IEA ECBCS Annex 36: Retrofitting in Educational Buildings – Energy Concept Adviser for Technical Retrofit Measures

SUBTASK A

Overview of Retrofitting Measures

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Chapter 5

Solar control and cooling systems

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Table of contents

5.1. Introduction

In school buildings, there is a need for sufficient daylighting in teaching areas for both comfort and energy savings purpose. As a result, large glazed surfaces are often proposed as part of the facade retrofit. It is of particular importance that the problems of glare and summer overheating can be analysed at the same time. Indeed, if the luminance of the sky seen through a window is very high compared to that of visual task, disability glare can result in a reduced performance (even a risk of accident). Discomfort due to high luminance contrast is most likely to happen and should be treated with special devices attached to the window design. These devices must be chosen in order to reduce at the same time inconveniences due to sunlight, likely to lead to excessive direct heat and glare.

As a result, ideal shading devices should reduce solar radiation whilst admitting diffuse radiation as daylight and allowing outside view. This selective mode of radiation control is difficult to attain because all shading devices reduce daylight availability.

The approaches to control sunlight and prevent glare from skylight can be classified into the following means [1]:

- Selection of appropriate orientation, tilt and size of the openings
- Obstruction of sun beam by use of envelope additions or shading devices
- Selection of internal or external shading devices according to their solar optical properties

This paper will not deal with bioclimatic buildings eg. solar collection or storage, but only with solar control and especially shading devices. Also, the design of the openings will not be discussed any more as a solar control technique although it is certainly the first step to avoid summer discomfort and visual glare in the design process.

As part of the solar control techniques we will then consider specific devices of last two kinds of the above list.

5.2. Shading systems and glare protections

To choose a solar control device we need to consider:

- The site latitude
- The orientation of the facade
- The orientation of the openings (vertical or horizontal)
- The aesthetic of the facade
- The glazing type of the window
- The need for daylight
- The need to get a completely opaque solution or not
- The need to have air passing through it
- The performance of the solar control device itself
- The control of the solar shading if movable

The overall thermal and optical performance of a solar control device in respect to solar radiation impinging on it is based on the phenomena:

- Primary transmission: beam solar radiation passes directly through the shading assembly
- Reflected transmission: beam solar transmission passes through the shading assembly by multiple reflection on the slats and/or the set-back (belonging to the building)
- Diffuse transmission: diffuse solar radiation passes through the shading assembly directly and by multiple reflection

- Solar absorption: solar radiation is absorbed by the shading assembly and may in turn be transmitted via:
  - Conduction within the shading assembly
  - Convection to the surrounding air
  - Longwave radiation towards the glazing, set-back; outdoor or indoor environment (depending on the location of the device) or another part of the shading assembly at a different temperature.

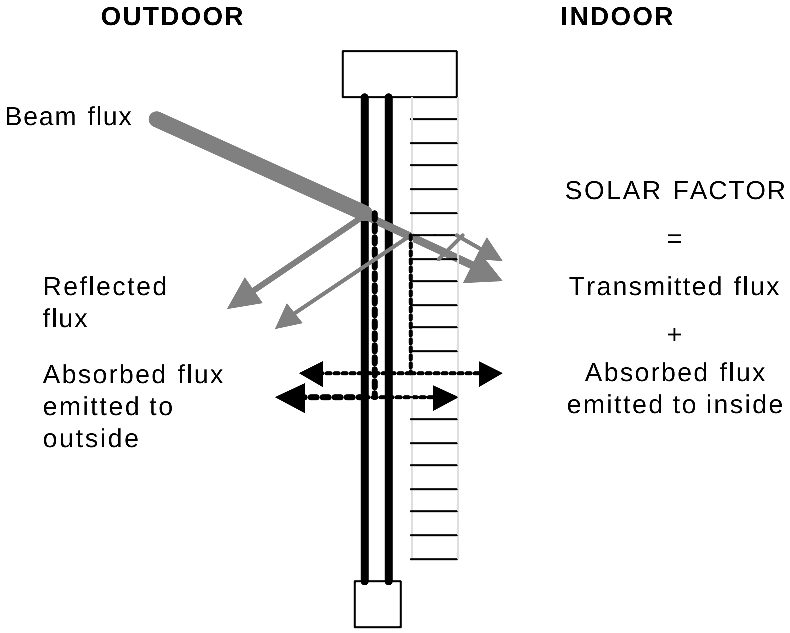


Fig. 5.1. Illustration of the thermal and optical performance of a solar control device in respect to solar radiation

