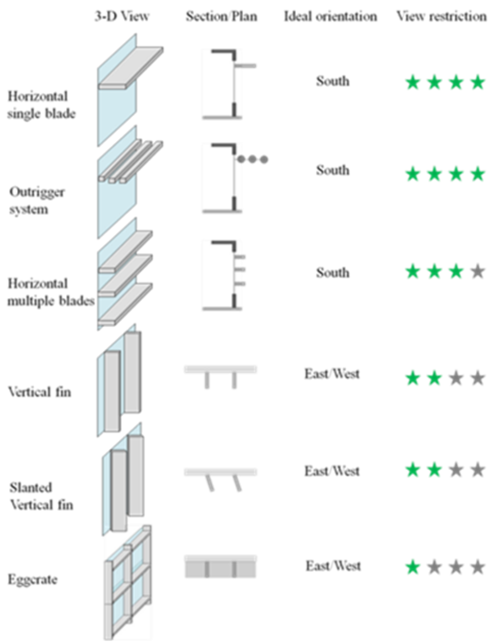
References

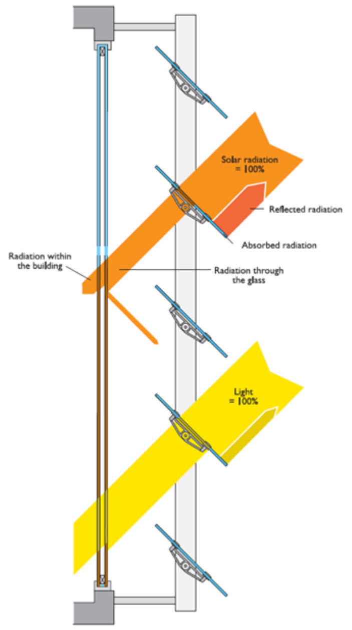
Brunoro, S., “An assessment of energetic efficiency improvement of existing building envelopes in Italy” in “Management of Environmental Quality. An international Journal”, Volume 19, Number 6/2008.
EN 14501:2006
www.bembook.ibpsa.us
http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/OAA_En_aug10.pdf (page 13-14)
http://windows.lbl.gov/daylighting/designguide/section5.pdf

Figure



Above: Origination of solar radiation and simple shading optimal design. Source: BEMBook (IBPSA-USA)
Below left: General types of horizontal and vertical exterior shading device. Source: BEMBook (IBPSA-USA)
Below right: Shading louvers system. Source: MESTEK Architectural





Parameters

Length, width, window orientation, shadow height and width, incidence angle
Solar factor G or ý (%)- "Blinds and shutters - Thermal Comfort and Visual - Performance characteristics and classification," which ranks the performance of a solar shading into 4 classes:
0.35 <g tot <0.50 (class 1 - moderate appraisal)
0.15 <g tot <0.35 (2 class - good judgment)
0.10 <g tot <0.15 (class 3 - very good judgment)
g tot <0.10 (4 class – excellent judgment)
Daylight factor (%)

Codes of practice

The use of shading device is an important aspect of many high-performance building design strategies. The use of shading device could improve building energy performance, prevent glare, increase useful daylight availability and create a sense of security as providing the opportunity for distinctive architectural impact. External shading systems are not maintenance-free as they collect dust and dirt and thus need to be maintained and cleaned.

3.1.11 SOLAR SHADINGS - INTERNAL: INTERNAL CURTAINS AND VENETIAN BLIND

[1.3.2]

Description

The use of **internal textile curtains** is mainly considered to get darkness inside a room, for bedrooms or meeting rooms with overhead projector.
If the outer face of the curtain is filled with metalized and reflective film, a small part of the solar energy can be rejected outside, but the impact on the power of air conditioning is very minor. The darker the fabric is, the lower impact it has on the solar factor of the system (glazing + blind). But on the other side, a dark fabric has a low light transmittance. So according to the use of the curtain, the choice of the fabric will be different.

On the other side, the use of perforated textile awnings, allows to limit glare without needing the use of artificial lighting in the room. In this case, the internal shading curtains have an impact on the energy efficiency of the building.

Venetian blind has horizontal slats, one above another. Venetian blinds are basic slatted blinds made of metal or plastic; wooden slats are sometimes used. They are suspended by strips of cloth called tapes, or by cords, by which all slats in unison can be rotated through nearly 180 degrees. The slats can be rotated such that they overlap with one side facing inward and then in the opposite direction such that they overlap with the other side facing inward. Between those extremes, various degrees of separation may be effected between the slats by varying the rotation. There are also lift cords passing through slots in each slat. When these cords are pulled, the bottom of the blind moves upward causing the lowest slats to press the underside of the next highest slat as the blind is raised. A modern variation of the lift cords combines them with the rotational cords in slots on the two edges of each slat. This avoids the slots otherwise required to allow a slat to rotate despite a lift cord passing through it, thus decreasing the amount of light passing through a closed blind. Slat width can be between 16–120 millimeters, with 25 millimeters being a common width.

The main effect of venetian blinds is to reduce sunlight's glare inside a room. The impact on the energy efficiency (air conditioning) is negligible.

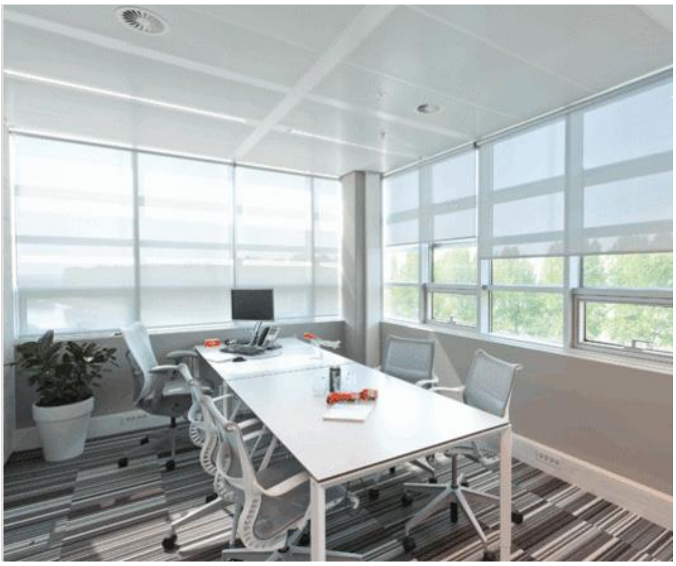
One major problem with venetian blinds, especially in healthcare buildings is their ability to collect dust because of their horizontality. Another problem with venetian blinds is their fragility, so if they are accessible to end-users, operating costs may become quite high.

This technology is suitable for the healthcare districts, to control daylight and improve the visual comfort oin the patient rooms. It is applicable both in the case of new and renovation actions, as in the most cases curtains and venetians can be independently installed on the internal side of the wall with their proper structure (no need of relevant modifies).

References

Griesser (CH) - http://www.griesser.ch
Mermet (FR) - http://www.sunscreen-mermet.com

Figure



Textile awnings (Griesser) and sunscreen (Mermet)

Parameters

Size of windows, width preferably limited to 2,50 m.
Needed functionality: darkness, anti-glare, energy efficiency.
Solar factor G or ý for sunscreen fabrics: 10 to 40% improvement according to the chosen colour of the fabric.
Glare effect, light transmittance reduced to 5 to 18% according to the colour of the fabric.
Daylight factor [%]

Codes of practice

Low impact on energy efficiency.
Main use for darkness and anti-glare purpose.

3.1.12 PASSIVE SOLAR ENERGY SYSTEM - SOLAR GREENHOUSE: SOLAR GREENHOUSE

[1.4.1]

Description

A solar greenhouse is an inside volume closed with a large glazed façade and/or roof, in order to take advantage of the sun light and energy for the building. South is the best orientation for solar greenhouses, and according to the location, glazed roofs are recommended or inadvisable.

The principles of the greenhouse functionality:
During heating season, greenhouses are usually used for three main functions, as following. First of all, it is a buffer between the outside and the building to be heated, protecting the building against the wind, reducing thermal amplitude between the inside and outside (in winter the indoor temperature is always higher than the outside temperature). Then it is a volume valuing solar gain, but also a volume improving the comfort by creating a new pleasant room.
Thus the solar energy received by the greenhouse can be stored by the adjacent walls and radiated back to the inside of the room (namely passive solar greenhouses), but also returned to preheat fresh air through the ventilation system, or returned through the hot air in the greenhouse which is injected into the building to heat with a forced cooling fan which starts when the air temperature of the greenhouse is higher than a setting point or the temperature of the adjacent rooms.
With solar greenhouse, solar gains may be improved up to a factor 3 on the considered façade, and the heating energy needs reduced from 20% to 40%, according to the location of the building.
But, during summer season, solar protection must be designed, to avoid overheating. In addition, warmed air in the greenhouse have to be exhausted from the greenhouse, with natural ventilation openings located at the top of the façade, or exhaust fans. Both can be regulated with the BEMS of the building.

The solar greenhouse principle can be compared to the double skin façade. The main difference is the larger space between the two parts of the façade, which can be used.

This space is often used as large corridor for common circulation, and a multi stores free volume has a better impact on the energy efficiency.

This solution is mostly diffused in the residential buildings. Anyway, if well designed it is recommended for hospitals as it is energy efficient and can bring energy savings (reduce heating system due to the thermal energy storage) and improve natural day lighting in the common areas (atrium, corridors, staircases).

References

Bioclimatic architecture: Ademe (FR) - http://www2.ademe.fr/servlet/getDoc?id=11433&m=3&cid=96

Figure

Paris – Pompidou Hospital (FR) – Main Lobby

Metz Hospital (FR) – Main Lobby

Parameters

Building south orientated
Check solar mask
Thermal Transmittance coefficient U_W [W/m^2K]
Solar factor G or ý [%]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Checklist for design phase:
- not forget the cleaning system,
- solar blinds and ventilation strategy,
- energy gain versus façade over cost,
- huge need of energy dynamic simulations,
- available space area in the program for hall/common circulations.

3.1.13 PASSIVE SOLAR ENERGY SYSTEM - SOLAR GREENHOUSE: SOLAR WALL ®

[1.4.1]

Description

SolarWall® system is a Trademark technology, which consists of pre-heating the ventilation or process air between the façade wall of a building and the external envelope. The SolarWall technology generates significant heat savings. It can be described as “backing up to a free gas pump”.

The system is an aluminum or steel cladding steel, dark and provided with tiny perforations to let the air through. The heated air passing through the cladding made hot by the sun is blown into the building through the ventilation system. On a sunny day the air may be heated from 16 to 38 °C above ambient temperature. Then the solar warmed air is distributed throughout the building via the conventional ventilation system or dedicated fans or ducting.

SolarWall® systems require no maintenance, generate huge amounts of thermal energy without any GHG emission. The technology has been used globally for over 20+ years, mainly on Manufacturing and Industrial buildings, reducing from 20 to 50% of the heating consumption.

The SolarWall® concept has been upgraded with a new version, called 2-Stage, configured to deliver a higher temperature rise, up to 20-47°C above ambient temperature. It operates on the same premise as the original technology in that outside air is heated and drawn into an air cavity via tiny micro-perforations in the SolarWall collector. The air is then heated a second time as it passes through a second stage, behind a glazing and then through the second stage of the SolarWall collector.

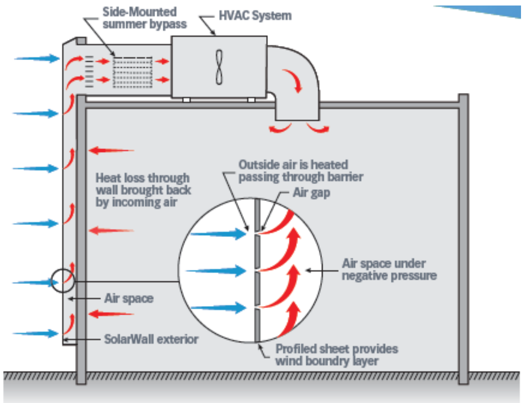
This solution is suitable for Hospital buildings, both in new buildings than in renovation actions, as it produces substantial costs savings. It can be used as a supplement of conventional heating system and amount of storage energy should be taken into account while calculating the total energy demand for heating system so that smaller units could be installed.

References

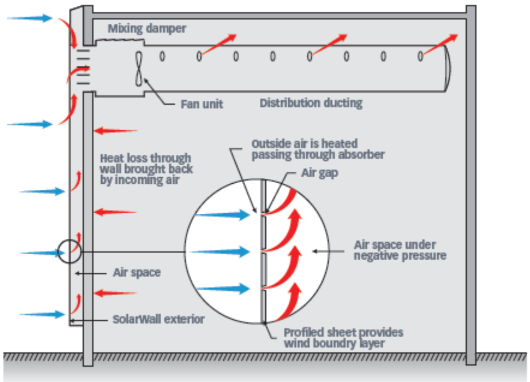
Conserval Engineering Inc. - 200 Wildcat Road - Toronto ON M3J 2N5 - Canada
SolarWall Europe - 66 Avenue des Champs Elysées - 75008 Paris – France
http://solarwall.com/en/home.php
http://solarwall.com/posts/grand-opening-of-world-s-largest-hospital-solarwallr-system91.php

Figure

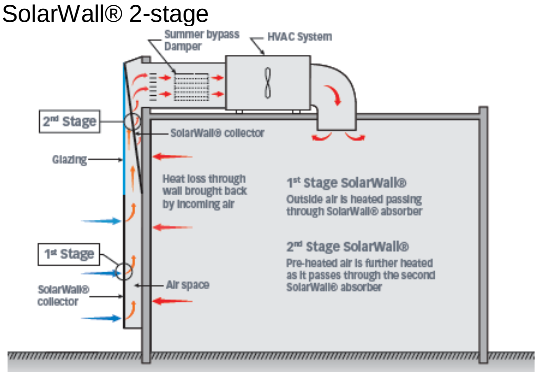
Classic SolarWall®



SolarWall® with dedicated ventilation



SolarWall® 2-stage



Parameters

Opaque façade (without windows)
South orientated façade
Height of usable façade
Check solar mask
Air change rate [m^3/h]
Air flow rate [m^3/h]

Codes of practice

SolarWall® capacity around 600 kWh/m² of collector.
South orientation is mandatory to obtain the best energy efficiency.
Either compatible with new building or retrofitting of envelope.
ROI roughly below ten years, depending on the price of energy. This can be less if associated to a façade renovation for example.

3.1.14 PASSIVE SOLAR ENERGY SYSTEM - SOLAR GREENHOUSE: SOLAR CHIMNEY OR VENTILATION CHIMNEY

[1.4.1]

Description

Solar or ventilation chimney
Not the stand alone solar chimney with power generator for energy generation, but building-related to provide ventilation.

Solar chimney
The Solar Chimney is using the sun as a driving force for the extraction of ventilation air. Ventilation air is exhausted through a Solar Chimney. The Venturi-ejector in the roof compensates the pressure drop of the heat exchanger.
Even larger is the importance of the Solar Chimney as an absorber of solar energy which can be used for heating buildings, thus contributing significantly to the energy neutrality of buildings. In the Solar Chimney also solar energy is harvested, that is used to heat the building in the heating season. With the aid of a heat exchanger in the top of the solar chimney, the solar heat could be transferred to the water and stored in for example the ATES.

Ventilation Chimney
Core of a natural climate system is a ventilation chimney, a gravity-activated heat exchanger for conditioning ventilation air, designed as an architectural shaft. In the ventilation chimney, ventilation air is cooled, heated, dried or humidified as necessary. In summer and winter water is sprayed from the top at a temperature of approximately 13°C. By momentum transfer from the droplets to the air, the downward movement of air from the pressure chamber is reinforced. This aerodynamic pressure, together with the hydraulic pressure and the downward thermal draft, makes fans superfluous. The required cooling is extracted from the soil, and heat is directly or indirectly supplied by the solar chimney. Because of the high heat transfer coefficient of the falling water droplets and the large active surface of the millions of droplets in the spray, the Ventilation Chimney can operate at very small temperature differences between air and water.

Points of attention/design for the best result
Combine both solar chimney and ventilation chimney in the building for maximum efficiency.
The system works only by enough high buildings, at least three floors.
These system could only designed by CFD-software.

Usability in healthcare districts
This system is only suitable in low qualified indoor air, like offices and not for hot floor.

Key properties
Solar Chimney
The thermal efficiency of a Solar Chimney, defined as the ratio of the heat absorbed by the airflow and the incident solar radiation is mainly determined by the properties of the glass wall. A good choice can yield an average annual efficiency of around 60%.
Ventilation Chimney
The Coefficient of Performance (COP) of a Ventilation Chimney depends on the water/air ratio and the height of the building and may vary from 50 to 15 in buildings of 4 to 20 stories.

References

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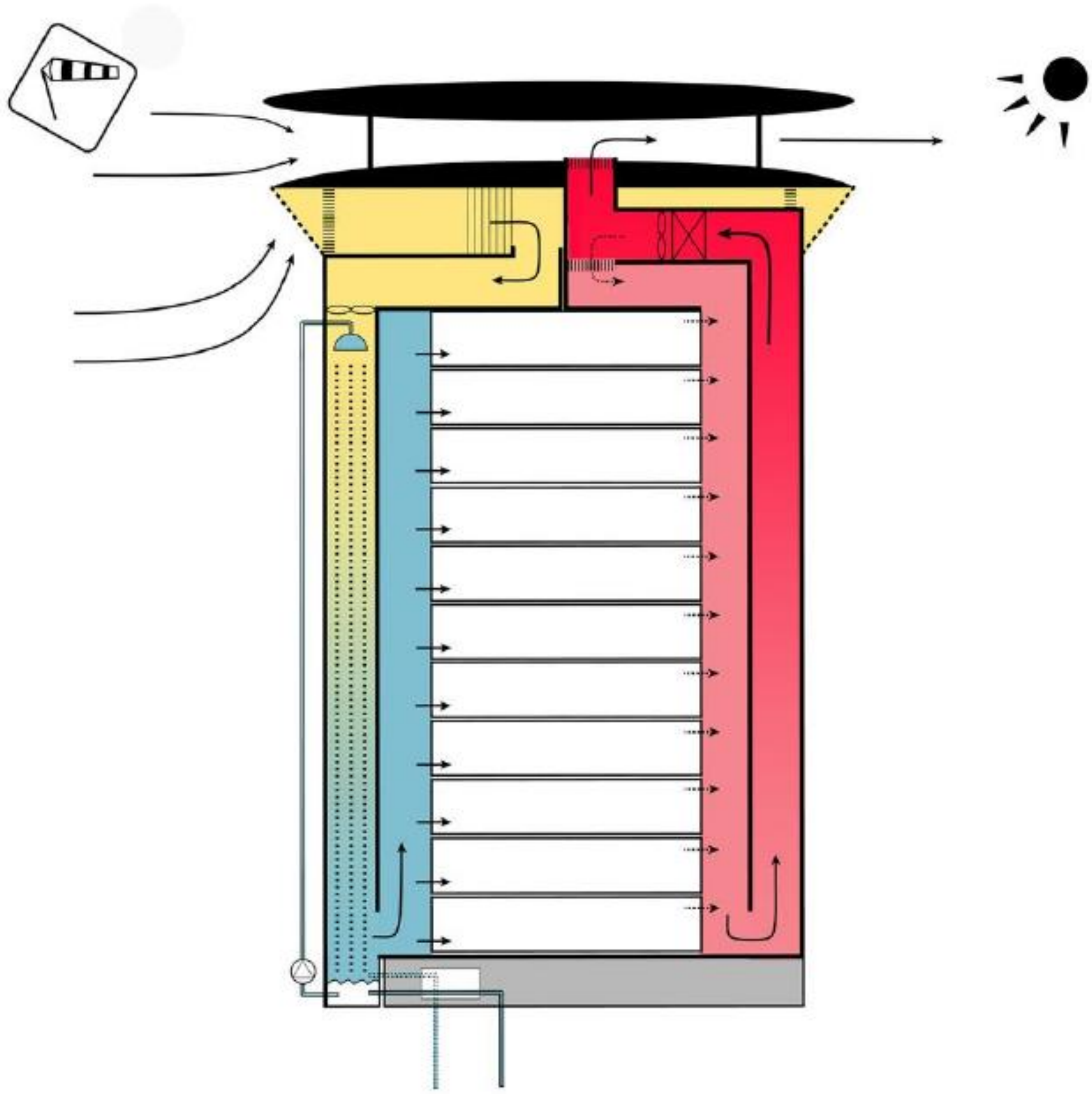
http://bronconsult.org/wp-content/uploads/2013/10/A-venturi-shaped-roof-for-wind-induced-natural-ventilation-of-buildings.pdf

Figure



Scheme of solar chimney (right) and ventilation chimney (left) in a building.
[Bronsema, B. (PhD Thesis), "Earth, wind and fire, natural airconditioning", 2013]

Parameters

Air change rate [m³/h]
Required space (diameter of chimney) [m³]
Heat/cold production [kwh/y]
Thermal efficiency [%]
COP [-]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

The Solar chimney and ventilation chimney could be used separately, but the efficiency is increased by combining the two functions. It is the architect who, in the conceptual design phase, lays the foundation of a successful architectural integration of these chimney's in a building.

3.1.15 PASSIVE SOLAR ENERGY SYSTEM - SOLAR GREENHOUSE: GREEN WALL

[1.4.1]

Description

Brief description of the design criteria A ‘Green Wall’, also commonly referred to as a ‘Vertical Garden’, is a descriptive term that is used to refer to all forms of vegetated wall surfaces. Green wall technologies may be divided into two major categories: Green Facades and Living Walls. Only the Green Façade technique is here described: technological typologies identified as more advanced (Living Walls and Murs Végétal) are, actually, energy-intensive and poorly sustainable, whereas Green Facades are most often sustainable from a constructive and maintenance point of view, thanks to their simplicity and little working energy. Green facades are a type of green wall system in which climbing plants or cascading groundcovers are trained to cover specially designed supporting structures. Rooted at the base of these structures, in the ground, in intermediate planters or even on rooftops, the plants typically take 3-5 years before achieving full coverage. Green facades can be anchored to existing walls or built as freestanding structures, such as fences or columns. Technological innovations in Europe and North America have resulted in the development of new trellises, rigid panels and cable systems to support vines, while keeping them away from walls and other building surfaces. Two green façade systems that are frequently used are Modular Trellis Panel and Cable and Wire-Rope Net systems.