The global shading efficiency of a device is the result of all these direct and indirect transmission processes. Two parameters are commonly used to characterise the device performance:

- Solar gain factor or solar factor (SF) defined as the fraction of the incident solar energy which passes through the device
- Shading coefficient (SC) defined as the ratio between the solar factor of the assembly and the solar factor of the reference opening made of a single pane clear glass (table 5.1).

Shading devices are also essential to avoid glare situations. If their luminous transmittance is too high (above 10% in general), the risk of glare is significant, with luminance reaching more than 1 000 cd/m^2 for an illuminance on the awning of 40 000 lux [2]. So, screens with transmission factors lower than 10% are sufficient to avoid glare from the sky.
The principle of an ‘ideal’ screen is to reflect the maximum amount of solar rays from its external surface and to reduce transmission to ensure optimum control of glare phenomena. From the table above, we can observe the performance for example of the grey screen, in outside position (ref: Hexcel Lyverscreen Satin 525). With this screen, we obtain a shading coefficient of 0.14, this signifies that the reduction of the thermal contribution of the window is significant since the screen eliminates around 80% of the thermal contribution of the window (the same screen placed inside eliminates around 50% of the thermal contribution of the window). The daylight transmittance equal to 5% is sufficient to avoid glare from the sky.

Table 5.1. Example of shading coefficient given by manufacturers for some shading devices

Type of shading device	Shading Coefficient	Daylight Transmittance
Screens (outside position) (ref: Hexcel Lyverscreen Satin 525)	0.14 grey 0.20 yellow 0.26 white	5% grey 18% yellow 25 % white
Screens (inside position) (ref: Hexcel Lyverscreen Satin 525)	0.48 grey 0.36 yellow 0.37 white	5% grey 18% yellow 25 % white
Reflective film inside (ref DTI reflective with a 4 mm clear glass)	0.26 argent 20 0.42 argent 35	20% argent 20 35% argent 35
Ionised film inside (ref DTI Sputter with a 4 mm clear glass)	0.67 inox 50 0.41 inox 75 0.46 bronze 50 0.26 bronze 75 0.49 XH50	50% inox 50 23% inox 75 45% bronze 50 22% bronze 75 45% XH50
Sealed blinds (for a chosen blades tilt)	depends on sun elevation, no data	No data

We have seen before that the choice of shading device is influenced by the site latitude and façade orientation. The choice of the screen fabric best adapted for each façade is defined by the trajectory of the sun or its absence on the façade concerned. In fact, in Northern European countries the sun is low over the horizon for most of the day, lighting south oriented façades. Therefore a screen with a very low transmission rate must be installed (3% for example). On the contrary, north facing facades need to optimise the sky's luminance, as there is no direct exposure to the sun. In this case, there is no point in using a screen with a low transmission rate, as this would considerably reduce the contribution of natural light inside the office. A screen with 10% daylight transmittance will manage this level of external luminance.

These parameters are based on the boundary conditions assumed in the ISO/DIS 9050 for glass tests. Designers and decision makers must be conscious that the performance of the shading assembly might be different in the actual application conditions. Main reasons are:

- Only the direct solar radiation and a fixed solar incidence angle are considered in the standard tests, although some experiments have shown that the shading device performance is strongly dependent on the ratio direct/diffuse.
- The distance between the shading device and the glazing is ignored. As far as the size of slats is small this distance can be disregarded but the fraction of sunlit device for medium/large slats can be influenced by this distance.

Moreover, the terminology itself is misleading as Shading Factor should consider the reduction of heat gain achieved by the shading device.

5.3. Cooling Systems

The control of the environmental conditions for educational facilities directly impacts the performance of the students and staff that occupy the space. One of the elements which control environmental conditions is the cooling (air conditioning) system selected. There are five categories of cooling systems with several variations within each. This section will highlight these five categories looking at appropriate climate zones to use, cost effectiveness, benefits, and operation and maintenance.

The five categories cooling to be described are:

a. Natural
b. Evaporative
c. Direct expansion
d. Chilled Water Plant
e. Geo-Exchange

Natural Cooling – There are two methods of providing natural cooling (ventilation): Cross and Stacked.

a. **Cross ventilation/cooling –** This method depends on the movement of air through the space to equalize the pressure. Wind, which blows against a wall or barrier is deflected around and above the barrier creating a higher pressure on the windward side of the building. The pressure on the leeward side of the building then has a lower pressure creating a suction and thus a pressure differential. When windows or other means of ventilation are opened, the outdoor air enters on the windward side moving to the lower pressure area. The movement across the teaching space, results in exhausting the internal air and cooling the space.

This method is very effective in mild climates and coastal climates. In coastal climates the need for a cooling system will almost be eliminated. This method does require an initial greater up front cost for operable windows which can range from 42 Euros to 62 Euros per classroom.

The benefits from using cross ventilation/cooling are:

1. In moderate climates meet most of the cooling load needs
2. Simple pay back for inclusion of this method from 8 to 10 years
3. Better indoor air quality
4. Simple to install and little maintenance
5. Give occupants a sense of individual control

b. Stack ventilation/cooling – This method depend on the difference in air densities to

Provide air movement in the teaching space. Two vents are needed for this method to work: One Close to the floor and the other high in the space. Warmed by internal loads (student/faculty, lights, and equipment) the indoor air rises. The warmer the air the less dense and it rises. This rising of the warmer air creates a vertical pressure gradient. The vent close to the system will allow the rising warmer air to escape and as it escapes it will draw in cooler air from the lower vent to replace it. Thus causing air movement and cooling of the space.

This method like the cross ventilation/cooling is very effective in mild and coastal climates. This method is especially effective in the winter when inside-outside temperature differential is at its maximum. And during mild weather conditions it can meet most of the cooling requirements. The benefits are the same as above as are the cost effectiveness.

Evaporative Cooling

Evaporative cooling is an alternative to air-conditioning with low energy costs because no compressor is needed, only a fan and a pump. This method is good for educational areas with high outside air ventilation requirements. Evaporative cooling can be either direct or indirect. Direct cooling involves the water being exposed to an air stream. This happens when water flows over a medium designed to maximize the surface area of water in contact with the air and air is cooled through evaporation. Effectiveness can be as high as 80 – 90%. Example: 26.7C air dry-blub with a 10C wetbulb, then the leaving air is cooled to 11.7C to 24.4C drybulb.
Indirect evaporative cooling is not as effective as direct, but adds no moisture to the air. Air passes over and through a cooling coil supplied with water from a remote cooling tower. This method is only 60% effective in reducing the dry blub temperature of the entering air to its wetblub temperature. When the direct method provides 22.2C to 23.3C air in the above example then indirect would only provide 25.6C air.
Initial installation costs are more than a typical AC unit the operating costs are significantly less. It is cost effective in warm and dry climates when higher indoor temperatures are acceptable during hot periods.