How the solution works The building block of the Modular Trellis Panel System is a rigid, light weight, three-dimensional panel made from a powder coated galvanized and welded steel wire that supports plants with both a face grid and a panel depth. This system is designed to hold a green facade off the wall surface so that plant materials do not attach to the building, provides a “captive” growing environment for the plant with multiple supports for the tendrils, and helps to maintain the integrity of a building membrane. Panels can be stacked and joined to cover large areas, or formed to create shapes and curves, are made from recycled content steel and are recyclable. Because the panels are rigid, they can span between structures and can also be used for freestanding green walls. The Cable and Wire-Rope Net Systems use either cables and/or a wire-net. Cables are employed on green facades that are designed to support faster growing climbing plants with denser foliage. Wire-nets are often used to support slower growing plants that need the added support these systems provide at closer intervals. They are more flexible and provide a greater degree of design applications than cables. Both systems use high tensile steel cables, anchors and supplementary equipment. Various sizes and patterns can be accommodated as flexible vertical and horizontal wire-ropes are connected through cross clamps.

Points of attention/design for the best result When considering a green wall design, it is important to carefully select plant species that will thrive under the given site conditions. In colder climates, for example, there are species of vines that maintain their foliage even during the winter months. Green wall design for a temperate climate zone should consider the changes of the seasons and how different plants will display their adaptation to this cycle. Plants selected may have to accommodate freezing temperatures during winter, and also show full blossom in the heat of summer. Plant choices might include both fast and slow growing species and require a combination of structures like a wire-net system in combination with a cable system. The wire-net system can support the slower growing greenery while the cables provide structure for faster developing vines.

Usability in healthcare districts Well applicable in health care districts, both in new buildings and in refurbishment interventions, preferably on opaque walls. In addition to the reduction of working energy consumptions and the improvement of indoor thermo-hygrometric conditions (important for any building typologies), the quality perception that the human being identifies with plants is a crucial quality for the comfort of patients and doctors in healthcare facilities.

Key properties The benefits accrued by a green wall depend on design factors that include leaf area, leaf density, site conditions and the scale of the project. Public benefits are the reduction of urban heat island effect, the improvement of exterior air quality and the aesthetic improvement as well. Private benefits are the building structure protection, the improvement of indoor air quality, the noise reduction and, most of all, the improvement of the energy efficiency. This is obtained thanks to the improvement of thermal insulation capacity through external temperature regulation. The extent of the savings depends on various factors such as climate, distance from sides of buildings, building envelope type, and density of plant coverage. This can impact both the cooling and heating.

References

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Green Roofs for Health Cities Introduction to Green Walls – Technology, Benefits and Design, 2008.
Blank, P., “Le mur vegetal”, Michel Lafone, 2011

Figure

Modular Trellis Panel

Cable and Wire-Rope Net systems
Source: http://www.intechopen.com

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient [W/m^{2}K]
Periodic Thermal Transmittance
Insulation material density [kg/m^3]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Sound absorbing [dB]
Water management
Volume [V]
Azimuth angle [% or degrees]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Attachment to building envelope – how the system will be secured to the building or freestanding structure.
Calculation of structural loads for larger systems, resulting from loads such as snow, plants, and wind.
Plant selection for wind and light exposure, hardiness zones, and amenity context.
Realistic expectations related to plant aesthetics and growth.
Specific well designed irrigation according to the green layer: water provided manually or with an automated and programmable system.
Plant maintenance and/or long term maintenance plan to secure the health of these living systems, including proper soil and irrigation considerations.
Check with manufacturers who may have registered or specially trained installers that will be able to complete the project successfully.
Appropriate plant selection for the geographic region, correct plant spacing for desired coverage, and release from the temporary support structure used by the nursery.

3.1.16 ACTIVE SOLAR ENERGY SYSTEM - PHOTOVOLTAIC PANELS: PHOTOVOLTAIC PANELS

[1.5.1]

Description

The solar PV panel is a semiconductor device that converts radiation energy to electrical energy through the photoelectric effect. When light strikes the PV material, it "rips off" electrons from the atoms they were bound to, leaving positive ions behind and allowing some electrons to flow, producing both an electrical current and a voltage drop and therefore electrical power

Most commercial solar panels are made of polycrystalline silicon. As of 2008, only twelve factories in the world produced this material, and more than half the silicon of sufficiently high grade was going to the production of solar cells. All the panels that we have to deal with are polycrystalline silicon; the grain boundaries between distinct silicon crystals are clearly visible. Commercial photovoltaic are increasingly made using semiconductor materials deposited in thin films rather than grown as crystals, of which the most common are cadmium telluride / cadmium sulphide and amorphous silicon. Thin film cells are lower in efficiency, but the hope is that the manufacturing can become cheaper than for crystalline silicon, making them the more economical choice. Thin films are also less subject to breakage.

A photovoltaic system that feeds all the power it generates into the grid essentially consists of the following components:

- PV cells in panels;
- Support structure;
- Inverter;
- Monitoring system;
- Feed-in meter;
- Grid connection

See also Solar collectors for integrated PV thermal system

Points of attention/design for the best result
The system efficiency depends most on location and orientation on earth. Preferably as close as possible to the equator. And of course no shadow. The payback time depends on the feed-in meter configuration and national laws

Usability in healthcare districts
Well applicable in health care districts. Health care districts have a large electricity demand and PV can help to fulfil part of this demand. The larger the façade area the more energy can be generated.

References

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http://www.law.stanford.edu/sites/default/files/publication/359530/doc/slspublic/prospects_for_cost_competitive_solar_pv_power.pdf
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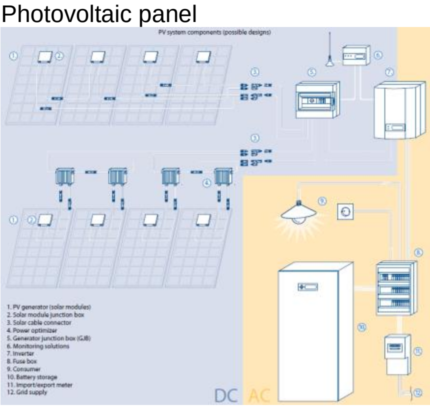
http://re.jrc.ec.europa.eu/pvgis/

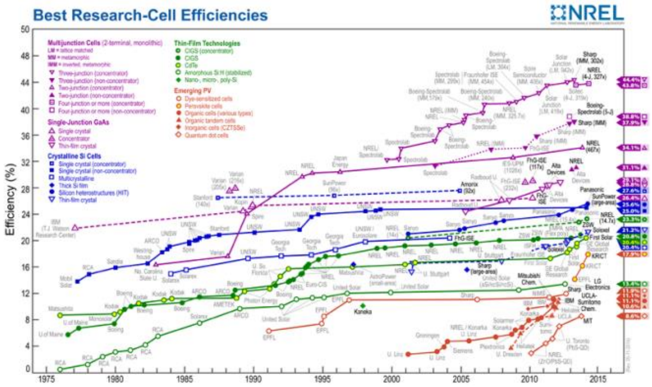
Figure

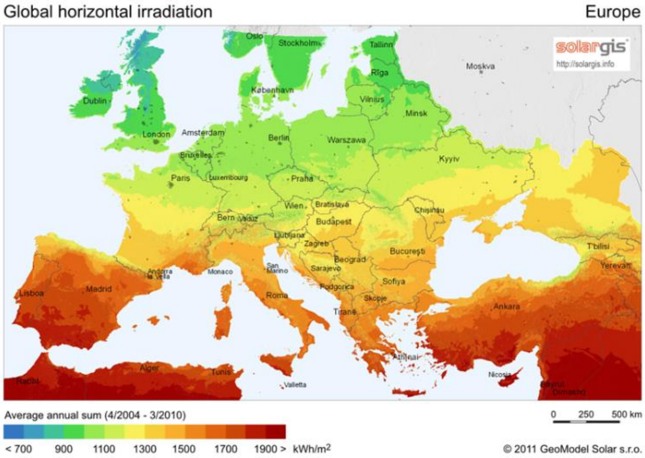
Photovoltaic panel



How photovoltaic work

Example Photovoltaic panel





Parameters

Location on earth
Orientation and angle
(Partial) shading
Ratio of Panel area to roof area [m²/m²]
PV efficiency [% or kWh/y/m²]
Efficiency [η_{TOT}]

Codes of practice

For aesthetic design and best construction use panels integrated into the roof.
Be aware of high voltage.

3.1.17 **ACTIVE SOLAR ENERGY SYSTEM - SOLAR COLLECTORS: SOLAR COLLECTORS**

[1.5.2]

Description

Solar energy collectors are a special kind of heat exchanger that transforms solar radiation energy to internal energy of the transport medium. The major component of any solar thermal system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days.

There are two types of solar collectors: non-concentrating or stationary and concentrating. A non-concentrating collector has the same area for intercepting and for absorbing solar radiation, whereas a sun-tracking concentrating solar collector usually has concave reflecting surfaces to intercept and focus the sun's beam radiation to smaller receiving area, thereby increasing the radiation flux. A large number of solar collectors are available in the market. Solar energy collectors are distinguished by their motion, i.e. stationary, single axis tracking and two-axes tracking, and the operating temperature.

The stationary solar collectors are permanently fixed in position and do not track the sun. There are three types of collectors that fall in this category: 1. Flat plate collectors (FPC); 2. Stationary compound parabolic collectors (CPC); 3. Evacuated tube collectors (ETC).

The other category is sun tracking concentrating collectors.

Temperatures far above those attainable by FPC can be reached if a large amount of solar radiation is concentrated on a relatively small collection area. This is done by interposing an optical device between the source of radiation and the energy-absorbing surface. Concentrating collectors exhibit certain advantages as compared with the conventional flat-plate type.

The collectors falling in this category are: 1. Parabolic through collector; 2. Linear Fresnel reflector (LFR); 3. Parabolic dish; 4. Central receiver.

Typical applications show the extent of the applicability. These include water heating, space heating and cooling, refrigeration, industrial process heat, thermal power systems, solar furnaces and chemistry applications. It should be noted that the applications of solar energy collectors are not limited to the above areas. Depending on the applicability, collector efficiency curves could be used for preliminary collector selection.

PV thermal panels absorb up to 80% of the solar irradiation. However, only 5–20% of the incoming energy is converted into electricity, depending on the PV cell technology used. The remaining energy is converted into heat. Owing to this effect, on sunny days PV laminates can reach temperatures as high as 35°C above ambient temperature. In PV thermal (PVT) panels this heat is extracted from the PV panel and made available for use in a building, e.g., for tap water heating and space heating. In this way, the useful energy output of a PV panel is strongly enhanced.

There are several reasons for the combination of PV and thermal into one device: larger overall conversion efficiency, reduced energy payback time, reduced economic payback time and improved aesthetics.

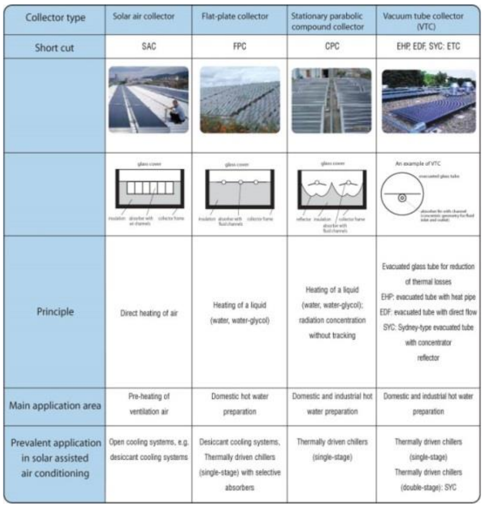
1. System calculations have been carried out, indicating that for a domestic hot water system with 1 m² of solar thermal collector and 1 m² of PV would together yield 520 kWh thermal and 72 kWh electrical energy annually, whereas 2 m² of PV thermal collector would yield 700 kWh thermal and 132 kWh electrical.
2. Energy payback calculations have been carried out indicating that the energy payback time of a PV thermal system under the Italian climate would be 2 yr, compared with 43 yr for a solar thermal collector and 34 yr for a PV system
3. With respect to aesthetics, architects and consumers prefer a uniform PVT roof area to a roof area partially covered with thermal collectors and partially with PV laminates.

The technology is applicable in healthcare districts: between the systems that use renewable energy, solar thermal collectors are the ones with the highest efficiency that require the less area for installation. With only 30 square meters of traditional flat collectors (south facing, 30° to the horizontal plane) it is possible to meet the hot water production of a five-storey building (about ten dwellings). Anyway the installation on the roof is more suitable due to the darkness of the panels (less suitable for façades). Anyway, the storage tank for hot water can be very large and needs to be carefully evaluated from the very first stages of the project.

References

http://www.mate.tue.nl/mate/pdfs/4555.pdf - http://re.jrc.ec.europa.eu/pvgis/

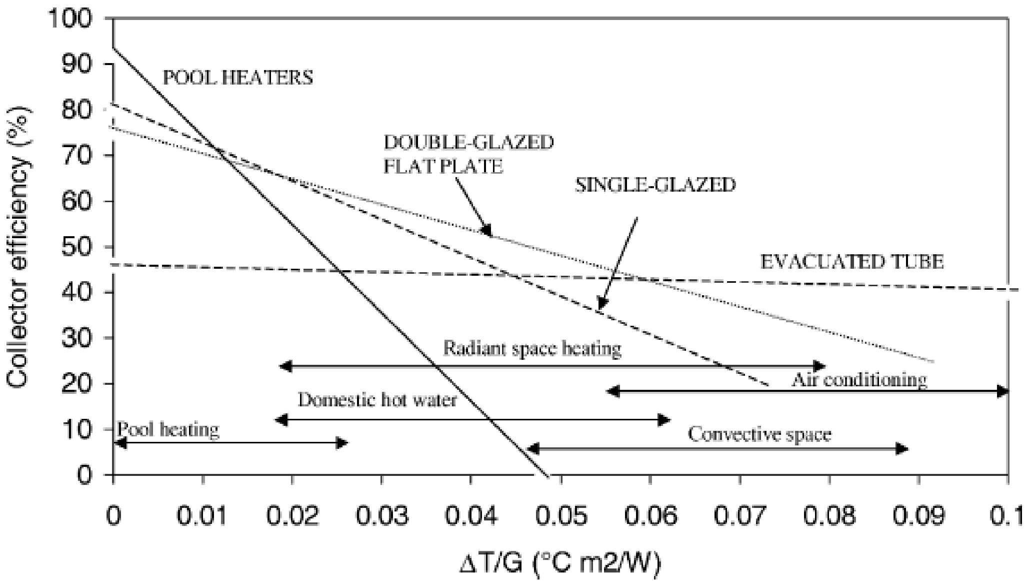
Figure



Collector type	Solar air collector	Flat-plate collector	Stationary parabolic compound collector	Vacuum tube collector (VTC)
Short cut	SAC	FPC	CPC	EHP, EDF, SYC: ETC
Principle	Direct heating of air	Heating of a liquid (water, water-glycol)	Heating of a liquid (water, water-glycol); radiation concentration without tracking	Evacuated glass tube for reduction of thermal losses EHP: evacuated tube with heat pipe EDF: evacuated tube with direct flow SYC: Sydney-type evacuated tube with concentrator reflector
Main application area	Pre-heating of ventilation air	Domestic hot water preparation	Domestic and industrial hot water preparation	Domestic and industrial hot water preparation
Prevalent application in solar assisted air conditioning	Open cooling systems, e.g. desiccant cooling systems	Desiccant cooling systems, Thermally driven chillers (single-stage) with selective absorbers	Thermally driven chillers (single-stage)	Thermally driven chillers (single-stage) Thermally driven chillers (double-stage): SYC

Solar thermal collectors

Sample Hybrid photovoltaic and thermal (PVT) system



Collector efficiencies of various liquid collectors

Parameters

Location on earth
Orientation and angle
(Partial) shading
Transparency and color
Efficiency [% or kWh/m²/year]
Ratio of Panel area to roof area [m²/m²]
Heat production [MJ/m²/y]
Efficiency [η_{TOT}]

Codes of practice

For aesthetic design and best construction use panels integrated into glass.
Be aware of high temperature.
Design the optimum ratio of collector and storage.

3.1.18 ACTIVE SOLAR ENERGY SYSTEM - MIXED SYSTEMS: TRANSPARENT PV OVERHANGS

[1.5.3]

Description

The organic PV cell or semitransparent PV panel is similar to the photovoltaic system. The system that feeds all the power it generates into the grid essentially consists of the following components: PV cells in panels, support structure, inverter, monitoring system, feed-in meter, grid connection.
Only the PV-cells and support structure is different.
Organic (or amorphous) PV cells is a promising new technology to harvest electricity from sunlight. Organic solar cells can be colored, transparent, and applied to flexible, light films. They generate electricity even under cloudy skies.
By the usage of a semi-transparent amorphous (or organic) silicon and transparent conductive oxide (TCO) films as two electrodes of the cells in the solar module, a PV module is characterized as semi-transparent. Unlike other see-through thin-film PV products, which are made with opaque electrodes (e.g. silver) and opaque active layers (e.g. microcrystalline silicon, CdTe, or CIGS films) which are partially removed by laser drilling. Semi-transparent PV modules have the following advantages:

- The mandarin color and semi-transparent characteristic provide wonderful visual comfort.
- PV module absorbs 99.9% UV light and can perfectly block harmful UV light.
- Without active area loss by laser drilling, organic PV module feature higher power conversion efficiency than other see-through thin-film PV modules.
- The high transmittance of red light is favorable to plant growth and crop cultivation.
- The high light transmission in the infra-red region creates a greenhouse effect favorable to the cultivation of particular plants.
- Among all thin-film PV technologies, silicon thin-film PV is the only one technology containing without heavy metals.
- No opaque back electrode, thus extra power is generated for receiving light from both front and rear sides.

Regarding the **PV overhang** and the integration of shading devices into building façades: what's the role of a solar shading? Improvement of internal environment, greater comfort for occupants and reduction of heat gains and cooling load.
There are several types of solar shading, both vertical and horizontal or combined. Like overhangs, (venetian) blinds or screens. Both active or passive.
Shading devices are very good elements in buildings for installing PV panels because PV panels can be designed for the optimum angle. PV cells can be integrated into the canopy shading system either horizontal or vertical. PV cells vary in size, shape, pattern, and color. Two types of PV glazing systems are: semi-transparent and opaque system. Not only south but also east and west facade can be covered with PV and still produce large amount of electricity.
PV cells can be integrated into windows, providing a semi-transparent facade. These kinds of Building Integrated PV (BIPV) can be also used as shading. Glass PV laminates, replacing conventional cladding material, are basically the same as tinted glass. The PV glazing is especially suitable for skylights or clerestories, since they are not designed for view to the outside.

Points of attention/design for the best result

The system efficiency depends most on location and orientation on earth. Preferably as close as possible to the equator. And of course no shadow. The payback time depends on the feed-in meter configuration and national laws.
Important for the design stage of PV overhang is the sufficient access to daylight and risk over-heating.

Usability in healthcare districts

Well applicable in health care districts. Health care districts have a large electricity demand and PV can help to fulfil part of this demand. The larger the PV area the more energy can be generated. Anyway, the cost of the semi-transparent panels is higher in comparison to the traditional PV panels, this limits the diffusion of the technology.

References

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Figure

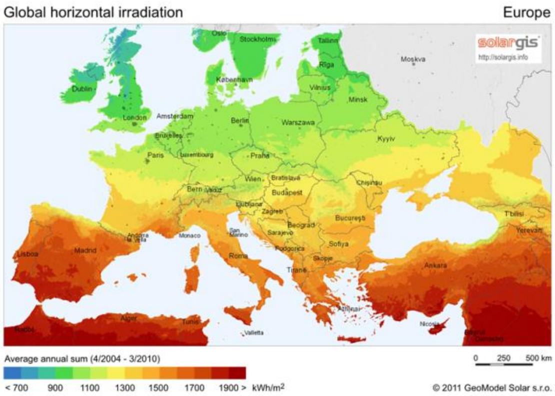
Example of overhang glass with integrated PV panels.

Example of horizontal tracking louver

Sample organic photovoltaic cells

Type	Name	picture	Criteria for Glare protection	View outside	Light guiding into the room
Overhang/ horizontal Canopy	Horizontal Canopy single		Depends	Yes	Yes
	Horizontal canopy double (light shelf)		Depends	Yes	Yes
Horizontal louvers	Tracking louver		Yes	Depends	Depends
	Horizontal shading		Yes	Depends	Depends
	Horizontal blind		Yes	Depends	Depends
Vertical louvers	Vertical louvers		Yes	Depends	Depends
	Sliding		Depends	Depends	Depends
	Roller blind		Yes	Depends	Depends
PV printed on glass			Yes	Depends	Depends

Typology's of shading devices



Parameters

Location on earth
Orientation and angle
(Partial) shading
Ratio of Panel area to glass area [m²/m²]
Transparency and color
PV efficiency [% or kWh/y/m²]
Efficiency [η_{TOT}]

Codes of practice

This description is only about the PV overhang.
For aesthetic design and best construction use panels integrated into glass.
Be aware of high voltage and vandalism.
The overhangs should design in an early design stage, because they're decreasing the energy consumption for heating.
The PV glazing is especially suitable for skylights or clerestories, since they are not designed for view to the outside.

3.1.19 HIGH EFFICIENCY WINDOWS: DOUBLE-TRIPLE GLAZING WITH SOLAR FILMS

[1.6.1]

Description

Coatings on glass surfaces to prevent a heat load by the sun. UPVC Double glazed windows will improve the heat retention of the building, whilst keeping exterior noise out. Heat retention will reduce energy costs and lower the carbon footprint. Tinted glass or addition of solar film will limit the effects of solar gain, and reduce the need for use of blinds / curtains. There a large range of design options, UPVC frames are long lasting, durable and can be recycled.

By using solar film we heat gains can be significantly reduced, about 52% of energy is reflected by the window glassing so that energy transmitted is reduced to 11% of total ray of sun light.

Window film can improve energy efficiency of a single paned window to perform like a double paned window. The same happens after adding solar film to double window, it has the same efficiency as a triple paned window.

Window film can block up to 99% of UV rays and a significant amount of the heat that would otherwise be allowed into the building through its windows.

Solar window film usually help to save 5-10% of energy, what can influence on the maintenance cost of the facility especially when amount of glassed partition is significant.

This technology is recommended in Healthcare districts as it helps to improve energy efficiency and can influence the energy savings and improve indoor and visual comfort.

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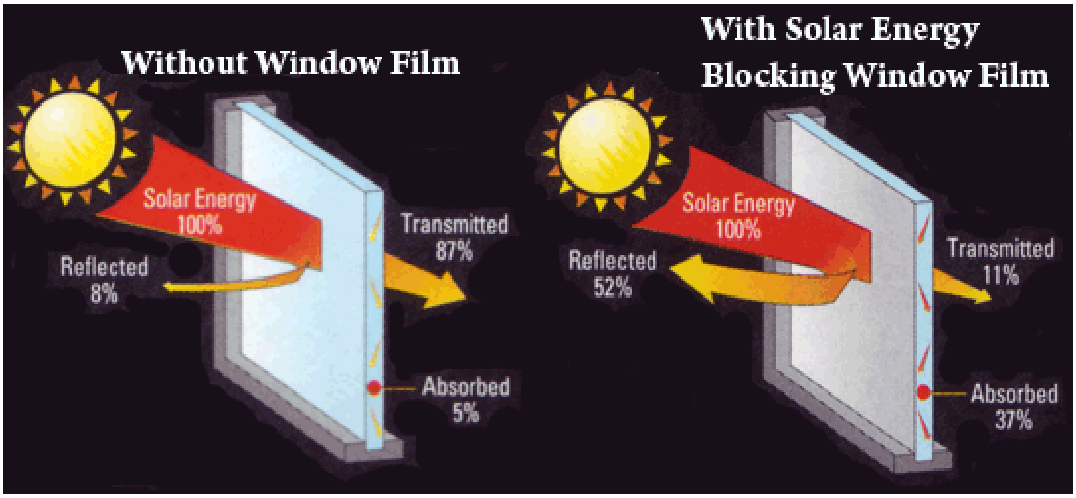
http://www.gpwindowfilms.com/

Figure



http://scottishwindowtinting.com/wp-content/uploads/2012/05/window-film-energy-savings.gif

http://www.gpwindowfilms.com/

Parameters

Thermal transmittance coefficient for window element U_w [W/m^{2}K]: *according to chosen window type*
G factor [%]
Daylight factor [%]

Codes of practice

Windows with improved glassing can significantly influence the energy savings, reducing the amount of solar gains and the same time reducing the energy needed for air conditioning system.
Can be recommended for all space types.

3.1.20 HIGH EFFICIENCY WINDOWS: DOUBLE-TRIPLE GLAZING WITH LOW-E GLASS

[1.6.1]

Description

Double or triple glazing are often named Insulated Glazing (IG). In IG windows glass panes are separated by an air or other gas what reduces heat transfer.

Low emissivity (low-e or low thermal emissivity) refers to a surface condition that emits low levels of radiant thermal energy. In Low – E windows thin film of anti-reflective metal oxide coatings are applied to the glass to improve thermal efficiency (insulation properties).

This results in more efficient windows because radiant heat originating from indoors in winter is reflected back inside, while infrared heat radiation from the sun during summer is reflected away, keeping it cooler inside. This results that buildings stay cool in the summer and warm in the winter by reflecting heat back into the room. It also greatly reduces ultraviolet light and creates a more comfortable indoor conditions.

This type of windows are recommended for rooms with high proportion of windows.

Installing double or triple glazing windows with Low-E glass can reduce heating bills effectively.

Typical thickness of glass range from 3mm to 10mm and if needed can be thicker in special cases.

Standard spacing thickness is 16-19mm.

Windows with Low E are used in low energy building that is why it is recommended to use them in hospital as they can help to reduce the energy use.

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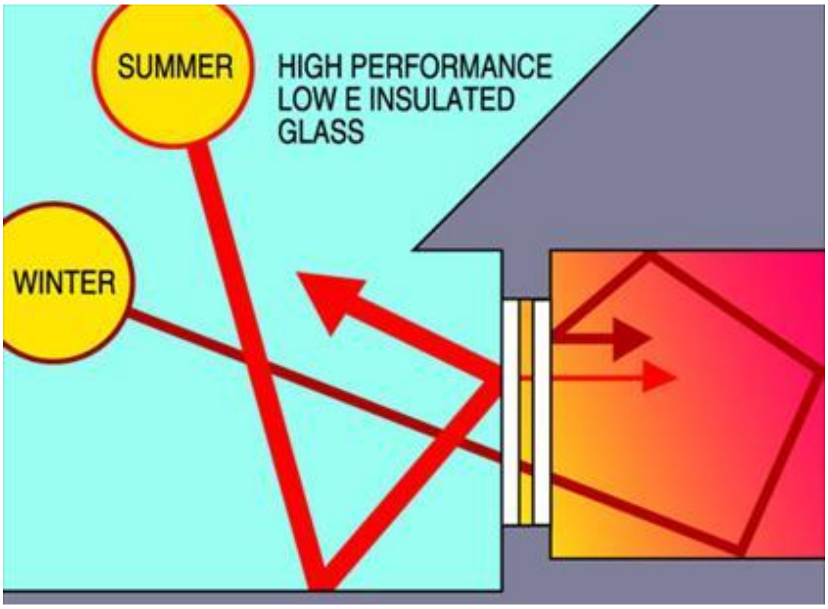
Figure



http://www.windsorwindows.com/learn/EnergyPerformance/EnergyLow-EGlass.page

http://www.gevergel-glass.com/img/p/26-97-thickbox.jpg

Parameters

Thermal transmittance coefficient for window element U_w [W/m^{2}K]:
according to window type and manufacturer
SHGC: *according to window type and manufacturer*
Emissivity: *according to glazing type*

Codes of practice

While installing windows is very important to prevent from thermal bridges which may occur.
The best way to eliminate thermal bridges is to install windows in the insulation layer. Window installation should be done carefully by trained monter. Windows should be insulated with foam and connection with the wall should be sealed.

3.2 Horizontal envelope (top closures)

2.1 Pitched roof with discontinuous waterproof surface	2.2 Pitched roof with continuous waterproof surface	2.3 Flat roof
2.1.1 Microvented (minimum mandatory)	2.2.1 Insulated	2.3.1 Insulated
2.1.2 Insulated	2.2.2 Vented (single VL)	2.3.2 Vented (double roof)
2.1.3 Vented (single VL)	2.2.3 Insulated + vented (single VL)	2.3.3 Insulated + vented
2.1.4 Vented (double VL)		2.3.4 Green roof
2.1.5 Insulated + vented (single VL)		2.3.5 Cool roof
2.1.6 Insulated + vented (double VL)		

Active solar energy system	Structure
a.1 Photovoltaic panels on top	A Massive
a.2 Integrated photovoltaic panels	B Light
a.3 Photovoltaic panels built in	
a.4 Photovoltaic waterproof panels	
b.1 Solar collectors	

List of the Technologies

categories		name	paragraph
2.1	2.1.1	MICROVENTED	3.2.1
	2.1.2	MICROVENTED INSULATED	3.2.2
	2.1.3	VENTED (SINGLE VENTILATION LAYER)	3.2.3
	2.1.4	VENTED (DOUBLE VENTILATION LAYER)	3.2.4
	2.1.5	INSULATED AND VENTED (SINGLE VENTILATION LAYER)	3.2.5
	2.1.6	INSULATED AND VENTED (DOUBLE VENTILATION LAYER)	3.2.6
2.2	2.2.1	INSULATED	3.2.7
	2.2.2	VENTED (SINGLE VENTILATIONS LAYER)	3.2.8
		VENTED ATTIC ROOF	3.2.10
	2.2.3	INSULATED AND VENTED (SINGLE VENTILATIONS LAYER)	3.2.11
2.3	2.3.1	INSULATED	3.2.12
	2.3.2	VENTED DOUBLE ROOF	3.2.13
	2.3.3	INSULATED AND VENTED	3.2.14
	2.3.4	GREEN ROOF	3.2.15
	2.3.5	COOL ROOF	3.2.16
a	a.1	PHOTOVOLTAIC PANELS ON TOP	3.2.17
	a.2	INTEGRATED PHOTOVOLTAIC PANELS	3.2.18
	a.3	PHOTOVOLTAIC PANELS BUILT IN	3.2.19
	a.4	PHOTOVOLTAIC WATERPROOF PANELS	3.2.20
b	b.1	SOLAR COLLECTORS	3.2.21
A		MASSIVE STRUCTURE	3.2.22
B		LIGHT STRUCTURE	3.2.23

3.2.1 PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE: MICROVENTED

[2.1.1]

Description

The micro-ventilation in a pitched roof with discontinuous surface (tiles and curved tiles) over a load bearing continuous pitched structure (hollow block floor, concrete floor, plank floor, etc.) can be realized through the installation of the elements of the waterproof surface on a bearing and anchor battens composed of wood, metal, plastic beadings, etc. parallel to the gutter line and placed in the tile axle spacing.
Most of the tiles on the market are characterized by one or two teeth specifically fitted for the anchoring of the elements to the bearing battens.

The micro-ventilation consists of air layer 25-40 millimeters thick realized thanks to the laying of the elements of the roof surface on bearing battens. This allows air circulation under the waterproof surface to be activated with functional benefits.

To activate this air circulation, the tiles laying system along the gutter and ridge lines requires the income and outcome of the air, thus the triggering of a convective motion due to the buoyancy forces and the possible presence of wind. In all cases, a high percentage of this air circulation is achieved thanks to the air permeability that happens among the overlapping of the tiles. The quantity of air passing through the tiles overlapping is definitely higher than the air incoming along the gutter line. Moreover, this air can be increased by the wind that have access on the four sides of the element. It will be higher in case of curved tiles and slightly lower in case of tiles but still strongly effective. This is an exclusive function of the discontinuous roof surfaces.

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context except in the case of small depth buildings (for instance containing patient department). In any case, where is used this type of pitched roof, micro ventilation must always be present as essential solution for the proper functioning of the roof.

Key properties

- To dispose part of the solar radiation that heats the tiles and instill heat in the living spaces under the roof (this benefit is secondary to the proper ventilation but, indeed, useful). When a high disposal of the summer radiation is necessary a ventilation layer is worth to be activated (see: 2.1.3 solution/2.2.3 paragraph and 2.1.4 solution/ 3.2.4 paragraph);
- To allow a fast drying of the imbibed water by the surface elements:
- To limit the freezing of the elements due to the fast drying of the matrix;
- To control the melting of the snow surface due to the different temperature in the roof, warmer at the ridge level and colder at the gutter level;
- To remove the possible condensation that could damage the waterproof elements or the bearing structure.

References

UNI 9460:2008 Coperture discontinue. Istruzioni per la progettazione, l’esecuzione e la manutenzione di coperture realizzate con tegole di laterizio o calcestruzzo
VV. AA., Una copertura chiamata tetto, Milano, BE-MA, 1979, pp. 191.
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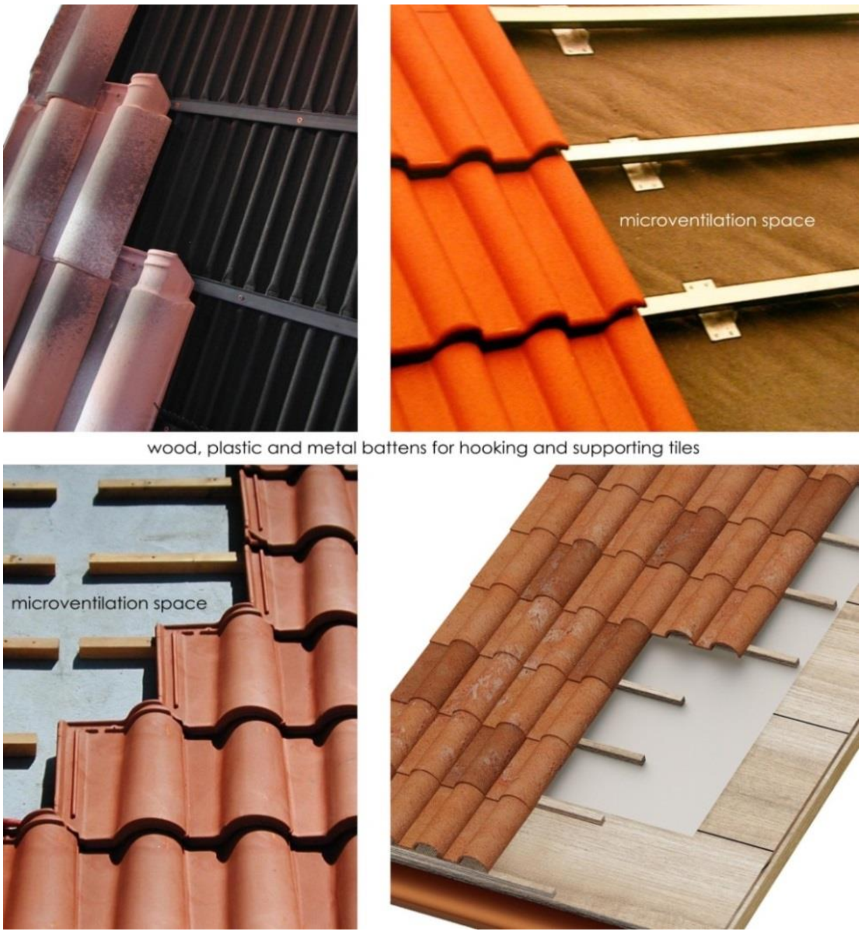
Andil Assolaterizi, “La corretta posa in opera dei manti di copertura in laterizio”, Roma.

Figure



Source: giovanni.zannoni@unife.it

Parameters

Cavity thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening in the gutter line [mm^2/m]
Opening in the ridge line [mm^2/m]
Roof slope [% or degrees]
Roof length [m]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

The tiles supporting lines can be realized with wood battens, metal beadings, plastic, etc. They are fixed to the underneath structure parallel to the gutter line (tiles axle spacing) with nails or expansion plugs depending on the structure. The battens lines should be interrupted for two centimeters every approximately four meters. The first batten of the gutter line should be characterized by a double thickness compared to the others.
When a waterproof membrane is present, appropriate fixing systems should be adopted in order to avoid the infiltrations through the holes for the battens fixing. This membrane should be characterized by vapor permeability properties as well.
Otherwise, instead of battens, mortar bond beams installed directly on the bearing structure or over a bituminous slating membrane can be used. This can be applied only if the tiles are laying after the mortar setting. The presence of a bituminous membrane prevents the vapor flow; thus this aspects should be taken into account.

3.2.2 PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE: MICROVENTED INSULATED

[2.1.2]

Description

Compared to the previous solution (considered the minimum mandatory), improvement from the energy point of view can be provide with an additional laying of a insulation layer that should be placed in any point of the roof package but always under the micro-ventilation layer. The position depends on whether the thermal wheel given by the floor structure is used (see a1/ 3.2.22 paragraph/Massive Structure and a2/ 3.2.23 paragraph/Light Structure) thus on the use of the building and the spaces underneath the roof in particular.
The insulation can be synthetic polymeric (EPS, XPS, PUR) or fibrous (fiberglass, mineral wood, wooden fiber, wooden wool, etc.) depending on the priority: the control of the heat loss from the inside to the outside or the damping of the thermal wave incoming due to the solar radiation. When a high level of insulation wants to be achieved, both typologies of materials can be used (light/synthetic, fibrous/heavy) keeping the material at higher density on the external side of the roof.
The thickness of the thermo-insulation layer(s) will depend on the location and the building typology and use. Generally, thickness of at least 7+7/8+8 centimeters or more are preferable.
The presence of an insulation material will provide insulation performance regarding the heat transmission by conduction in particular. An additional membrane within the roof package will also control the heat transmission by convection.
The heat transmission by thermal radiation could be controlled by a thermo-reflective membrane placed as external as possible in the roof package. Considering the fact that the installation of this membrane should always foresee an air layer above the membrane itself (otherwise a heat transmission by contact and conduction will happen), the best position is immediately below the micro-ventilation layer in order to use the presence of the micro-ventilation cavity.
Many thermo-reflective products also have waterproof properties and can have a double role as secondary waterproof layer (in case of crack or movement of the tiles) and as thermo-reflective screen against the solar radiation. The market offers thin thermo-reflective multilayer membranes where layers of reflective material (aluminum or similar) are alternated with layers of few millimeters thick of thermo-insulation material (polyethylene foam and/or fibrous materials, etc.).
Naturally, a thermo-reflective multilayer membrane, thus characterized by multiple layers, improves the insulation effect from all the three transmission modality perspective. Nevertheless, these products cannot be used alternatively to a proper insulation layer. The best benefits can be achieved combining the best properties of each of these.
Some products that realize the insulation layer are already characterized by the presence of anchoring lines for the tiles (metal beadings, plastic elements or grooves). This products simplifies and speeds the laying of the tiles avoiding a further laying of the battens for the micro-ventilation.

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context except in the case of small depth buildings (for instance containing patient department). In any case, where is used this type of pitched roof, micro ventilation will always be present as essential solution for the proper functioning of the roof, and the presence of a thermal insulation is anyway useful for energy saving.

Key properties (in addition to the previously defined for the 2.1.1 solution/3.2.1 paragraph):
- Summer and winter thermal insulation
- Energy savings

References

UNI 9460:2008 Coperture discontinue. Istruzioni per la progettazione, l’esecuzione e la manutenzione di coperture realizzate con tegole di laterizio o calcestruzzo
VV. AA., Una copertura chiamata tetto, Milano, BE-MA, 1979, pp. 191.
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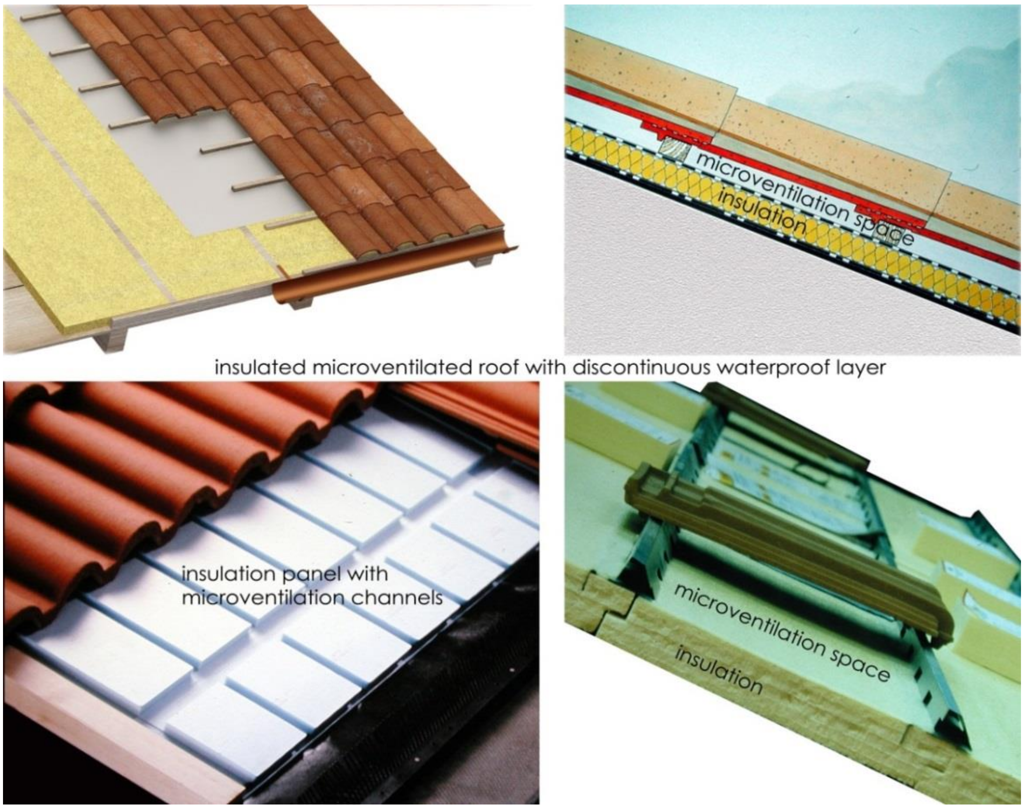
Andil Assolaterizi, “La corretta posa in opera dei manti di copertura in laterizio”, Roma.

Figure



Source: giovanni.zannoni@unife.it

Parameters

Cavity thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening in the gutter line [mm^2/m]
Opening in the ridge line [mm^2/m]
Roof slope [% or degrees]
Roof length
Thickness of the insulation material [mm]
Insulation material density [kg/m^3]
Thermal conductivity[λ] [W/(m·K)]
Thermal resistance [m^2K/W]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Compressive strength [kPa]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

The insulation layer should always laid underneath any air circulation layer.
Generally, a batten placed along the gutter line against which the first line of panels is positioned is enough. The following panels are positioned against the previous ones and are kept in place by the weight of the waterproof surface. Therefore, mechanical fixings are generally not necessary. Any membranes are positioned according to the waterproof and vapour permeability. This possible thermo-reflective membrane must have an air cavity at least two centimeters thick above. Generally, it is laid immediately underneath the micro-ventilation cavity.

3.2.3 PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE: VENTED (SINGLE VENTILATION LAYER)

[2.1.3]

Description

Compared to the microvented roof (see 2.1.1/3.2.1 paragraph), the vented pitched roof has a thicker ventilation layer and, thus, a higher amount of air circulating. The bigger thickness of the ventilation layer is built by the laying of a perpendicular double wooden batten frame: the first underlying frame is laid perpendicular to the gutter line. In this way, it offers less resistance to the air upward motion. The second frame is laid parallel to the gutter line as in microvented roof.

The upper frame supports the tiles by the teeth present in their intrados (as seen in 2.1.1/3.2.1 paragraph). The thickness of the upper frame battens is generally between 25 and 40 millimeters. The lower frame provides the bigger amount of air circulating and, thus, the solar heat disposal. Even if the air circulating layer is only one, this solution theoretically has a double overlapping ventilation layers: the upper micro-ventilation layer and the lower ventilation layer. This consideration has a clearer meaning in 2.1.4 *Vented (Double Ventilation Layer),* where the two layers are separated.

The thickness of the lower battens frame, which produces the higher quantity of air circulation, can vary from 40 mm up to 70-80 millimeters. Smaller thicknesses do not give significant benefits compared to the ones by micro-ventilation, considering also the higher construction cost of the double frame. Bigger thicknesses do not improve significantly the performance of solar heat disposal, still considering the higher construction cost.

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context except in the case of small depth buildings (for instance containing patient department). The solution presented could be interesting in a building where the mansard space has an frequent and important use. Otherwise, in a large building like an hospital, micro-ventilation seen in 2.1.1/3.2.1 paragraph could be considered enough.

Key properties:
The ventilation layer provides the same performances defined for the micro-vented roof. The additional performance guaranteed by this solution is an higher quantity of solar heat disposal before it moves to the living space underneath the roof. This solution should be adopted depending on the solar radiation by orientation of the pitched roof and on the destination of the spaces underneath the roof. Therefore, the micro-ventilation is mandatory, the ventilation is a design choice, sometimes redundant (e.g. in case of surrounding taller buildings that overshadow the roof).