Direct Expansion Cooling

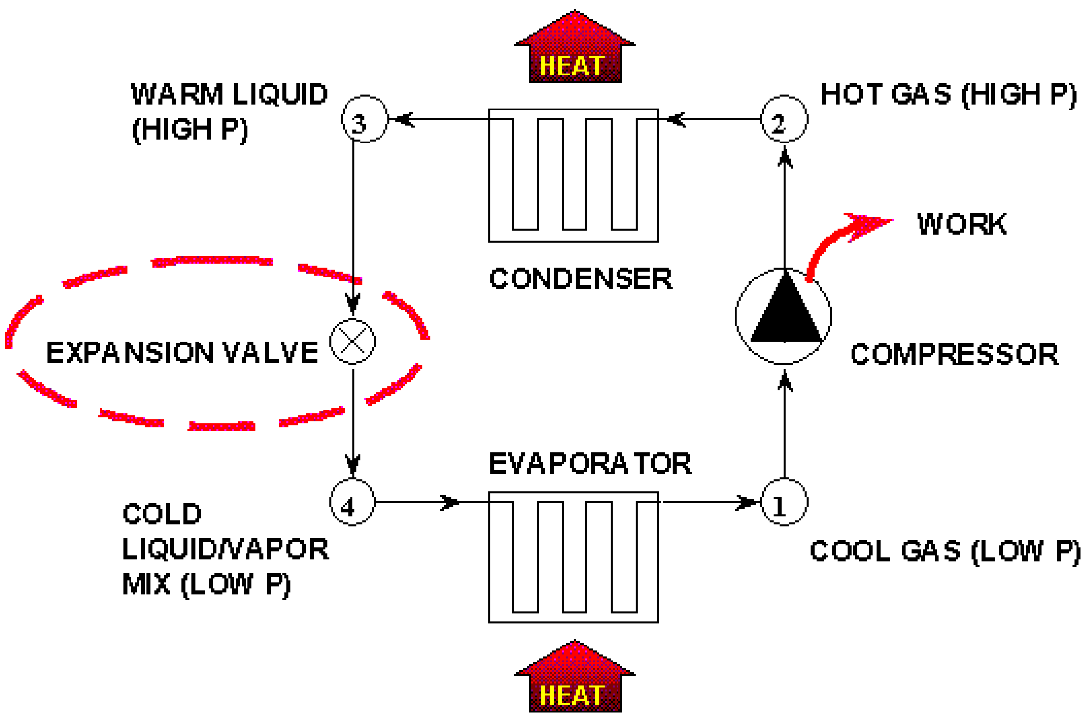


Fig. 5.2. The flow diagram of Direct Expansion Cooling cycle

Direct Expansion, or "DX", cooling uses the vapour compression refrigeration cycle in which a fluid called a refrigerant moves heat from one part of the cycle to another. The "cool" refrigerant is produced between states 3 and 4, after a large pressure drop (expansion) takes place. Typical devices used to produce the pressure drop include expansion valves, capillary tubes, and orifice plates. The cool refrigerant can then be used as a heat transfer medium in the evaporator to absorb heat where needed. In a normal DX unit this medium in air. DX systems are connected to Air Handling units for distribution of cooled air to specific zones of the educational facility these are know as split-systems.

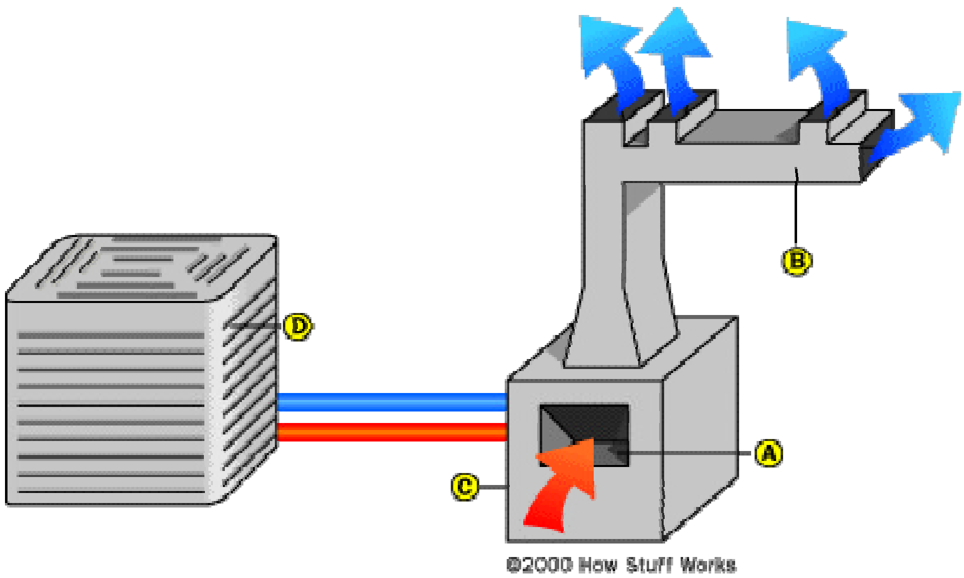


Fig. 5.3. A **split-system air conditioner** splits the hot side from the cold side of the system