References

UNI 9460:2008 Coperture discontinue. Istruzioni per la progettazione, l’esecuzione e la manutenzione di coperture realizzate con tegole di laterizio o calcestruzzo
VV. AA., Una copertura chiamata tetto, Milano, BE-MA, 1979, pp. 191.
Nelva, R., Le coperture discontinue, Milano, BE-MA, 1987, pp.94.
Zannoni, G., Il sistema tetto. Manuale di progettazione, Rimini, Maggioli Editore, 1992, pp. 213.
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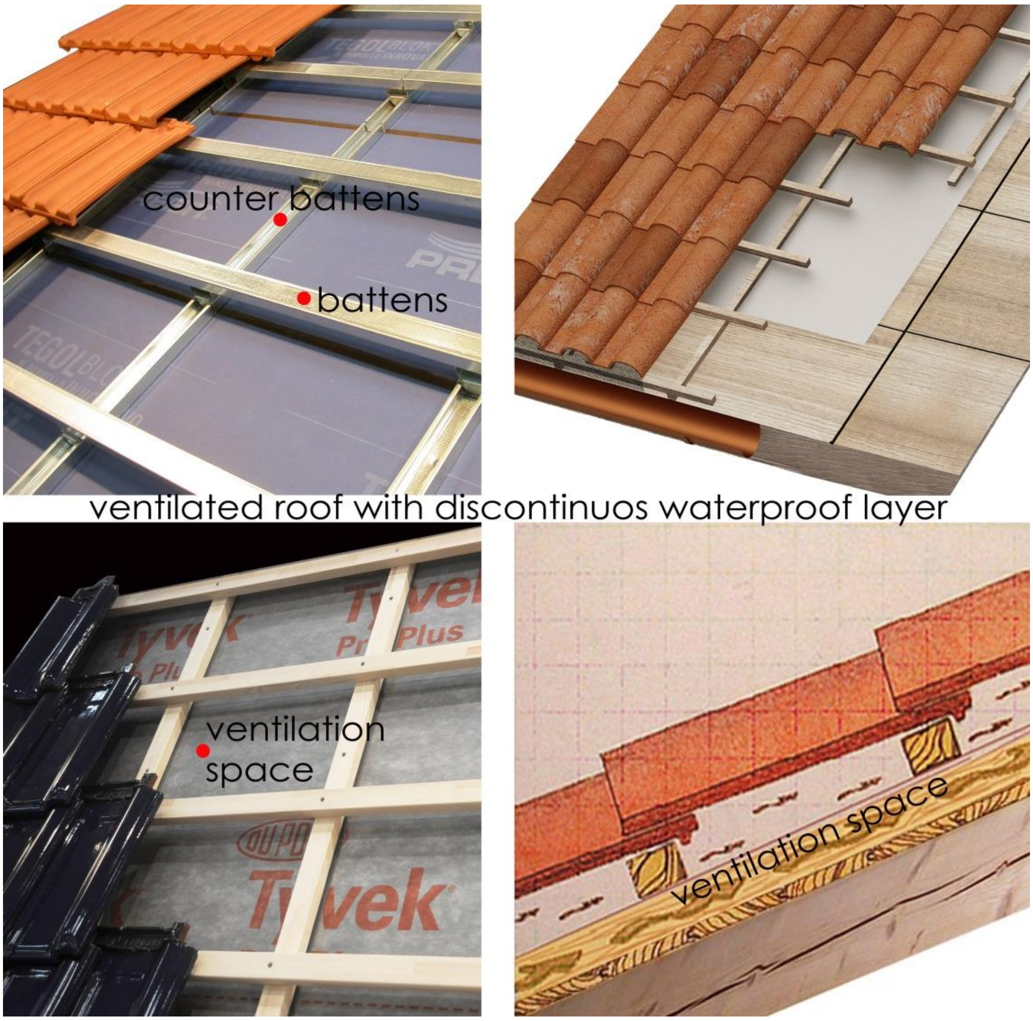
Schunck, E., Finke, T., Jenisch, R., Oster, H.J., “Atlante dei tetti”, Torino, UTET, 1998, pp. 394 (or.ed. Dach Atas – Geneigte Dächer, 1996).
Andil Assolaterizi, “La corretta posa in opera dei manti di copertura in laterizio”, Roma.

Figure



Source: giovanni.zannoni@unife.it

Parameters

Lower battens thickness [mm]
Higher battens thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening of the gutter line [mm^2/m]
Opening of the ridge line [mm^2/m]
Roof slope [% or degrees]
Pitch length
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

This solution has the same laying manners as in 2.1.1/3.2.1 paragraph. The lower layer of battens is laid with screws or expansion plugs according to the structure (wood, hollow block floor, etc.). The higher layer of battens is instead fixed with screws to the lower one. The supporting battens for the tiles at the gutter line always have a double thickness. Particular attention should be put on the making of the ridge line, which has to ensure the outcome of the bigger amount of air, avoiding any infiltration at the same time. For this, suitable sub-ridge beadings are available according to the tiles typology and the aesthetic choices. Any membranes are positioned according to the waterproof and vapour permeability.

3.2.4 PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE: VENTED (DOUBLE VENTILATION LAYER)

[2.1.4]

Description

In the 2.1.3 *Single Ventilation Layer* solution (3.2.3 paragraph), the double frame creates the condition for a vented roof. The solution here described improves the previous one performances and it is characterized by the laying of a roof boarding in order to separate the two frames and, thus, the double overlapping ventilation layers seen in 2.1.3.

In 2.1.3 configuration the air upward motion meets the tiles supporting battens parallel to the gutter line and, thus, against the air motion. This can cause the air speed decrease and some vortexes that decrease the performance of solar heat disposal. The roof boarding installed between the two frames allows a more homogeneous and uniform air flow in the lower layer (ventilation layer). Both 2.1.3 and 2.1.4 solutions are considered efficient. The last one, 2.1.4, is more expensive, but it works better.

After the installation of the first frame, perpendicular to the gutter line (ventilation layer), a continuous roof boarding is installed. Later, the second frame supporting the tiles, parallel to the gutter line, is installed. The upper frame (micro-ventilation layer) carries out the functions already seen in the 2.1.1 solution/3.2.1 paragraph, the lower frame (ventilation layer), parallel to the air motion, is enclosed between the pitched roof floor extrados and the intrados of the boarding roof.
Cheaper solutions can be obtained by the laying of a membrane stretched between the two frames instead of the boarding roof. This last solution needs more attention during the laying in order to avoid laceration of the membrane.

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context except in the case of small depth buildings (for instance containing patient department). It would be a functional solution, from the point of view of passive control of solar radiation in summer condition, thanks to the performances of the ventilation layer in a building where the mansard space has an frequent and important use. Otherwise micro-ventilation seen in 2.1.1 could be considered enough.

Key properties:
- High efficiency in the solar radiation passive disposal during summer, with improved performances compared to the ones defined in 2.1.3 solution.

References

UNI 9460:2008 Coperture discontinue. Istruzioni per la progettazione, l’esecuzione e la manutenzione di coperture realizzate con tegole di laterizio o calcestruzzo
VV. AA., Una copertura chiamata tetto, Milano, BE-MA, 1979, pp. 191.
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Zannoni, G., Il sistema tetto. Manuale di progettazione, Rimini, Maggioli Editore, 1992, pp. 213.
Lauria, A., “I manti di copertura in laterizio”, Roma, Edizioni Laterconsult, 2005 (ed. or. 2002), pp.118.
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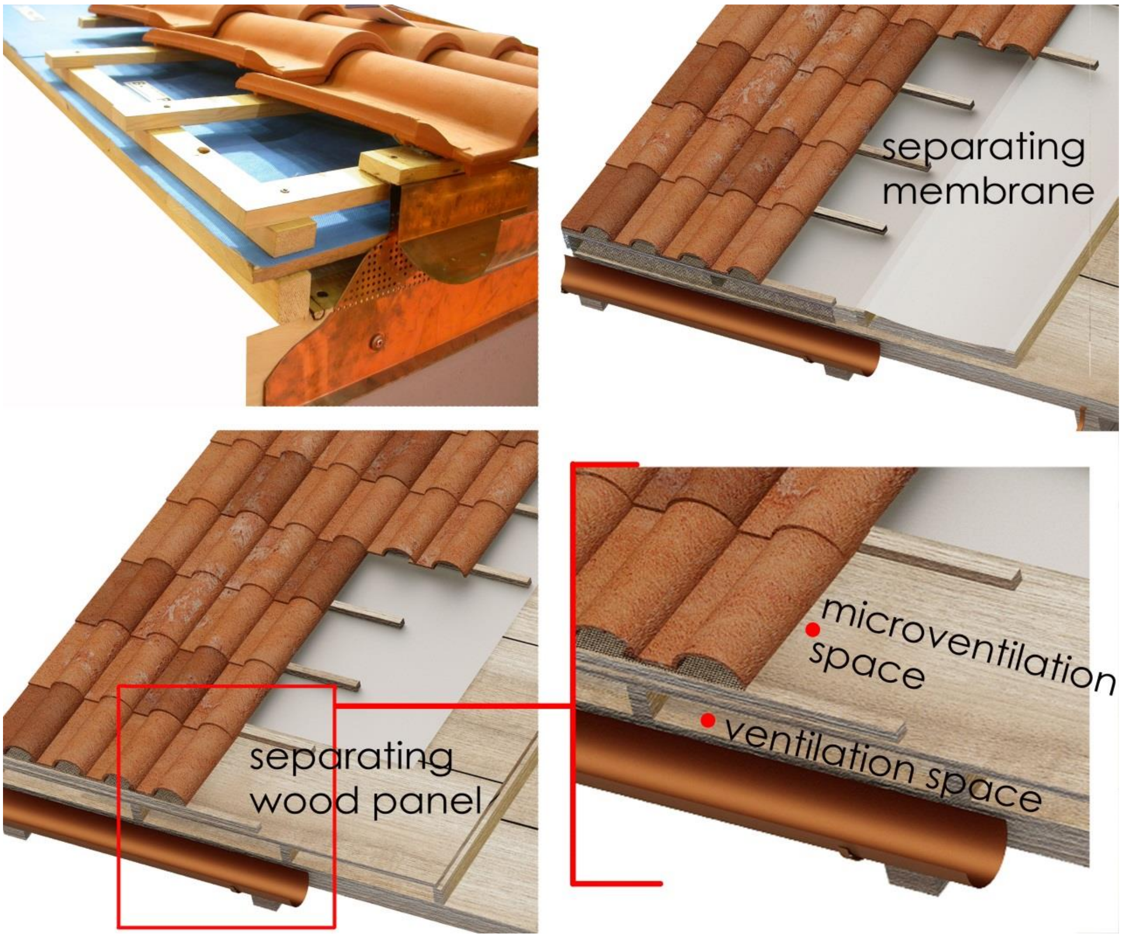
Andil Assolaterizi, “La corretta posa in opera dei manti di copertura in laterizio”, Roma.

Figure



Source: giovanni.zannoni@unife.it

Parameters

Lower battens thickness [mm]
Higher battens thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening of the gutter line [mm^2/m]
Opening of the ridge line [mm^2/m]
Roof slope [% or degrees]
Pitch length
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

The laying should consider the supporting structure (as seen in the previous solutions) and, thus, using screws and expansion plugs. All the following layers can be fixed to each other with screws. A waterproof membrane should be placed on the boarding roof that separates the two frames with no particular vapour permeability; the vapour can be removed by the below ventilation layer.

3.2.5 PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE: INSULATED AND VENTED (SINGLE VENTILATION LAYER)

[2.1.5]

Description

This solution requires the laying of an insulation layer to be installed in any point of the roof package but still below the ventilation layer and, thus, underneath the double battens frame. The position depends on the use of the thermal wheel given by the floor structure or not (see A/3.2.22 paragraph/Massive Structure and B/3.2.23 paragraph/Light Structure) thus on the use of the spaces underneath the roof.
The insulation layer gives a contribution to the control of the heat loss in winter. According to its density (mass), it could also contribute to the control of the income of the thermal wave of the solar radiation in summer. The insulation can be synthetic polymeric (EPS, XPS, PUR) or fibrous (fiberglass, mineral wood, wood fiber, wood wool, etc.) depending on the choice to control the heat loss from the inside to the outside or the damping of the thermal wave incoming due to the solar radiation. When a high level of insulation performance wants to be achieved, both typologies of materials can be used (light/synthetic, fibrous/heavy) keeping the material at higher density on the external side of the roof in order to meet optimal performances in all seasons. The presence of a insulation material will provide insulation performance regarding the heat transmission for conduction in particular. An additional membrane within the roof package will also control the heat transmission by convection.
The heat transmission by thermal radiation could be controlled by a thermo-reflective membrane placed as external as possible in the roof package. Considering the fact that the installation of this membrane should always foresee an air layer above the membrane itself (otherwise a heat transmission by contact and conduction will happen), the best position is immediately below the micro-ventilation layer in order to use the presence of the micro-ventilation cavity.
Many thermo-reflective products also have waterproof properties and can have a double role as secondary waterproof layer (in case of crack or movement of the tiles) and as thermo-reflective screen against the solar radiation. The market offers thin thermo-reflective multilayer membranes where layers of reflective material (aluminum or similar) are alternated with layers of few millimeters thick of thermo-insulation material (polyethylene foam and/or fibrous materials, etc.). Also in this configuration, thermo-reflective multilayer membranes can be adopted, as seen in 2.1.2 solution/3.2.2 paragraph *Microvented Insulated*.
The thickness of the thermo-insulation layer(s) will depend on the location and the building typology and use. Generally, thickness of at least 7+7/8+8 centimeters or more are preferable.
Some products that realize the insulation layer are already characterized by a presence of anchoring lines for the tiles (metal beadings, plastic elements or simple teeth). This products simplifies and speeds the laying of the tiles avoiding a further laying of the battens for the micro-ventilation.

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context except in the case of small depth buildings (for instance containing patient department). It would instead be a functional solution, from the point of view of passive control of solar radiation in summer condition, thanks to the performances of the ventilation layer. In any cases the solution of a double insulating layer with different density is also applicable in flat roofs. Not instead the thermo-reflective membrane due to the absence of an air layer. Similar benefits are obtainable with the solution of the flat cool roof (see 2.3.5 solution/3.2.16 paragraph).

Key properties (in addition to the ones previously defined for the 2.1.1 solution/3.2.1 paragraph)
- Efficiency in the solar radiation passive disposal during summer,
- High control of the heat dispersion in winter,
- Good control of the damping of the thermal wave incoming during summer.

References

UNI 9460:2008 Coperture discontinue. Istruzioni per la progettazione, l'esecuzione e la manutenzione di coperture realizzate con tegole di laterizio o calcestruzzo
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Schunck, E., Finke, T., Jenisch, R., Oster, H.J., "Atlante dei tetti", Torino, UTET, 1998, pp. 394 (or.ed. Dach Atas – Geneigte Dächer, 1996).
Andil Assolaterizi, "La corretta posa in opera dei manti di copertura in laterizio", Roma.

Figure

Source: giovanni.zannoni@unife.it

Parameters

Lower battens thickness [mm]
Higher battens for supporting and fixing thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening of the gutter line [mm^2/m]
Opening of the ridge line [mm^2/m]
Roof slope [% or degrees]
Pitch length
Thickness of the insulation material [mm]
Insulation material density [kg/m^3]
Thermal conductivity[λ] [W/(m·K)]
Thermal resistance [m^2K/W]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Compressive strength [kPa]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

When the insulation layer is placed inside the roof package, the material's compressive strength must be considered. When it is placed immediately below the ventilation layer, it should be alternated by battens (in the axle spacing of the panels, around 60 cm) that allows the following mechanical fixing of the upper battens frame, which cannot be fixed directly to the insulation. Some insulation products are already pre-assembled with tiles supporting beadings and shapes suitable for an appropriate ventilation layer.

3.2.6 PITCHED ROOF WITH DISCONTINUOUS WATERPROOF SURFACE: INSULATED AND VENTED (DOUBLE VENTILATION LAYER)

[2.1.6]

Description

This solution combines the 2.1.4 solution/3.2.4 paragraph (Vented - double ventilation layer) and 2.1.5 solution/3.2.5 paragraph (Insulated and vented - single ventilation layer) performance features.

The 2.1.4 double ventilation layer with a roof boarding in between (incrementing the ventilation performance) is coupled with a single - or multi-density - insulation and a possible thermo-reflective membrane as seen in 2.1.5 solution/3.2.5 paragraph.

This solution provides highest benefits in summer and winter.
The ventilation layers help the damping of the solar radiation.
The insulation layer, single or double density, avoids the outward thermal dissipation during winter and restraints the inward thermal wave during summer.
The possible thermo-reflective membrane partially reduces the incoming of the solar radiation during summer.

This solution is quite complex to be made; special attention has to be taken in:
- the design of the ventilation and insulation layers (see the previous solutions),
- the proper position of the possible thermo-reflective membrane,
- the proper placing of the layers.

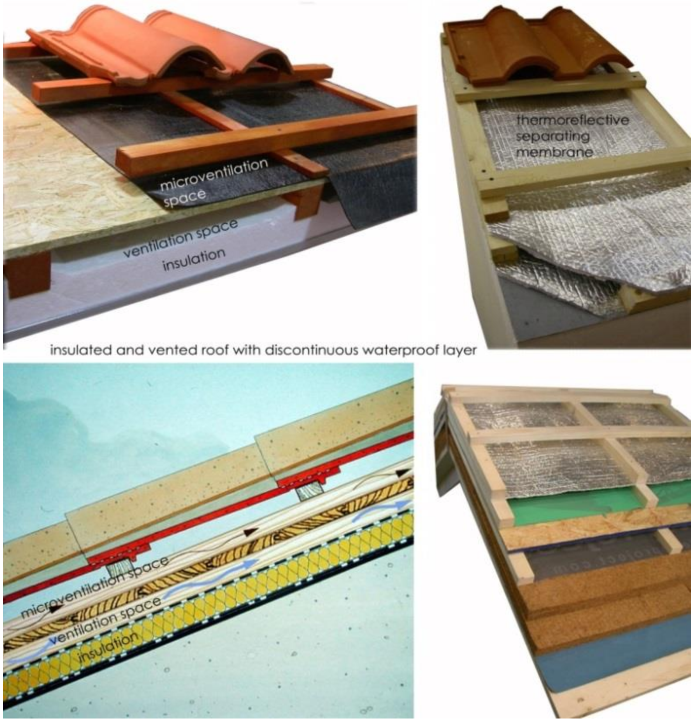
Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context except in the case of small depth buildings (for instance containing patient department). In any case the constructive complexity of this solution, its cost and its performances does not make it particularly interesting and suitable for healthcare districts, although small.

Key properties
(in addition to the properties see in 2.1.4 and 2.1.5)
- high efficiency of the heat passive disposal of the summer solar radiation,
- high control of the thermal dissipation during winter,
- high control of the summer inward thermal wave damping.

References

UNI 9460:2008 Coperture discontinue. Istruzioni per la progettazione, l’esecuzione e la manutenzione di coperture realizzate con tegole di laterizio o calcestruzzo
VV. AA., Una copertura chiamata tetto, Milano, BE-MA, 1979, pp. 191.
Nelva, R., Le coperture discontinue, Milano, BE-MA, 1987, pp.94.
Zannoni, G., “Il sistema tetto. Manuale di progettazione”, Rimini, Maggioli Editore, 1992, pp. 213.
Lauria, A., “I manti di copertura in laterizio”, Roma, Edizioni Laterconsult, 2005 (ed. or. 2002), pp.118.
Schunck, E., Finke, T., Jenisch, R., Oster, H.J., “Atlante dei tetti”, Torino, UTET, 1998, pp. 394 (or.ed. Dach Atas – Geneigte Dächer, 1996).
Andil Assolaterizi, “La corretta posa in opera dei manti di copertura in laterizio”, Roma.

Figure



Source: giovanni.zannoni@unife.it

Parameters

Lower battens thickness [mm]
Higher battens for supporting and fixing thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening of the gutter line [mm^2/m]
Opening of the ridge line [mm^2/m]
Roof slope [% or degrees]
Pitch length
Thickness of the insulation material [mm]
Insulation material density [kg/m^3]
Thermal conductivity[λ] [W/(m·K)]
Thermal resistance [m^2K/W]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Compressive strength [kPa]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

High complexity solution: the construction must be in situ because no commercial pre-assembled components are available. Wooden frames are placed onto the continuous framework surface: the first frame (either parallel or perpendicular to the gutter line) is fixed with expansion plugs or screws (depending on the framework), it houses the insulation panels and it is the support for the upper frame of the ventilation layer. All the following layers are fixed to the underneath components by screws; the second frame (ventilation) is perpendicular to the gutter line, the boarding roof is fixed to the ventilation frame and battens (parallel to the gutter line) for the tiles is fixed onto the boarding roof.
Further complex solutions include more ventilation layers (see figure in 2.1.6/3.2.6 paragraph), thermo-reflective membranes and double density insulation materials.

3.2.7 **PITCHED ROOF WITH CONTINUOUS WATERPROOF SURFACE: INSULATED**

[2.2.1]

Description

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context, although they are very common in other building types, especially residential. However, hospital buildings with smaller depth (for instance containing patient department) are suitable for a pitched roof solution.

Key insulated roof with insulation inside properties:

- Insulation keeps out the cold in the winter and the heat in the summer.
- The thermal insulation improves as the insulation material becomes thicker.
- Main risk: thermal leakage through load-bearing construction between the insulation panels (thermal bridge). As the insulation thickness increases, this “weak link” becomes more important. Softwood typically has a conductivity of 0.13 W/mK, whereas insulation of mineral wool has a conductivity of approximately 0.04W/mK.
- Unvented roofs can perform well in cold and mixed climates if measures are taken to control indoor humidity, to minimize inside heat sources, and to minimize air leakage from below.

Key roof covering properties:

- Function is to provide a strong, watertight, airtight surface.
- Steel roof covering is very long-lasting and is relatively maintenance-free.
- The color of the roof covering influences the thermal build-up, caused by the sun: the darker the color, the warmer the surface becomes.
- Because the roof covering is vapour and airtight; condense and vapour from the inside should be transported away to avoid damage to the wooden structure caused by rot.
- As the angle decreases, the danger of water penetrating the surface increases.

Key seamed plain roof covering properties:

- Most common material: aluminum, zinc, copper
- The type of seam (single, double, roll cap) has a great influence on the water tightness of the roof (especially at low roof angles)
- There is a serious danger of condensation between the roof covering and the decking, especially in situations where the outside temperature is significantly lower than the inside temperature. This moisture should be transported to the outside (downwards, towards the gutter), for instance through the roll caps. In countries with a warm climate, the amount of condensation will be less.

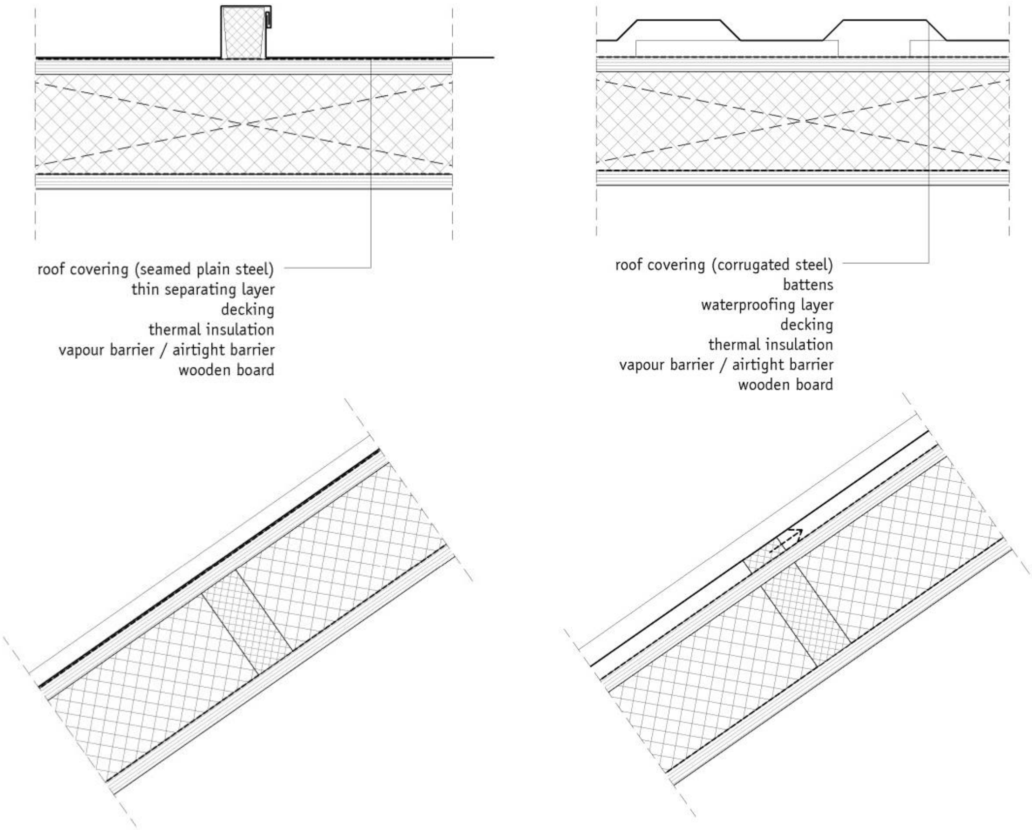
Key corrugated roof covering properties:

- Most common materials: steel, aluminum with a finish.
- There is danger of condensation between the roof covering and the decking, this can be avoided by ventilation between the battens.

References

Zannoni, G., “Opere di lattoneria e coperture. Manuale di progettazione e posa”, BE-MA, Milano, 2008.
https://www.smacna.org

Figure



Source: stefan.vannederpelt@djga.nl

Parameters

Thickness of the insulation material [mm]
Insulation material density [kg/m^3]
Thermal conductivity[λ] [W/(m·K)]
Thermal resistance [m^{2}K/W]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Compressive strength [kPa]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Periodic Thermal Transmittance
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Detailing of the metal roof covering should anticipate expansion/contraction due to varying thermal loads.
Screwed attachment of roof covering to the slope wooden batten.
Placement of thin separating layer to improve vapor distribution between roof covering and wood is preferred.

3.2.8 PITCHED ROOF WITH CONTINUOUS WATERPROOF SURFACE: VENTED (SINGLE VENTILATION LAYER)

[2.2.2]

Description

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context, although they are very common in other building types, especially residential. However, hospital buildings with smaller depth (for instance containing patient department) are suitable for a pitched roof solution.

Key ventilated roof properties:

- Roof ventilation improves building cooling when it's warm outside
- The airflow through the structure is useful against over-heating, but is only effective if ventilation perpendicular to the gutter is possible.
- Airflow from the inside towards the ventilation layer of the roof should be avoided, especially in cold climate zones.
- Because there is no thermal insulation, a roof with just ventilation will not sufficiently provide a comfortable inside temperature in cold climate zone
- Moisture problems caused by condensation are overcome by ventilation.
- The need for venting to avoid icing depends on the climate
- However, ventilation is necessary in climates with a lot of snow to prevent icing at eaves, regardless of insulation level.

Key roof covering properties:

- Function is to provide a strong, watertight, airtight surface.
- roof covering is very long-lasting and is relatively maintenance-free.
- The color of the roof covering influences the thermal build-up, caused by the sun: the darker the color, the warmer the surface becomes.
- Because the roof covering is vapor and airtight; condense and vapor from the inside should be transported away to avoid damage to the wooden structure caused by rot.
- As the angle decreases, the danger of water penetrating the surface increases.

Key seamed plain roof covering properties:

- Most common material: aluminum, zinc, copper
- The type of seam (single, double, roll cap) has a great influence on the water tightness of the roof (especially at low roof angles)

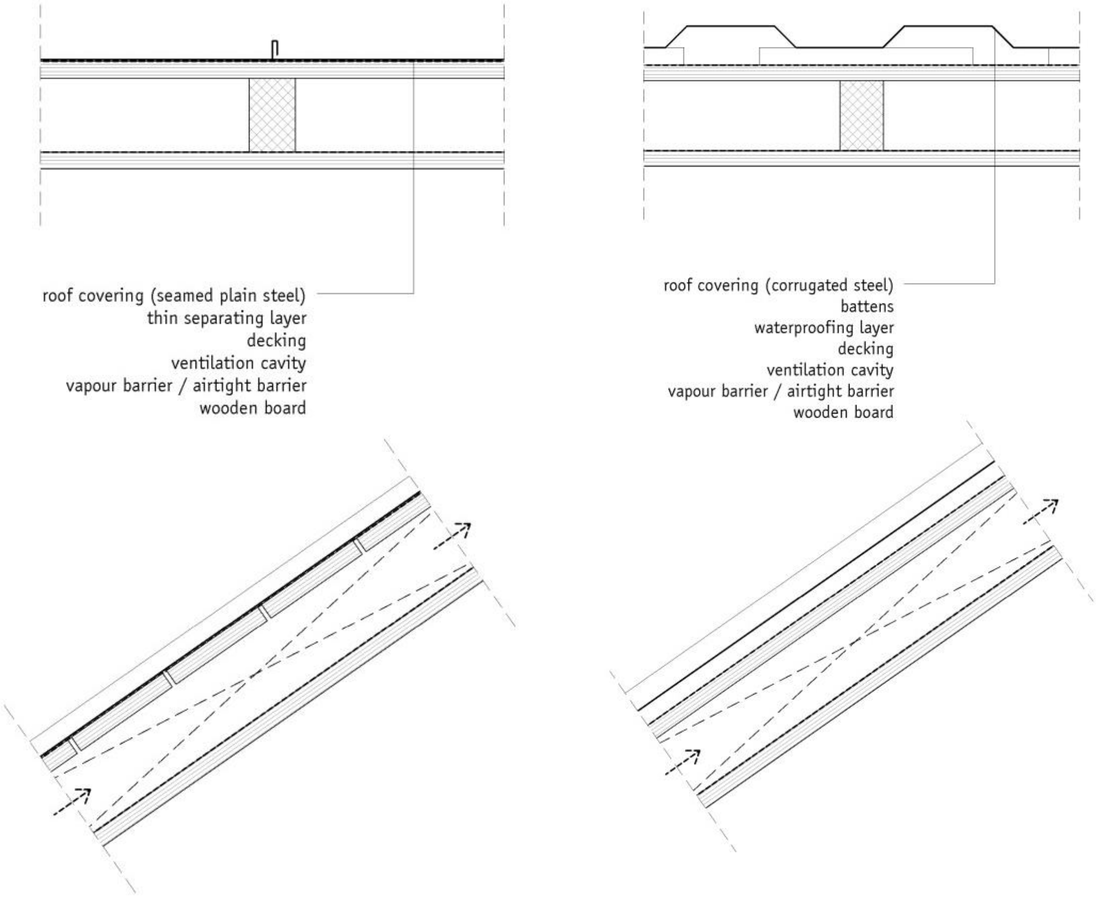
Key corrugated steel roof covering properties:

- Most common materials: steel, aluminum with a finish.

References

Zannoni, G., “Opere di lattoneria e coperture. Manuale di progettazione e posa”, BE-MA, Milano, 2008
https://www.smacna.org

Figure



Source: stefan.vannederpelt@djga.nl

Parameters

Ventilation cavity thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening of the gutter line [mm^2/m]
Opening of the ridge line [mm^2/m]
Roof slope [% or degrees]
Pitch length [m]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Detailing of the metal roof covering should anticipate expansion/contraction due to varying thermal loads.
Screwed attachment of roof covering to slope wooden batten.
The air tightness of the bottom of the roof is very important. The so-called blower-door test can be used to check the air tightness of a building after completion.
Placement of thin separating layer to improve vapour distribution barrier between steel and wood is preferred.

3.2.9 PITCHED ROOF WITH CONTINUOUS WATERPROOF SURFACE: VENTED (ATTIC ROOF)

[2.2.2]

Description

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context, although they are very common in other building types, especially residential. However, hospital buildings with smaller depth (for instance containing patient department) are suitable for a pitched roof solution.

A ventilated attic roof is an uninhabited space. The insulation layer is above the horizontal floor. Ventilation enters through the gutter line; hot air is let out through the top of the roof.

Attic ventilation has various advantages:
- Prevention of ice dams. Underneath non-ventilated roofs, built-up heat will cause the roof temperature to rise, causing snow to melt. The roof overhang is usually colder, so this is where water freezes into an ice dam that can rise up to a height that exceeds the slope of the roof. At this point, the melting water enters under the roof and begins to run downward and entering the attic. Attic ventilation disposals built-up heat before it causes the melting.
- Airflow from the inside towards the ventilated inside of the roof should be avoided, especially in cold climate zones.
- Attic space ventilation improves attic cooling when it's warm outside; the hot air directly under the roof is vented away.
- Moisture problems caused by condensation are overcome by ventilation.
- Moisture reduction and less extreme roof temperatures will extend the lifespan of the roof significantly.

There are different types of air in and outlets (fig. 2): most effective venting setup consists of soffit and ridge vents, because they take advantage of the fact that heat rises.
There are three other types:
1. Gable vents
These are the rectangular or square vents on the sides of houses near the peak of the roof. They are not particularly effective because the wind has to blow nearly directly on one side of the house or the other for them to flow well.
2. Powered vents
They will pull their air from the path of least resistance, which is often through air leaks in the ceiling of the house (conditioned air) and not soffit vents.
3. Can vents
They are slightly less effective than ridge vents because they are not quite at the very top of the attic and don't let as much heat out.

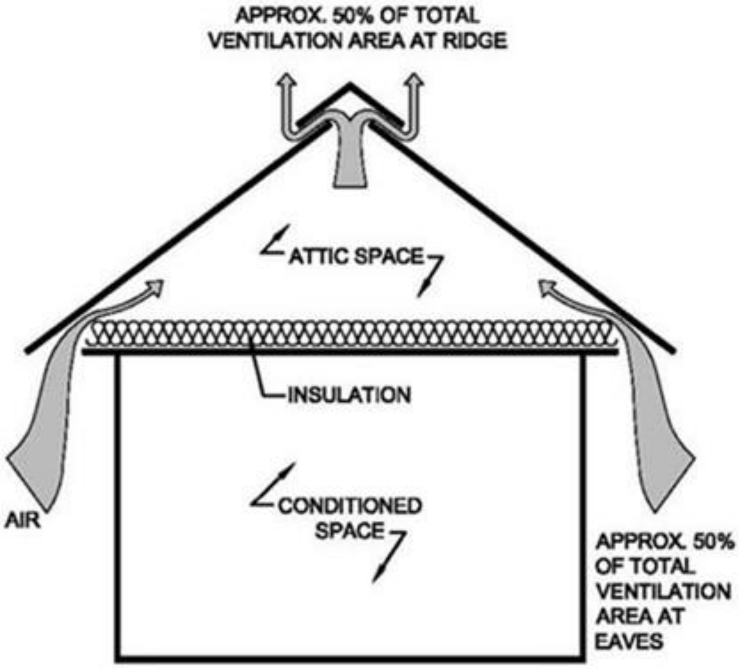
Key roof covering properties:
- Function is to provide a strong, watertight, airtight surface.
- Roof covering is very long-lasting and is relatively maintenance-free.
- The color of the roof covering influences the thermal build-up, caused by the sun: the darker the color, the warmer the surface becomes.
- Because the roof covering is vapor and airtight; condense and vapor from the inside should be transported away to avoid damage to the wooden structure caused by rot.
- As the angle decreases, the danger of water penetrating the surface increases.

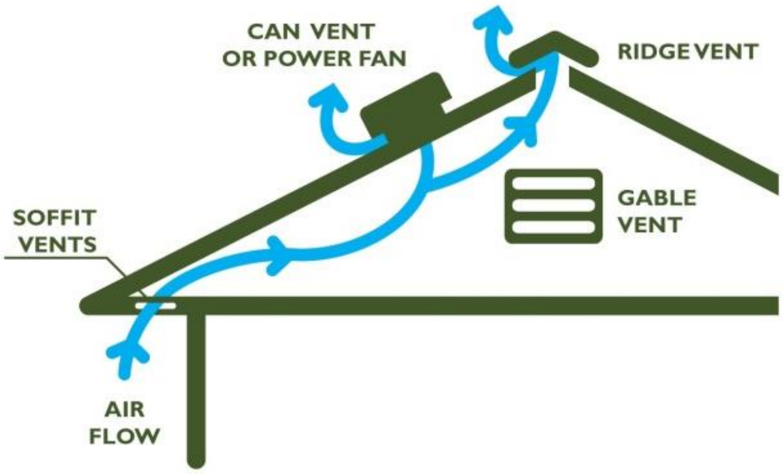
Key seamed plain roof covering properties:
- Most common material: aluminum, zinc, copper
- The type of seam (single, double, roll cap) has a great influence on the water tightness of the roof (especially at low roof angles).

References

http://energysmartohio.com/plan-your-job/attic-ventilation

Figure





Source figure 1:
http://www.nrca.net/roofing/Passive-ventilation-885

Source figure 2:
http://energysmartohio.com/plan-your-job/attic-ventilation

Parameters

Inlet/outlet cross section per m^2 of floor area [cm^2]
Wind direction and intensity
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Detailing of the roof covering should anticipate expansion/contraction due to varying thermal loads.
The air tightness of the bottom of the roof is very important. The so-called blower-door test can be used to check the air tightness of a building after completion.
Placement of thin separating layer to improve vapor distribution barrier between metal and wood is preferred.

3.2.10 PITCHED ROOF WITH CONTINUOUS WATERPROOF SURFACE: INSULATED AND VENTED (SINGLE VENTILATION LAYER)

[2.2.3]

Description

Generally roofs for hospitals are flat because of the large building depth. Pitched roofs are therefore less widely used in this context, although they are very common in other building types, especially residential. However, hospital buildings with smaller depth (for instance containing patient department) are suitable for a pitched roof solution.

Key insulated and ventilated roof properties:

- Suitable for any climate. Insulation keeps out the cold in the winter and the heat in the summer (in summer: above all with heavy density).
- The thermal insulation improves as the insulation material becomes thicker.
- Roof ventilation improves building cooling during the summer, although the added effect of ventilation on top of insulation is limited.
- The airflow through the structure is useful against over-heating, but is only effective if ventilation perpendicular to the gutter is possible.
- Airflow from the inside towards the ventilated inside of the roof should be avoided, especially in cold climate zones.
- The need for venting to avoid icing depends on the climate and the amount of insulation in the ceiling. However, ventilation is necessary in climates with a lot of snow to prevent icing at eaves, regardless of insulation level.

Key seamed plain roof covering properties:

- Function is to provide a strong, watertight, airtight surface.
- Roof covering is very long-lasting and is relatively maintenance-free.
- The color of the roof covering influences the thermal build-up, caused by the sun: the darker the color, the warmer the surface becomes.
- Because the roof covering is vapor and airtight; condense and vapor from the inside should be transported away to avoid damage to the wooden structure caused by rot.
- As the angle decreases, the danger of water penetrating the surface increases.

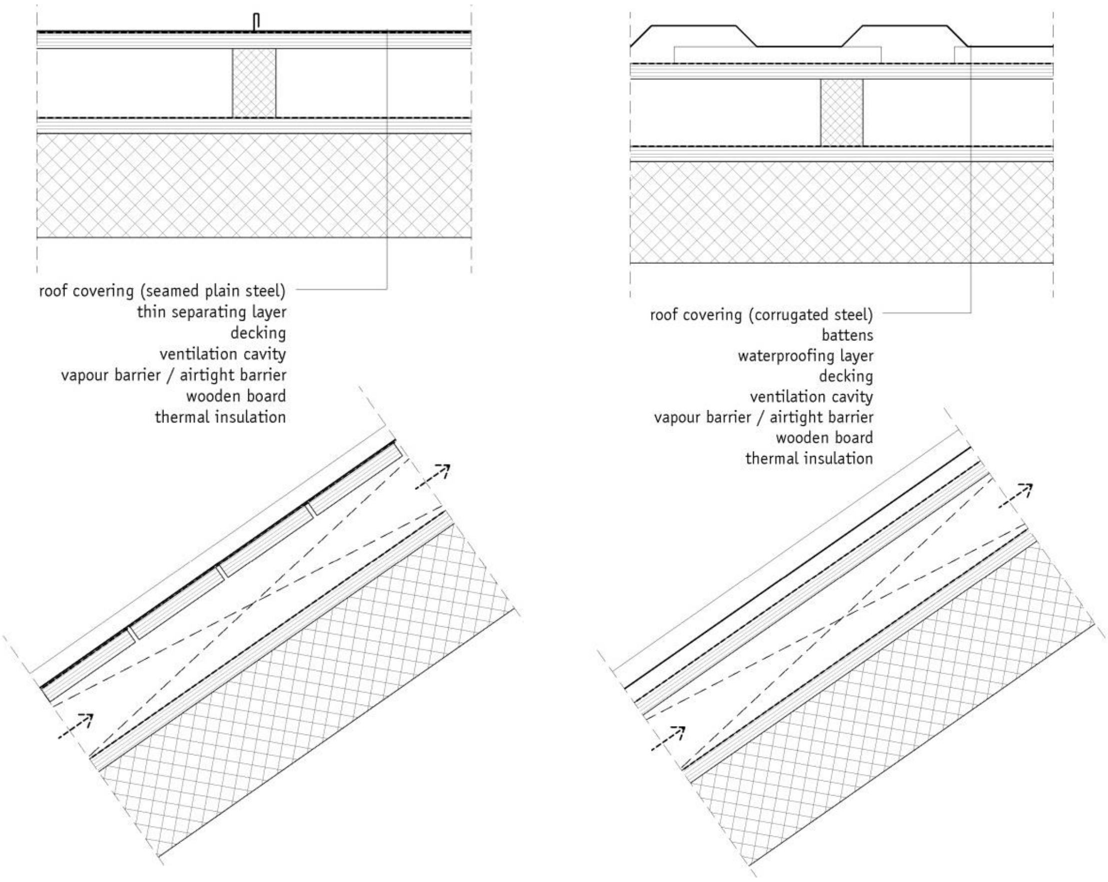
Key seamed plain roof covering properties:

- Most common material: aluminum, zinc, copper.
- The type of seam (single, double, roll cap) has a great influence on the water tightness of the roof (especially at low roof angles).

References

Zannoni, G., “Opere di lattoneria e coperture. Manuale di progettazione e posa”, BE-MA, Milano, 2008.
https://www.smacna.org

Figure



Source: stefan.vannederpelt@djga.nl

Parameters

Thickness of the insulation material [mm]
Insulation material density [kg/m^3]
Thermal conductivity[λ] [W/(m·K)]
Thermal resistance [m^{2}K/W]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Compressive strength [kPa]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Periodic Thermal Transmittance
Ventilation cavity thickness [mm]
Air speed [m/s]
Wind direction and intensity
Opening of the gutter line [mm^2/m]
Opening of the ridge line [mm^2/m]
Roof slope [% or degrees]
Pitch length [m]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Detailing of the roof covering should anticipate expansion/contraction due to varying thermal loads.
The air tightness of the bottom of the roof is very important. The so-called blower-door test can be used to check the air tightness of a building after completion. Placement of thin separating layer to improve vapor distribution barrier between metal and wood is preferred.

3.2.11 **FLAT ROOF:**

INSULATED

[2.3.1]

Description

Flat roofs are generally considered to be those built below a pitch of 5°. The main components are the structural deck, thermal insulation and waterproof membrane covering.

- **Structural deck**: timber decks are usually found on housing and smaller non domestic buildings, whereas concrete and metal decks are found on larger developments. Concrete rarely deflects to the extent that problems arise for the coverings, whereas this can occur in a timber construction
- **Thermal insulation**: the location of the insulation largely determines the type of insulation used. The inclusion and location of the vapour control layer is critical to avoid condensation
- **Waterproof membrane/covering**: options include bitumen, plastics and rubber sheets or metal. Dark surfaces will absorb more heat than light coloured ones.

The most typical type of flat roof is considered to be the warm deck sandwich roof.
The construction sequence is (from outside):

- surface finish,
- weatherproofing,
- insulation,
- vapour control layer,
- structural deck.

If the roof is subject to heavy traffic then the insulation and weather proofing will require protection from a material with high compressive strength (e.g. paving slabs).

Another solution is the reverse deck sandwich roof.
The construction sequence is (from outside):

- ballast protection,
- separation-protection sheet,
- insulation,
- waterproof membrane (single or double layer),
- liquid primer,
- structural deck.

If the roof is subject to heavy traffic then the insulation and weather proofing will require protection from a material with high compressive strength (e.g. paving slabs).