The **cold side**, consisting of the expansion valve and the cold coil, is generally placed into a **air handler**. The air handler blows air through the coil and routes the air throughout the building using a series of ducts. The **hot side**, known as the **condensing unit**, lives outside the educational facility and in most cases on the roof. In other systems the medium will be a liquid which is normally a treated water.

Chilled-water System

In larger educational buildings and particularly in multi-story educational buildings, the split-system approach begins to run into problems. Either running the pipe between the condenser and the air handler exceeds distance limitations (runs that are too long start to cause lubrication difficulties in the compressor), or the amount of duct work and the length of ducts becomes unmanageable. At this point, it is time to think about a **chilled-water system**.

In a chilled-water system, the entire system lives in a mechanical room or behind the building. It cools water to between 40 and 45 F (4.4 and 7.2 C). This chilled water is then piped throughout the building and connected to air handlers as needed. There is no practical limit to the length of a chilled-water pipe if it is well-insulated.

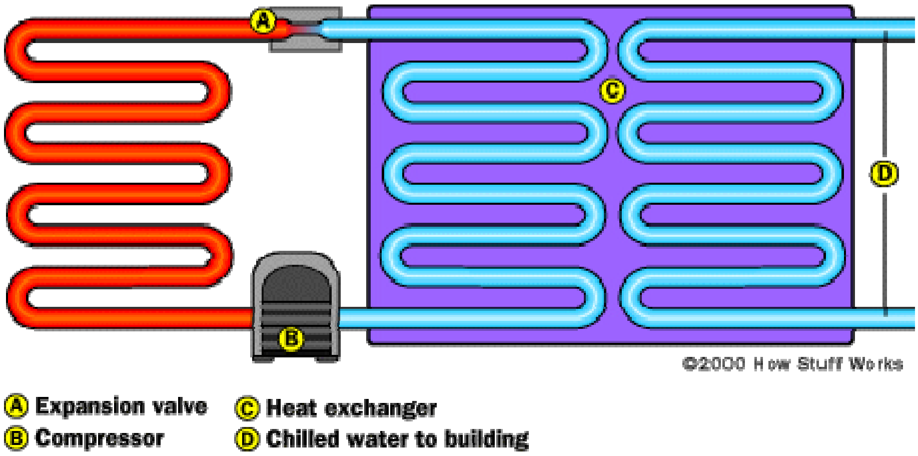


Fig. 5.4. Cooling Tower

You can see in this diagram that the air conditioner (on the left) is completely standard. The heat exchanger lets the cold Freon chill the water that runs throughout the building. To obtain maximum cooling capability of the Water in ©, a cooling tower is added in the flow of water in (D) to remove the heat gained while in the building and before it returns to © to be chilled again. Cooling towers fall into two configurations: Direct and Indirect. The direct one is when the fluid in D comes in direct contact with air in the cooling tower and is cooled. The other is indirect and the fluid is cooled by cascading water over the outside of the tubes. Air flow through the towers can be by either force draft (blown air through the tower) or induced draft (air pulled through the tower).

<u>Geo-Exchange</u>

The earth around an educational facility can serve as a heat and cooling source. These system are known by many names include geothermal, earth-coupled, ground-coupled, close-loop and water-coupled. They all use a fluid transported by a hydronic system through a Ground Source Heat Pump (GSHP) to either remove heat from the ground to the air in a space when heat is needed or to transfer the heat from a space to the ground when cooling is required using a refrigeration cycle.