Key risks to be aware of are:

- **Interstitial condensation**: depending on the activity within the occupied space below and relating to the outdoor climate, the risk of condensation occurring within the roof fabric must be minimized. Should condensation occur then if unprotected it can flood the insulation layer and drastically reduce the performance of the fabric, potentially leading to a runaway problem. Particular care is needed in high moisture environments such as swimming pools.

Key properties:

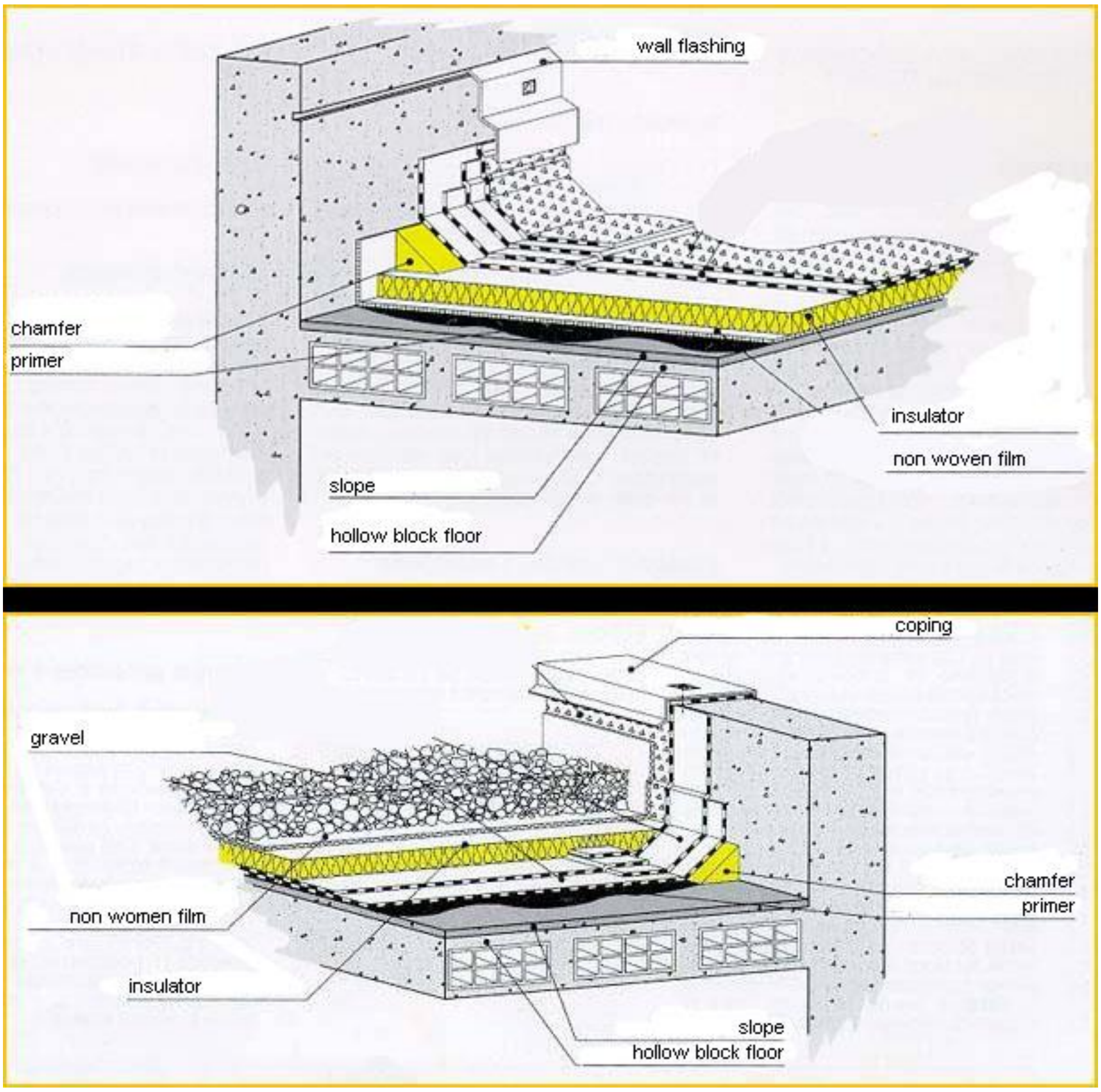
- Insulation – thickness typically determines the overall performance of the roof
- Waterproof membrane/vapour barrier – resistance and location typically inform the design of where interstitial condensation risk will occur.

A flat roof is suitable for large floor areas, for this reason it is more suited for hospitals because it offers greater compactness in building S/V ratio. Anyway the waterproof has to be carefully evaluated, as the biggest is the surface, the higher is the risk of breaking of sheaths.

References

http://www.kingspaninsulation.co.uk/
http://www.itcgfermi.it/

Figure



Source: giovanni.zannoni@unife.it

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient [W/m^{2}K]
Periodic Thermal Transmittance
Insulation material density [kg/m^3]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Care must be taken to ensure the contractor construction of the roof takes into account for continuity of layers, and the fixings involved. This is crucial as any unwanted penetrations into the roof build up (e.g. nail fixings compromising the waterproof membrane) can lead to moisture buildup within the fabric.

3.2.12 FLAT ROOF:

VENTED DOUBLE ROOF

[2.3.2]

Description

Flat roofs are generally considered to be those built below a pitch of 5°. The main components are the structural deck, thermal insulation and waterproof membrane covering.

- **Structural deck**: timber decks are usually found on housing and smaller non domestic buildings, whereas concrete and metal decks are found on larger developments. Concrete rarely deflects to the extent that problems arise for the coverings, whereas this can occur in a timber construction
- **Thermal insulation**: the location of the insulation largely determines the type of insulation used. The inclusion and location of the vapour control layer is critical to avoid condensation
- **Waterproof membrane/covering**: options include bitumen, plastics and rubber sheets or metal. Dark surfaces will absorb more heat than light coloured ones.

Key properties
A ventilated double flat roof design can take several forms, but the primary form will typically consist of an upper exposed roof and a lower protected roof. The upper roof provides rainwater screening, and should the airflow be consistent will remove solar gains before heat is transferred to the lower roof.

Alternatively other types of ventilated double roofs consist of complex designs to increase the Venturi effect, increasing wind flow between the two roofs and hence driving buoyancy forces within the building below. The roof type can be used to naturally cool spaces below.

This type of roof typically has insulation and the overall design should be carefully considered based on climate.

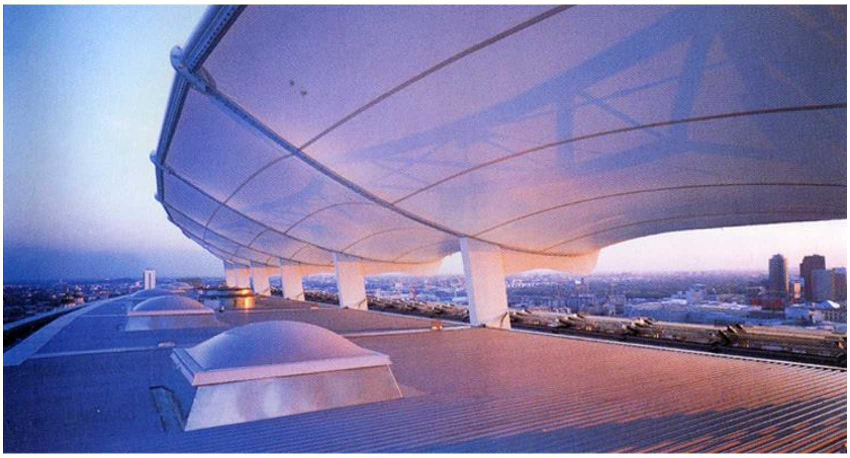
Ventilated double roofs are more commonly used in healthcare facilities in more temperate climates, however their use should be carefully considered to balance the level of beneficial/unwanted solar gains, plus the ventilation forces required to drive air through the roof construction.

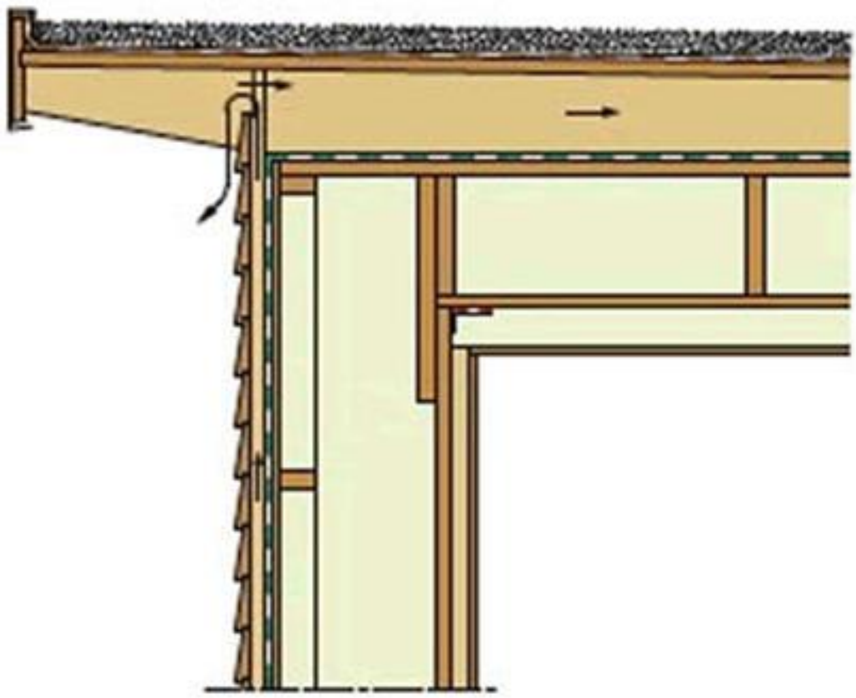
A flat roof is suitable for large floor areas, for this reason it is more suited for hospitals because it offers greater compactness in building S/V ratio. Anyway the waterproof membrane has to be carefully evaluated, as the larger the surface area, the higher is the risk of breaking of sheaths.

References

http://wiki.naturalfrequency.com/wiki/Passive_Cooling
http://www.zintek.it/en/content/Professionals~32/Application_techniques~88

Figure





Source: http://www.flumroc.ch/

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient [W/m^{2}K]
Periodic Thermal Transmittance
Space between the roofs [cm]
Shape of secondary roof
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Care must be taken to ensure the contractor construction of the roof takes into account for continuity of layers, and the fixings involved. This is crucial as any unwanted penetrations into the roof build up (e.g. nail fixings compromising the waterproof membrane) can lead to moisture buildup within the fabric.

3.2.13 FLAT ROOF: INSULATED AND VENTED

[2.3.3]

Description

Flat roofs are generally considered to be those built below a pitch of 5°. The main components are the structural deck, thermal insulation and waterproof membrane covering.

- **Structural deck**: timber decks are usually found on housing and smaller non domestic buildings, whereas concrete and metal decks are found on larger developments. Concrete rarely deflects to the extent that problems arise for the coverings, whereas this can occur in a timber construction
- **Thermal insulation**: the location of the insulation largely determines the type of insulation used. The inclusion and location of the vapour control layer is critical to avoid condensation
- **Waterproof membrane/covering**: options include bitumen, plastics and rubber sheets or metal. Dark surfaces will absorb more heat than light coloured ones.

Unlike the most typical type of flat roof, the warm deck sandwich roof, an insulated and ventilated roof is often referred to as a cold deck roof.
The construction sequence is (from outside):

- surface finish,
- weatherproofing,
- structural deck,
- ventilation space,
- insulation,
- vapour control layer.

This roof configuration is prone to condensation forming on the underside of the structural deck, especially where ventilation is not well designed and/or realized.

Key risks to be aware of are:

- **Ventilation:** care should be taken to ensure airflow through the cavity within the roof, otherwise condensation will occur. This should be considered at the design but also when in operation where insect meshes etc. may get clogged.
- **Interstitial condensation**: depending on the activity within the occupied space below and relating to the outdoor climate the risk of condensation occurring within the roof fabric must be minimized. Should condensation occur then if unprotected it can flood the insulation layer and drastically reduce the performance of the fabric, potentially leading to a runaway problem. Particular care is needed in high moisture environments such as swimming pools.

Key properties:

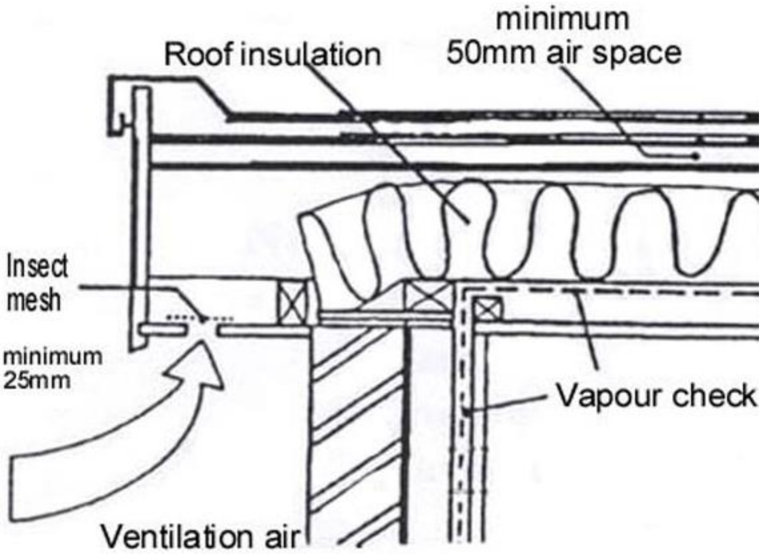
- Insulation – thickness typically determines the overall performance of the roof.
- Waterproof membrane/vapour barrier – resistance and location typically inform the design of where interstitial condensation risk will occur.
- Ventilation grille area – free area will dictate how much air can pass through the roof and help to prevent condensation from forming.

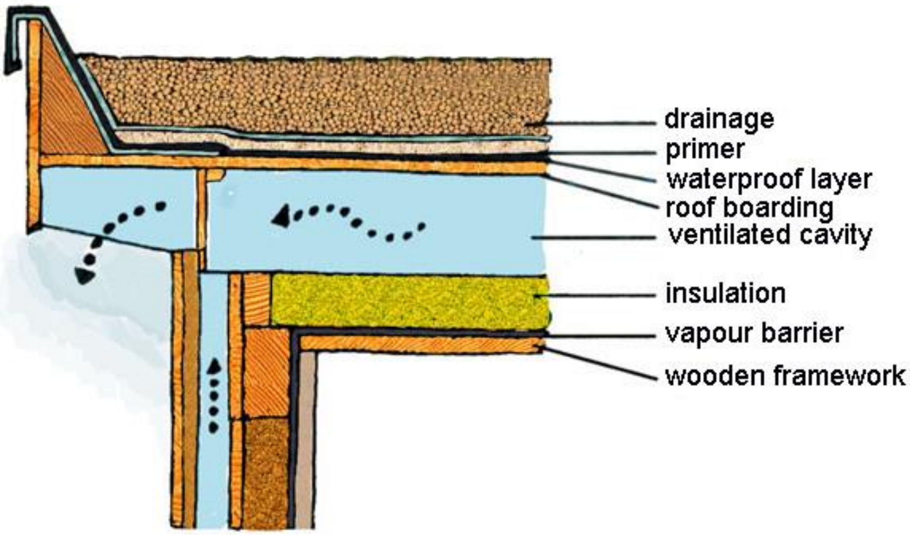
Flat roofs are fairly common in healthcare projects and the most common would be the standard insulated and unventilated roof type. This is due to issues with the ventilated flat roofs where condensation forms on the underside of the structural deck, which typically occurs when ventilation through the roof is poor.

References

http://www.touchstonelofts.co.uk/ventilation-loft-conversions.htm (image source - original unknown)

Figure





Source: http://www.faidanoi.it/

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient [W/m^{2}K]
Periodic Thermal Transmittance
Insulation material density [kg/m^3]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Volume [V]
Azimuth angle [% or degrees]

Codes of practice

Care must be taken to ensure the contractor construction of the roof takes into account for continuity of layers, and the fixings involved. This is crucial as any unwanted penetrations into the roof build up (e.g. nail fixings compromising the waterproof membrane) can lead to moisture buildup within the fabric.

3.2.14 FLAT ROOF: GREEN ROOF

[2.3.4]

Description

A green roof, or sometimes called a living roof, is a roof package with a waterproof covering and a thermal insulation, with various layers over the waterproof membrane, above all a soil substrate in the upper position, where a range of plants and vegetation can grow or form habitats for wildlife. Green roofs fall into 3 main types, according to their depth of substrate/growing medium, maintenance requirement and intended use.

Types of Green Roof

1. Extensive

This is a popular form and is not normally intended for human use. Generally has, low weight loadings and requires minimal/low maintenance. Usually plants are set in a lightweight growing substrate or medium generally of a depth between 20mm and 100mm. The plants used tend to be drought resistant types, due to the low water retention capacity as they are usually not artificially irrigated.

The 'extensive' roof is the simpler of the green roof types. The thin soil layer will only support low growing plants or turf and rarely water retaining reservoir is included in the make-up.

2. Intensive

Are very much intended for human use and is essentially a roof garden accessible to people and often incorporates a paved terrace. Has high weight loadings, deeper growing medium, of depths from 150mm up to around 1 meter, caters for a wide variety of shrubs, trees and grasses and requires maintenance and artificial irrigation. The 'intensive' roof makeup includes a water retaining reservoir

3. Biodiverse/Wildlife

This type of roof has a limited level of human interaction. Generally it as a similar build-up to that of an Extensive roof, but where varying depths of growing medium and a selection of plants are provided to increase the biodiversity to attract various or particular wildlife, depending on the biodiversity objective.

The green roof in comparison to an insulated roof offers more benefits in terms of thermal inertia (very suitable for Mediterranean climate), moreover it is helpful in reducing heat island in big districts (green helps in lower surface temperature) and in water retention (reducing water flow in sanitation and consequently the risk of flooding). It could also be an interesting solution for the patients and employees wellness.

Main Features and Benefits

Building Elements

- Improves thermal efficiency (thermal wheel) and energy saving.
- Reduces sound transmission.
- Increases roof lifespan.

Storm Water Management

- A key characteristic of green roofs is their ability to retain significant quantities of water and to release it through slow run off and vaporisation, reducing flows in surface water drainage systems.

Recycled Materials

- Many of the materials used in green roof construction are manufactured from recycled materials such as plastics, rubber and other materials, reducing landfill.

Environmental

- Absorbs greenhouse gases and air pollution (photosynthesis).
- Reduction of Urban heat island affect, caused by increase in temperatures due to impervious surfaces

Habitats

- Bio diverse roofs can provide habitats for animals and plants.

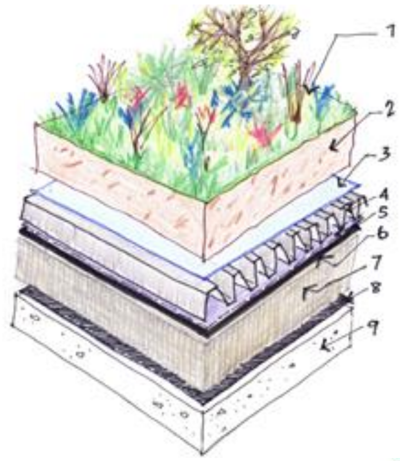
Utility and Value

- Provide amenity space where people can work and relax.
- Provide extra living space.
- Adds value to property.

References

Giacomello, E., "Copertura a verde e risorsa idrica. Implicazioni tecnologiche e benefici per l'ambiente urbano", Franco Angeli editore, Milano, 2012.

Figure



Typical Green Roof Construction/Make-up

1. Vegetation.
2. Substrate/growing medium.
3. Filter layer.
4. Water retention layer.
5. Roof waterproofing membrane protection /root barrier
6. Roof waterproofing membrane layer.
7. Thermal insulation.
8. Vapour control layer.
9. Roof structure. (Concrete / steel / Timber).

Source: http://www.genitronsviluppo.com/

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient [W/m^{2}K]
Periodic Thermal Transmittance
Insulation material density [kg/m^3]
Water absorption [vol %]
Vapour resistance [μ] or vapour permeability [sd or WDD]
Heat capacity [J/kg·K]
Fire reaction [EN 13501-1]
Sound absorbing [dB]
Water management
Volume [V]
Azimuth angle [% or degrees]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Particular attention must be paid to water retention layer and to the protection of the waterproof membrane from the plant roots.

3.2.15 FLAT ROOF:

COOL ROOF

[2.3.5]

Description

Flat roofs are generally considered to be those built below a pitch of 5°. The main components are the structural deck, thermal insulation and waterproof membrane covering.

- **Structural deck**: timber decks are usually found on housing and smaller non domestic buildings, whereas concrete and metal decks are found on larger developments. Concrete rarely deflects to the extent that problems arise for the coverings, whereas this can occur in a timber construction
- **Thermal insulation**: the location of the insulation largely determines the type of insulation used. The inclusion and location of the vapour control layer is critical to avoid condensation.
- **Waterproof membrane/covering**: options include bitumen, plastics and rubber sheets or metal. Dark surfaces will absorb more heat than light coloured ones.

The most typical type of flat roof is considered to be the warm deck sandwich roof.
The construction sequence is (from outside):

- surface finish,
- weatherproofing,
- insulation,
- vapour control layer,
- structural deck.

If the roof is subject to heavy traffic then the insulation and weather proofing will require protection from a material with high compressive strength (e.g. paving slabs).

Cool roofs are those with a surface designed to reflect much of the suns energy away from the building, thus leading to less energy being absorbed by the buildings thermal mass, and therefore a reduction of internal space cooling energy. Cool roofs are often associated as being light or white in colour, however with modern materials/finishes a wide range of possible alternatives are available.
Additionally cool roofs are able to reduce the urban heat island effect.

Key risks to be aware of are:

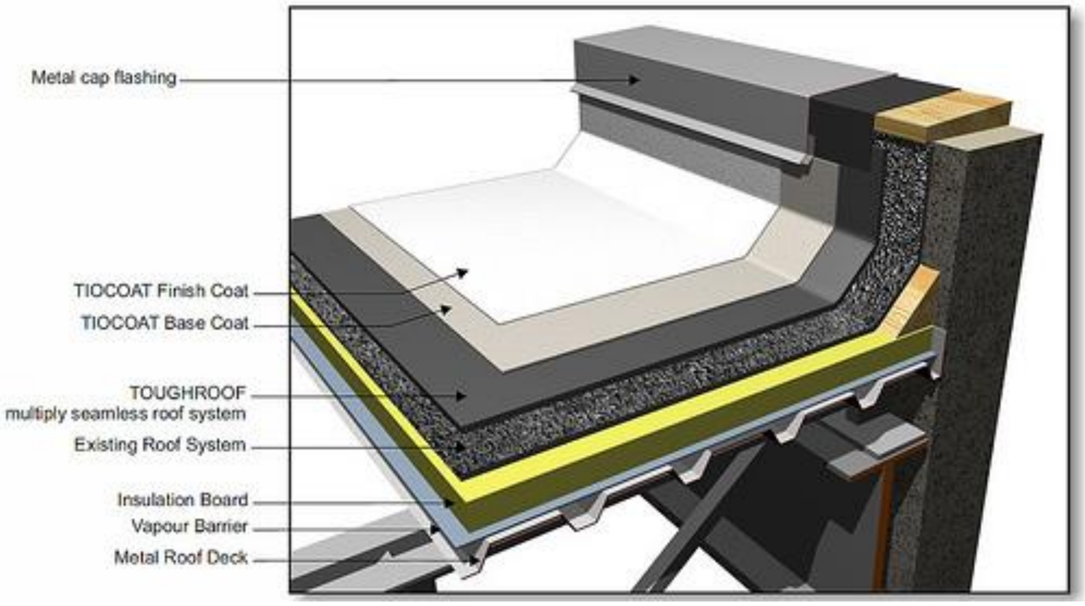
- **Climate:** depending on the local climate, it may or may not be beneficial to utilize a cool roof. For example in cooler climates with a predominant heating demand a cool roof will reflect away energy that would be useful in heating the building.
- **Interstitial condensation**: depending on the activity within the occupied space below and relating to the outdoor climate the risk of condensation occurring within the roof fabric must be minimized. Should condensation occur then if unprotected it can flood the insulation layer and drastically reduce the performance of the fabric, potentially leading to a runaway problem. Particular care is needed in high moisture environments such as swimming pools.

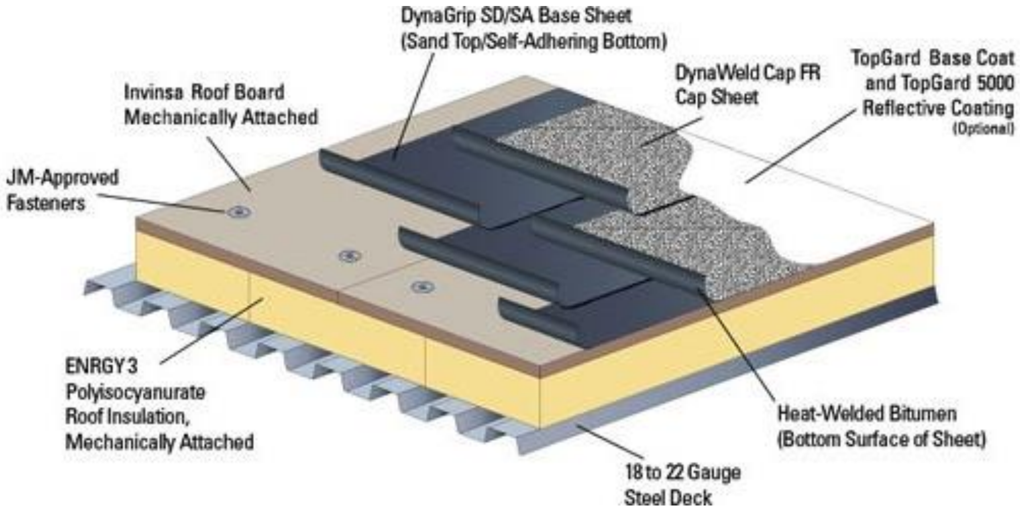
Cool roofs are typically utilized healthcare facilities in temperate climates where solar gain is seen as unwanted particularly in buildings with a primary cooling demand. In cooler northern climates utilizing a cool roof would have little benefit as the solar gain in winter would be useful in assisting the heating of the building.

References

http://www.italianamembrane.com/_upload/documenti/1052_62750_Depl_Color_Roof_ING_3.pdf
http://coolroofs.org/

Figure





Source: http://www.monstercommercial.com

Source: http://www.bestroofing.net

Parameters

Insulation material thickness d [m]
Heat conductivity coefficient λ [W/mK]
Thermal transmittance coefficient [W/m^{2}K]
Periodic Thermal Transmittance
Emissivity
Solar reflectance
Volume (V)
Azimuth angle [% or degrees]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

Care must be taken to ensure the contractor construction of the roof takes into account for continuity of layers, and the fixings involved. This is crucial as any unwanted penetrations into the roof build up (e.g. nail fixings compromising the waterproof membrane) can lead to moisture buildup within the fabric.

3.2.16 ACTIVE SOLAR ENERGY SYSTEM: PHOTOVOLTAIC PANELS ON TOP

[a.1]

Description

Photovoltaic panels are often used to lower the energy consumption of an existing building; in this case the structure of the system is independent and applied on the roof with connectors and metal frames in order to guarantee its resistance to the wind load and the snow load; this technology is named on top panels because the panels do not substitute the structure of the roof itself.

The visual impact depends on the type of roof the panels are applied to:

- Pinched roof: (Figure 1) the slope of the roof is enough for the panel to optimize the light absorption, so the panels are coplanar with the tiles;
- Flat roof: (Figure 2) the structure should ensure the optimal panels inclination from the sun rays throughout the year or, more often, when the intensity is the highest. The materials and the structure should be chosen to ensure maximum protection from the weather damage.

Independently from the type of roof the system is applied to, the project of photovoltaic panels must take into account the orientation of the roof and the buildings around to avoid shades and other obstacles to the maximum absorption. The roof surface occupied by the system depends on the requested final power and on the efficiency of each panel (e.g. amorphous modules occupy a wider surface per kW installed than the ones required for crystalline ones); therefore the design of a PV system should be obtain combining the best technology and the existing environment to satisfy the needs of the future user.

Average working time [h/year]: site specific, ranging from 900 kWh/kWp of Northern Europe to 1350 kWh/kWp of Southern Europe, depending also on the angle of the rooftop with respect to the horizontal and the South directions.
Lifespan [years]: 25.
Annual preventive maintenance [euro/year] : normally included in the plant management O&M contract.

Beyond the power supply obtained by this system, the on top solution allows an air circulation under the panel facilitating the panel cooling and, thus, a better efficiency.

It could be a good solution for any healthcare buildings thanks to the power supply obtained.

References

Luque, A. and Steven Hegedus, S., “Handbook of Photovoltaic Science and Engineering”, John Wiley & Sons Ltd, 2011.
Yogi Goswami, D. and Kreith, F., “Handbook of Energy Efficiency and Renewable Energy”, CRC Press, May 7, 2007.

Figure

Figure 1 Example of PV panels.

Figure 2 PV panels can be installed on different type of roof.

Source: http://www.hedar.it - http://www.ecoo.it - http://www.ondulit.it - http://www.greenstyle.it - http://www.sylesystem.com - http://www.leggilo.net

Parameters

PV module area [m^2]: *according to designed/ installed device*
PV cell efficiency [%]: *according to designed/ installed device*
Azimuth angle [% or degrees]
Efficiency [η_{TOT}]

Codes of practice

The system is independent and applied on the roof with connectors and metal frames in order to guarantee its resistance to the wind load and the snow load.

3.2.17 ACTIVE SOLAR ENERGY SYSTEM: INTEGRATED PHOTOVOLTAIC PANELS

[a.2]

Description

Photovoltaic systems are defined as integrated in the building envelope, if their structure is completely a part or integrated in the building envelope (on the roof or on the facades); this happens when the panels are installed on the same structure supporting the roof itself.

Being part of the roof and having no tiles below it, the system should keep the high level of waterproofing of the other standard waterproof surface; thus a waterproofing membrane must be provided during the installation.

A particular option is possible using amorphous silicon systems that, having a stiff shape, can be easily placed onto the waterproof surface. This kind of plants is usually cheaper than the traditional photovoltaic system, due to the lack of a supporting frame and the easily installation. Amorphous panels have a lower efficiency than polycrystalline systems, but this changes in case of cloudy weather and low sun light, since their characteristic to exploit the infrared portion of the solar radiation.

By simultaneously serving as building envelope and power generator, BIPV system is getting more and more popular thanks also to the architectural interest added to the building; the modules can also be made translucent making them suitable for windows and skylight (so far this type is less efficient and have a shorter lifespan).

Average working time [h/year]: site specific, ranging from 900 kWh/kWp of Northern Europe to 1350 kWh/kWp of Southern Europe, depending also on the angle of the rooftop with respect to the horizontal and the South directions.
Lifespan [years]: 25-30.
Annual preventive maintenance [euro/year]: normally included in the plant management O&M contract.

Beyond the power supply obtained by this system, the integrated solution works efficiently above all if an air circulation under the waterproof surface, and consequently under the PV panel is provided, facilitating the panel cooling and, thus, a better efficiency.

Being this solution more complex to be built than the simple installation on the rooftop, it is mainly used for new buildings or in case of total replacement of an existing roof.

It could be a good solution for any healthcare buildings thanks to the power supply obtained.

References

Luque, A. and Steven Hegedus, S., “Handbook of Photovoltaic Science and Engineering”, John Wiley & Sons Ltd, 2011.
Yogi Goswami, D. and Kreith, F., “Handbook of Energy Efficiency and Renewable Energy”, CRC Press, May 7, 2007.

Figure

PV panels integrated in a pinched roof

Source: http://www.braas.de - http://www.copertecnica.it - http://www.tegolacanadese.com - http://www.lavorincasa.it/sistema-tetto

Parameters

PV module area [m^2]: *according to designed/ installed device*
PV cell efficiency [%]: *according to designed/ installed device*
Azimuth angle [% or degrees]
Efficiency [η_{TOT}]

Codes of practice

The laying of the integrated PV panels follows the same procedure of the elements of the standard waterproof surface they refer to.
Always paying attention to get a good air circulation under the panels in order to get them cool.

3.2.18 ACTIVE SOLAR ENERGY SYSTEM: PHOTOVOLTAIC PANELS BUILT IN

[a.3]

Description

PV panels are built in when they are merged with the waterproof elements; the most common type of built in panels are the solar tiles.

The solar tile allows the roof to be not only the passive element covering the building, but also an active way to low the energy demand of the building itself.

Each tile works exactly like a PV panels: each module is connected to the others making a series or a parallel circuit; the energy is then directed to the inverter and then to the building in alternative current.

The Average operating time per year is site specific, ranging from 900 kWh/kWp of Northern Europe to 1350 kWh/kWp of Southern Europe, depending also on the angle of the rooftop with respect to the horizontal (tilt angle) and the South direction (azimuth angle). Since the full integration with the building envelope, it is very rare that the installation meets the optimal tilt and azimuth requirements.
Lifespan [years]: 25-30.

Beyond the power supply obtained by this system, the integrated solution works efficiently above all if an air circulation under the waterproof surface, and consequently under the PV panel is provided, facilitating the panel cooling and, thus, a better efficiency.

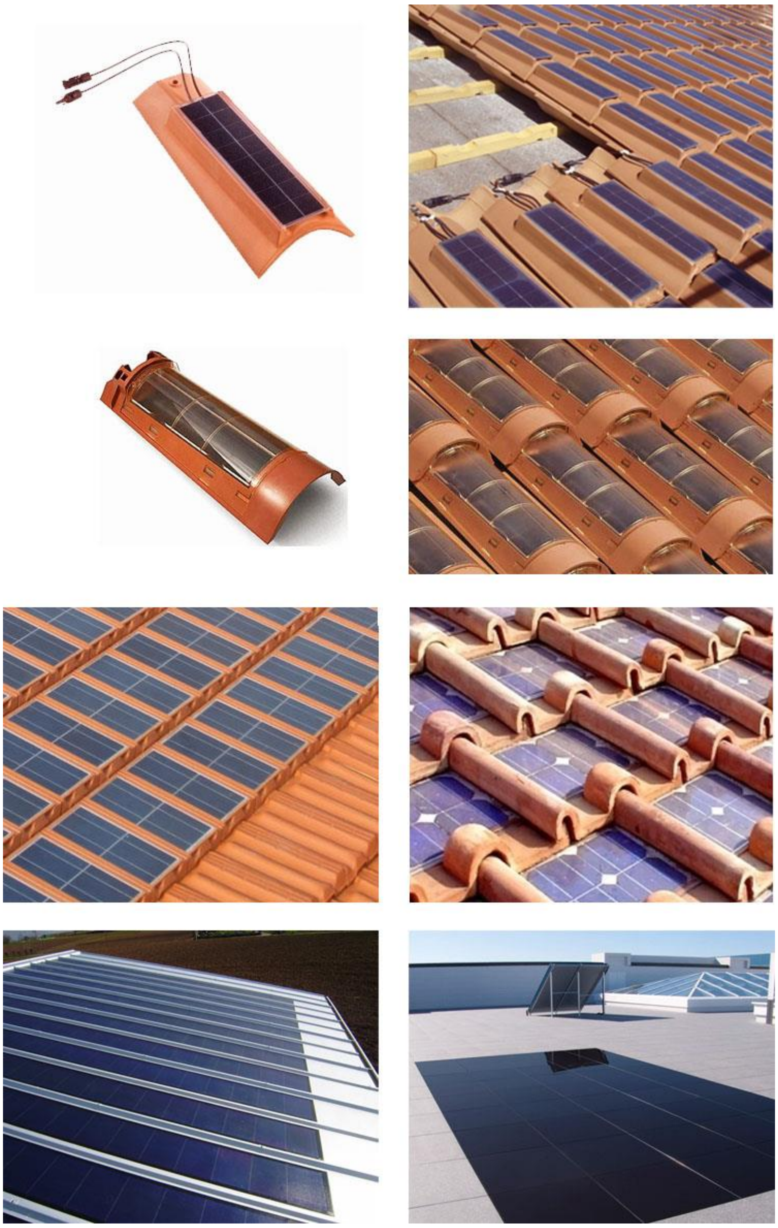
This technology is one of the solution for the integration of architecture and solar energy and it is useful where the use of PV panels has to deal with the architectonical and historical value of a building. In fact these systems are perfectly integrated in the roof and their visual impact is almost null.

It could be a good solution for any healthcare buildings thanks to the power supply obtained.

References

Luque, A. and Steven Hegedus, S., “Handbook of Photovoltaic Science and Engineering”, John Wiley & Sons Ltd, 2011.
Yogi Goswami, D. and Kreith, F., “Handbook of Energy Efficiency and Renewable Energy”, CRC Press, May 7, 2007.

Figure



Source: http://www.ecorisoluzioni.org/tegole-fotovoltaiche - http://www.fornacefonti.it - http://www.mdr-srl.it - http://www.butech.es - http://www.cottopossagno.com - http://www.cottopossagno.com - http://www.remenergies.it - http://www.remenergies.it

Parameters

PV cell area [m^2]: *according to designed/ installed device*
PV cell efficiency [%]: *according to designed/ installed device*
Azimuth angle [% or degrees]
Efficiency [η_{TOT}]

Codes of practice

The laying of the PV panels built in follows the same procedure of the elements of the standard waterproof surface they are built in.
Always paying attention to get a good air circulation under the panels in order to get them cool since they have to deal with the heat absorbed by the waterproof elements they are built in.

3.2.19 ACTIVE SOLAR ENERGY SYSTEM: PHOTOVOLTAIC WATERPROOF PANELS

[a.4]

Description

Photovoltaic systems can be used not only to collect the solar energy, but also as a waterproof layers of the rooftop sandwich envelope.

Unlike integrated PV panels – laid only on a portion of the waterproof surface – this panels fully substitute the whole waterproof surface with both performance of power supply and waterproof surface.

It is also been proved through resistance tests that the modules resist even extremely strong hailstorms not showing a significant drop of efficiency.

The Average operating time per year is site specific, ranging from 900 kWh/kWp of Northern Europe to 1350 kWh/kWp of Southern Europe, depending also on the angle of the rooftop with respect to the horizontal (tilt angle) and the South direction (azimuth angle). Since the full integration with the building envelope, it is very rare that the installation meets the optimal tilt and azimuth requirements.
Lifespan [years]: 25-30.

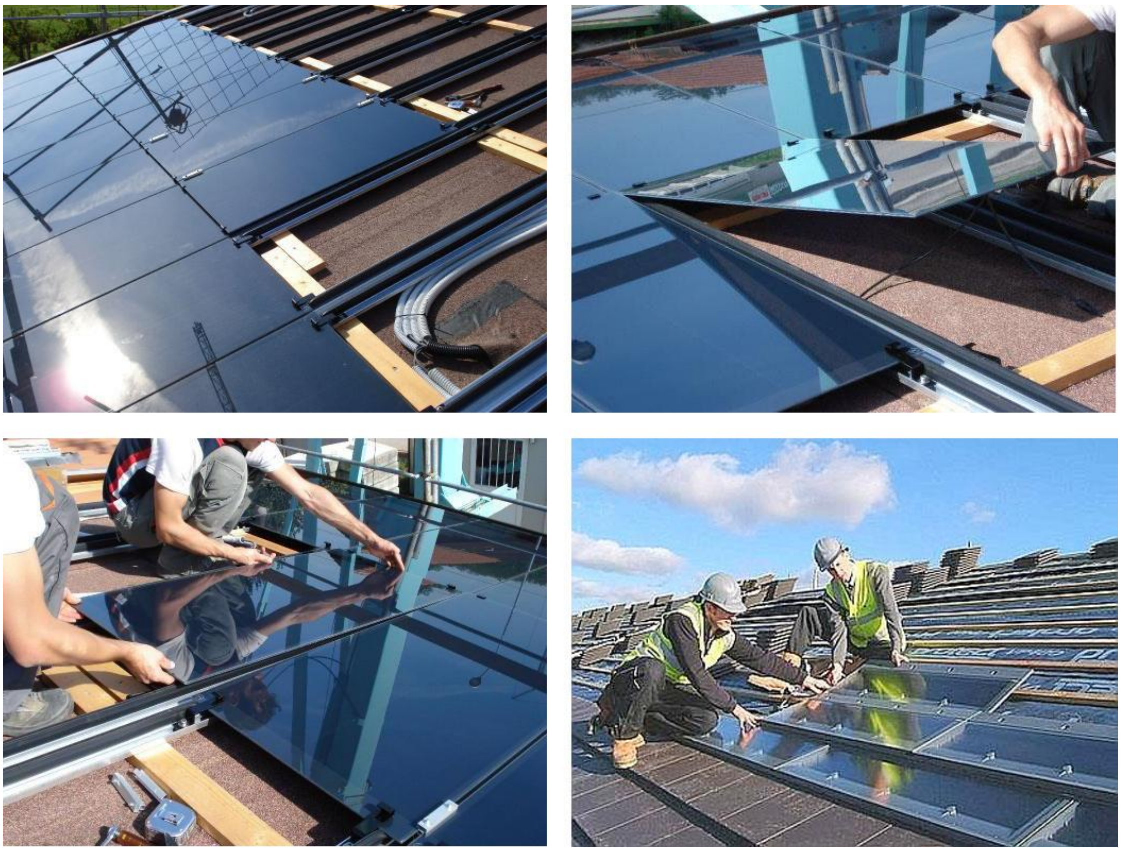
As the previous panels, also this system must be kept cool in order not to decrease its performances.

Being this solution more complex to be built than the others, it is only used for new pitched-roof healthcare buildings or in case of total replacement of an existing pitched roof.

References

Luque, A. and Steven Hegedus, S., “Handbook of Photovoltaic Science and Engineering”, John Wiley & Sons Ltd, 2011.
Yogi Goswami, D. and Kreith, F., “Handbook of Energy Efficiency and Renewable Energy”, CRC Press, May 7, 2007.

Figure



Sources: http://www.pallonetto.it - http://www.aniketos.it - http://www.aniketos.it - http://www1.adnkronos.com

Parameters

PV cell area [m^2]: *according to designed/ installed device*
PV cell efficiency [%]: *according to designed/ installed device*
Azimuth angle [% or degrees]
Efficiency [η_{TOT}]

Codes of practice

The laying of the PV waterproof panels follows the same procedure of the elements of a standard discontinuous waterproof surface.
Always paying attention to get a good air circulation under the panels in order to get them cool.

3.2.20 **ACTIVE SOLAR ENERGY SYSTEM:**

SOLAR COLLECTORS

[b.1]

Description

Solar thermal collector is used to obtain thermal power out of solar energy; this energy is then directed to an accumulator where it can be stored.

The plants are classified based on the average working temperature in low, medium and high temperature. Common installed systems work below 150°C (low temperature) or 200°C (medium), high temperature systems work at 1000°C and they are used for industrial plants and/or the production of electricity as well. The heat transfer fluid, mainly water, is warmed up in the solar circuit: it can be made of different materials from the simplest: the black painted copper pipes to the high tech solutions: titanium dioxide flat plate.

Average working time [h/year]: very site specific, depending on the final end uses, from the site climates, and from the collector typology.
Lifespan [years]: 15-20.
Annual preventive maintenance [euro/year] : 50-200 €/year.

The circulation of the fluid within the tubes can be either driven by temperature gradient (natural circulation) or by the hydraulic head given by a pump, the last solution leading the warmed water to a water storage tank, lodged in indoor spaces, instead of keeping it in the tubular tank installed on the top on the collectors, outside, directly on the rooftop, provides higher efficiency especially in cold climates.

The efficiency of the system depends mainly on the chosen materials and on the plants typology. As shown in Figure 1 solar collector can be easily integrated in the roof tiles: the pipes inside collect the energy and it is covered with tempered glass that protects the system and increases the energy absorption.

Choosing the best kind of technology between panels or pipes, it may be considered that normally a flat plate is made of two metal sheets and the fluid in between, the heating surface is then really high and this system can be classified as the more efficient in normal thermal condition.
Tubes vacuum collector are more common in colder areas because the vacuum inside each tube perfectly isolates the system maintaining a reasonable loss of energy; a different kind of transfer fluid is used: it is mainly water but it can also be an antifreeze fluid such as propylene glycol.

It could be a good solution for any healthcare buildings thanks to the thermal supply obtained, due to the higher hot water demand.

References

Kreith, F. and West, R.E. ,"CRC Handbook of Energy Efficiency", CRC Press, 24 October 1996.
Yogi Goswami, D. and Kreith, F., "Handbook of Energy Efficiency and Renewable Energy", CRC Press, May 7, 2007.

Figure

Figure 1 Example of solar collector

Figure 2 - Application on roofs

Source: http://www.viessmann.it - http://www.remenergies.it - http://www.energianuova.info - http://www.tettolares.com – http://www.portuguese.alibaba.com – http://www.solarthermie.bz.it

Parameters

solar collector area [m^2]: *according to designed/ installed device*
solar collector efficiency [%]: *depending on the system typology*
Azimuth angle [% or degrees]
Efficiency [η_{TOT}]

Codes of practice

The laying of the solar collectors follows the same procedure of all the PV solutions since they could be laid on top, integrated or built in with no needs of cooling air circulation.

3.2.21 **STRUCTURE:**

MASSIVE

[A]

Description

The massive framework of a roof, either flat roof or pitched roof, can be mainly make using "wet" technologies (hollow tile floor slab or poured concrete slab).

Other technologies may use:

- prefab components (concrete panels or mixed concrete-hollow tile panels),
- small clay components placed onto a wooden or steel framework (similar to Light structure) with or without the additional concrete casting,
- corrugated steel panels with additional concrete casting,
- etc.

The characteristic of this solution is to have an heavy mass working as a thermal wheel.

The energetic behaviour of this solution strictly depends on the position of the insulation layer:

- if laid above the roof structure it is warmed by the heating system and it works as an energy wheel for the underneath rooms (permanent use),
- if laid under the roof structure it is not warmed by the heating system and the underneath rooms reach the indoor temperature in a shorter time (temporary use).

Design for best solutions from an energy point of view do not exist, only issues of structural type.

Massive structure can be used for flat or pitched roof. Healthcare buildings can benefit from its performances: this kind of solution contributes to maintain both the indoor air temperature and the surface temperature steady, with limited variations and greater comfort level.

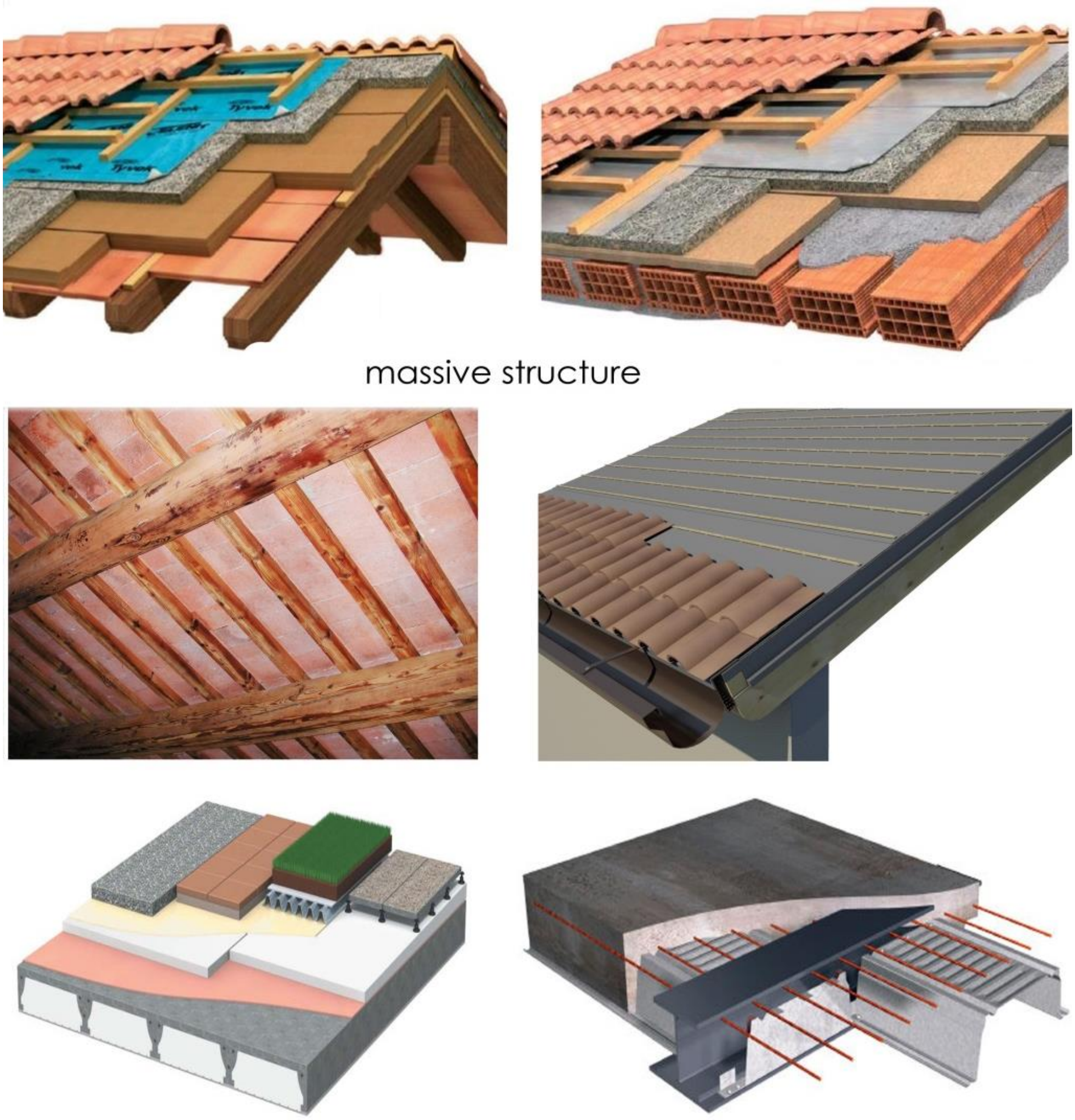
Key properties:

- thermal wheel effect,
- indoor temperature more steady with limited day/night variations and HVAC system on/off.

References

Zaffagnini, M. (edited by), "Manuale di progettazione edilizia", Hoepli, Milano, 1992.

Figure



Source: giovanni.zannoni@unife.it - http://www.celenit.com - http://www.re-pack.it - http://www.knauftherm.it - http://www.archiexpo.com

Parameters

Slab mass [kg/m^3]
Thermal wave phase shifting [h]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

The laying of an heavy-framework roof does not need specific caution from an energetic point of view.
Structural features have to be carefully deal with the control of thermal bridges to avoid gaps in the transmittance of the horizontal surface.

3.2.22 STRUCTURE:

LIGHT

[B]

Description

The light framework of a roof, either flat roof or pitched roof, can be mainly make using “dry” technologies of wooden and steel components.

On this solution, made up with different overlapping frames, the elements of waterproof layer could be laid or could be realized a continuous surface by a roof boarding. In any case, it is not a solution fitted for healthcare buildings.

The construction technologies based on wooden or steel linear elements can be transformed also in a massive structure framework (see Massive structure) with:

- clay blocks with additional concrete casting,
- corrugated steel panels or wooden panels with additional concrete casting,
- prefab elements,

equally increasing the mass of the roof for the entire surface.

The characteristic of the light framework is to have a small mass, lighter weight, whatever technical solution – depending on framework needs – is chosen.
There are no structural minus but, from an energy point of view, the light mass of the roof does not help to limit the thermal exchanges between indoor and outdoor and there is no thermal wheel effect. This constraint can be partially solved by placing one or two high-density thermal insulation layers even if similar levels of thermal inertia of a massive structure are no achievable.

Light structure can be used for flat or pitched roof. Usually this solution is not used in healthcare buildings due to its floating indoor air temperature and surface temperature: almost similar performance of a thermal wheel can be achievable only using technologies and components more expensive and more complex to be adopted.

Key properties:

- structural lightness,
- quick installation,
- low thermal wheel effect.

References

Zaffagnini, M. (edited by), “Manuale di progettazione edilizia”, Hoepli, Milano, 1992.

Figure

Sources: giovanni.zannoni@unife.it - http://www.nordbitumi.wordpress.com - http://www.marianaluigi.com – http://www.artigianarte2010.altervista.org - http://www.arealegno.it - http://www.holzfanil.it - http://www.zamperetti.com

Parameters

Slab mass [kg/m^3]
Thermal wave phase shifting [h]
Specific heat capacity or Specific heat [c_p]
Thermal diffusivity [α]

Codes of practice

These constructive systems are usually dry assembled: appropriate equipment (handling of the components) and skilled labour (knowledge and control of the connection among components) are needed.
Any particular energy requirements have to be solved during the design phase and are comparable to those related to an insulated roof.

4. Parameters

In this section, the parameters that measures the energy performance are listed and described. This is helpful in describing the energy performance of each technology by considering a standard value and the range between this is accepted (with reference to European standard, mentioned in the table).
It is important to underline that the following parameters are needed to correctly evaluate the energy requirements of a building in terms of energy transfer processes taking place through its envelope.
The acknowledgement of the parameters should then be considered pivotal in the implementation of BIM software as well.

Parameters were described according to the following classification:

- A Geometrical parameter
  - A1 Building parameter
- B Physical parameter
  - B1 Heat Transfer Phenomena
    - i General
    - ii Opaque elements
    - iii Transparent elements
  - B2 Thermal conduction phenomena
  - B3 Thermal Convection Phenomena
  - B4 Radiation Phenomena
- C Technological parameters
  - C1 General
  - C2 Ventilation plants
  - C3 Photovoltaic Systems
  - C4 Solar Low Temperature Thermal Collectors

Geometrical parameters allow to describe the building envelope and then they are particularly useful since the heat transfer from its component is directly proportional to the outer surface of the envelope. The wider is the frontier, the higher is the heat transfer, thus it is essential to link this parameter to the indoor volume that is served by the plant: compact building are normally more efficient compare to distributed ones.
The second group of parameters derives directly from the need to describe the heat transfer phenomena through the envelope, their nature is then straight related to physics since they appear in the laws (e.g. Fourier, Newton, etc.), that describe the thermal energy flow in accordance to the three possible transfer mechanisms - conduction, convection and radiation - taking in account energy storage within the building envelope elements as well (thermal capacity).
Some indirect parameters are added as well to the list (thermal diffusivity).
Finally technological parameters describing the potential of building integrated plants are provided.

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
A	**GEOMETRICAL PARAMETERS**							
A1	**Building Parameter**							
01	Surface area (elements of the building envelope)	Extension of a certain part of the building envelope, distinguished by the same properties in terms of materials and their thermal properties (e.g. thermal transmittance, etc.)	Numbers	m^2	[SI]	Site Specific	A	Allows to group the envelope elements into macro-categories identified in accordance to their materials characteristics and thermal properties
02	Floor surface area	Floor surface area of indoor spaces	Numbers	m^2	[SI]	Site Specific	S	Surface of indoor spaces (walkable surfaces) describes the extension of a certain room, or of a certain building areas. In hospitals and big facilities, for energy calculation it is effective to define the floor surface of the parts of the building that are homogeneous in terms of end uses and/or plants that operate there (e.g. area served by the same ventilation unit, etc.)
03	Floor height	Floor height of indoor spaces	Numbers	m	[SI]	Site Specific	h	Floor height of indoor spaces measured considering or not the layers ceiling/floor
04	Volume	Extension in terms of volume of a certain part of the building, whose indoor spaces are characterised by the same properties in terms of materials and their thermal properties (e.g. thermal transmittance, etc.)	Numbers	m^3	[SI]	Site Specific	V	Allows to group the indoor areas into macro-categories identified in accordance to their materials characteristics and thermal properties
05	Roof slope	Angle between the pitch and the horizontal plane (Tilt angle)	Numbers	% or degrees	[SI]	Site Specific	i	It provides the angle between the roof pitch and the horizontal, these parameters are very important in the evaluation of the potential of solar technologies
06	Roof length	Lengthwise dimension of the roof	Numbers	m	[SI]	Site Specific	ξ	Lengthwise dimension of the roof

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
07	Roof Pitch length	Latitudinal dimension of the roof, measured in parallel to the pitch.	Numbers	m	[SI]	Site Specific	η	Latitudinal dimension of the roof, measured in parallel to the pitch
08	Azimuth angle	Angle between the south vector and the perpendicular projection of a certain element of the envelope (origin)	Numbers	% or degrees	[SI]	Site Specific	i	It provides the angle between the south vector and the perpendicular projection of a certain element of the envelope from an observer , these parameters are very important in the evaluation of the potential of solar technologies
B	**PHYSICAL PARAMETER**							
B1	**Heat Transfer Phenomena**							
i)	**General**							
01	Thermal Transmittance coefficient / U Value	Indicates the amount of heat flow through a certain element with the temperature difference of 1 Kelvin. EN ISO 6946 - UNI TS 11300	Numbers	W/m^2K	[SI]	Depends on national regulation	U	Refers to thermal property of a certain element of the building envelope to be passed though by heat
02	Periodic Thermal Transmittance	Capacity of an opaque part of the envelope wall to phase shift and to mitigate the thermal flow over 24 hours EN ISO 13786:2008	Numbers	W/m^2K	[SI]	Depends on national regulation	YiE	Refers to thermal property in summer regime of the wall (layers)
03	Heat capacity	Heat capacity, or thermal capacity, is the measurable physical quantity of heat energy required to change the temperature of an object by one Kelvin degree.	Numbers	J/K	[SI]	Site Specific – Depend on Materials	C_m	Refers to the thermal properties of the envelope (e.g. water flow control for roofs – wet earth improves heat capacity)
04	Specific heat capacity or Specific heat	Specific heat is the heat capacity per unit mass of a material (at constant pressure or volume). In engineering contexts (e.g. heat transfer phenomena throughout building envelope) it is used the heat capacity at constant pressure (atmospheric pressure)	Numbers	J/(kgK)	[SI]	Site Specific – Depend on Materials	c_p	Specific heat capacity is a fundamental parameters necessary to properly evaluate the heat transfer phenomena throughout the envelope. It provides ad esteem of the characteristic of the materials constituting the envelope to overstock thermal energy in their mass

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
05	Thermal diffusivity	Thermal diffusivity is the ratio between thermal conductivity and the product of the density and the specific heat capacity at constant pressure	Numbers	m^2/s	[SI]	Site Specific – Depend on Materials	α	This indirect parameter is fundamental since it allows to measure the aptitude of a certain element of the envelope to overstock thermal energy (denominator) rather than to let the heat passing through its mass (numerator)
06	Material density	In physics density is defined as mass per unit volume.	Numbers	kg/m^3	[SI]	Depend on Materials	δ	Given a certain element, density is the mass divided by its volume. In general density of a material varies with temperature and pressure. This variation is small in solids and liquids but much greater in gases where it cannot be neglected
ii)	**Opaque Elements**							
01	Thermal Transmittance coefficient for wall	Indicates the amount of heat flow through a wall with the temperature difference of 1 Kelvin. EN ISO 6946 - UNI TS 11300	Numbers	W/m^2K	[SI]	Depends on national regulation	U_W	Refers to thermal property of the wall (layers)
02	Thermal Transmittance coefficient for roof	Indicates the amount of heat flow through a wall with the temperature difference of 1 Kelvin. EN ISO 6946 - UNI TS 11300	Numbers	W/m^2K	[SI]	Depends on national regulation	U_W	Refers to thermal property of the roof (layers)
iii)	**Transparent Elements**							
01	Thermal transmittance coefficient for window element	Indicates the amount of heat flow through a window (glass and frame) with the temperature difference of 1 Kelvin. EN ISO 10077	Numbers	W/m^2K	[SI]	Depends on national regulation	Uw	Refers to thermal property of the window
02	Solar factor	The ratio between the thermal energy globally transmitted from the glass pane and that incident on it. EN 410	Numbers	% or simple number		Depends on glass properties	G or ý	Refers to thermal and light properties of the window

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
B2	**Thermal Conduction Phenomena**							
01	Heat conductivity coefficient/thermal conductivity	Is the property of a material to conduct heat. According to Fourier's law, it is the ratio between the heat transfer and the temperature gradient that generates heat flow between the material. UNI 10351 Building materials and products. Hygrothermal properties. Tabulated design values EN ISO 12524:2000	Numbers	W/m K	[SI]	Depends on material: from 10-2 W/mK, for insulating materials, to 10-1 W/mK, for concretes, from 100 for stones, glass, etc. to 102 for metals	λ	Refers to thermal property of a single material
02	Thickness	Distance between two opposites parallel surfaces of the same material in the direction perpendicular to the heat flow	Numbers	m	[SI]	Site Specific	d	Insulation material thickness is fundamental in the thermal transmittance calculation
B3	**Thermal Convection Phenomena**							
01	Outdoor Air Speed/Wind direction and intensity	The flow of outdoor air in proximity to the external surfaces of the elements of the building envelope	Numbers	m/s	[SI]	Site Specific	v	Refers to convection phenomena interesting outdoor skins of the envelopes
02	Air gap ventilation speed	The flow of air in a cavity as a result of pressure or temperature differences UNI 11018	Numbers	m/s	[SI]	Depends on national regulation	v_{GAP}	Refers to passive cooling properties (passive ventilation)
B4	**Radiation Phenomena**							
01	Emissivity coefficient	Indicates the radiation of heat from a 'grey body' according the Stefan-Boltzmann Law, compared with the radiation of heat from an ideal 'black body' with the emissivity coefficient ε = 1	Numbers	simple number		[0,1] Site Specific – Depend on Materials	ε	This parameter is very important in radiation heat transfer phenomena influencing for instance the faculty of the external surface of a certain element to emit energy after having absorbed heat

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
C	**TECHNOLOGICAL PARAMETERS**							
C1	**General**							
01	Efficiency	In an energy transformation this is the ratio between the energy output of the transformation (independently from the kind of energy) and the energy input (every time it is possible, better if measured in terms of primary energy)	Numbers	% or simple number		[0,1]	η_{TOT}	This parameter directly provides a measure of how the energy is converted during a transformation, the highest the value, the lowest are the irreversible losses
02	Coefficient of Performance	In refrigeration-type cycles Coefficient of Performance is defined as the ratio between the desired energy output (cooling for refrigerators, heating for heat pump) and the required energy input (normally electricity), it is the equivalent of the efficiency parameter for reverse cycles plants	Numbers	% or simple number		≥ 0	COP or ε	Refers to the efficiency with whom the desired energy output is obtained in reverse cycles plants
C2	**Ventilation Plants**							
01	Air flow rate	Volume of fresh/recirculated air guaranteed by a ventilation plant in a certain indoor environment	Numbers	m^3/h	[SI]	Site Specific	V	Refers to mechanical ventilation systems
02	Air change rate	Volume of fresh/recirculated air guaranteed by a ventilation plant in a certain indoor environment divided by its volume	Numbers	simple number		Site Specific – recommended values depend on the end uses in the indoor space	n_V	Refers to mechanical ventilation systems
C3	**Photovoltaic Systems**							
01	PV module area	Surface of the photovoltaic modules able to collect solar energy	Numbers	m^2	[SI]	Depend on the Product	S_{PV}	Refers to energy active systems
02	PV cell efficiency	It measures the capacity of a PV cell to transform solar radiation in electrical energy	Numbers	% or simple number		Depends on PV cells properties	η_{PV}	Refers to energy active systems

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
C4	**Solar Low Temperature Thermal Collectors**							
01	Solar collector area	surface of the solar collector able to collect solar energy	Numbers	m^2	[SI]	Depend on the product	S_S	Refers to energy active systems
02	Solar thermal collectors efficiency	It is the capacity of a solar collector to transform solar radiation in heat by means of the absorber area that collects solar energy, based on the % of solar thermal radiation hitting the absorber and transferred to the fluid loops	Numbers	%		Depends on collectors properties	η_S	Refers to energy active systems

5. Conclusion

The report offers an overview of technical and architectural solutions for envelope and building space that can be applied to healthcare districts in order to fulfil or improve the energy standards.
The criterion related to the research and the selection of the technologies, especially considering their use on healthcare district envelopes, was the crucial point in the implementation of the report.

In the early stage of work, focused on a brief overview on the overall parameters that influence energy performances, Thermal insulation (U value), Thermal inertia (Yie value), ventilation, and all other basic factors recommended for to design a low-energy-use building has been listed.
Some technical parameters are commonly adopted and represent the usual basis for the energy balance calculation (e. g. the U value for thermal insulation performance). Some other ones can be considered as "innovative" parameters as they can influence energy performance but they are rarely mentioned in energy regulations. As an example the "albedo coefficient" has been considered very important to decrease the cooling load significantly. Heat radiation can be reduced by using light coloured coating with high reflectance, as explained in the technical solution 1.1.2 "light color of the outside wall".

In a second stage, the technologies able to perform a determined performance were listed, considering vertical envelope (façades) and horizontal envelope (roofs).
The classification of technologies can be based on several criteria: it can be either done by envelope materials (opaque/glass) or structural solutions (light/heavy). As the final objective of the deliverable is to give indication on the suitability of a technology and on its benefit in terms of energy saving in the hospital buildings, the energy performance was the "driven-indicator" that the choice of the system was related to.
The recommendations do not include all the existing technologies for envelopes, anyway they focus on the most important parameters applied for the energy balance (insulation, ventilation, solar energy) including both traditional systems (e.g. ETICS) and innovative systems (e.g. aerogel panels, double skin façades). In the case of innovative techniques, the applicability of a certain system to the Healthcare District has been based on scientific references, literature and technical websites.
Otherwise, since all the solutions are subject to an aging process, it should be considered that their energy efficiency performance can be guaranteed only if a correct maintenance programme is ever carried out during their life cycle.

The design and construction of a high-performance hospital requires an integrated approach where energy saving measures are a priority at the same level as health and comfort of the occupants.
The ways in which indoor environmental factors, such as thermal conditions, acoustics, and illumination, interact can be either beneficial to both sustainability efforts and occupant health. How these factors interact with the design of the building spaces and layouts is an issue analyzed in the first section of the deliverable (Chapter 2).
Basically, this deliverable can provide some indications for achieving energy savings goals by using architectural and technical solutions (envelope and space) that are feasible, operationally workable, and

otherwise readily achievable. These recommendations can be used to meet further requirements in terms of MEP by “meshing” data and inputs to combine the best energy saving performance.

The individual components of the envelope building design are highly integrated and impact the energy savings of the whole system, so an overview of possible usable strategies can give the clearest picture of how they can meet the needed requirements in a whole-building energy use.

The report is strictly connected with:

- Task 1.1 “Typology models of healthcare districts”, D1.1 “Taxonomy of healthcare districts focusing on EeB morphology and features” due to their cross topic “building layout” (see paragraph 1.1);
- Task 3.1 “EeB performance indicators”, D3.1 “Building-oriented EeB KPIs of newly designed and retrofitted buildings” due to their cross topic “parameters” (see chapter 4).

Results achieved will provide inputs and will be applied in the work to be carried out in Tasks 7.1/7.2/7.3/7.4: classification and selected parameters will be tested on the Demonstration Projects. Other outcomes related to this work will give inputs to WP3, WP5, WP6.

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