Fig. 5.5. Typical Ground Source Heat Pumps for Varied Requirements

There are two types of geo exchange systems: Open-loop and Closed-loop. An open-loop system takes water directly from a well, lake, stream or other source and passes it directly through condenser loop GSHP. When cooling, the water is warmed as it passes through the condenser loop and the water is returned to the lake or stream or to another well. These systems have limited use. The system that is used the most is the closed loop system. This system circulates a fluid (usually containing a substance that prevents freezing in cold weather) through a subsurface loop of pipe to a heat pump. See illustration below.

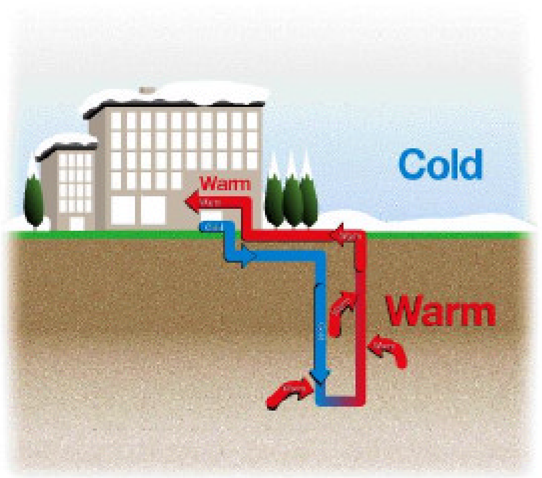


Fig. 5.6. Typical Geo Exchange Closed Loop Diagram

The subsurface loop typically consists of polyethylene pipe, which can be placed horizontally in a trench or vertically in a well. This pipe can also be placed in a pond or lake in coils to serve the same purpose. This thin-walled pipe is a heat exchanger, transferring heat to and from the earth. The earth temperature normally ranges from 10 to 15 (50 – 60 F) degrees C. The fluid inside the pipe circulates to the heat exchanger of an indoor heat pump where the exchange takes place with the refrigerant. The use of GSHP, allow for individual controls in the classrooms and allows for heating and cooling to occur at the same time in a educational building.

Cost of these system are normally more costly than a typical system from 10-15% but this first cost is offset by a 20-50% reduction in energy costs and a 30% reduction in maintenance costs. Payback for a typical Geo-exchange system ranges from 5 to 10 years. These systems can reduce peak energy demand and reduce the heat island effect, since waste heat is returned to the ground and not to the air.

All of the cooling systems described above are used in different configuration for installation in schools. The next section will describe air conditioning installations.

5.4. Air conditioning Installations

Air conditioning installation in the retrofit of educational facilities is dependent on many elements including use of space, size of facility and climate. In this section several Air Conditioning installation options will be discussed each has it specific use and advantages and disadvantages. These are: Split DX Installation, Packaged Rooftop Installation, Displacement Ventilation, Ductless Split, Hydronic Distribution, and VAV Reheat System.

<u>Split DX Installation</u>

A split DX installation normally is for a single room. These units known as a split unit can be two separate units – Air Handler and evaporator coil inside and the compressor and condenser outside. Some units can operate a split unit but all wall though units with the Air Handling unit on the inside of the wall and the compressor and condenser on the outside of the wall. Some units have natural gas as a means for heating if that is required and they are known as a split Gas/Electric units. Individual temperature control is a benefit.

Efficiency of these units can range as high as 14 seasonal energy efficiency rating (SEER). These units can range in cost for a classroom from 93 euros/m^2 to 112 euros/ m^2. Economizer units can be added to these units for between 260 to 435 euros. Moderate initial cost and operating costs. Energy use will average about 190 kWh/square meter/year

Package Rooftop Installation

A package rooftop unit is fully self-contained and most consist of a constant volume supply fan, DX cooling coil, heating strips if required, filters, compressors, condenser coils and fans. The entire unit is mounted on the roof. Package units are normally installed for a single zone and are a retro-fit package for educational facilities where older units might exist. Units should include an integrated economizer and design of the duct work should allow for proper flow for both low and medium fan speed. Since this unit supply's cooling to a zone and not a room then the control of temperature is central and not allow for individual room control.

High efficiency cooling units have a (SEER) of 12 to 13. Units can be purchased as heat pumps to allow for both heating and cooling. These units come in sizes from 24000 btu/hour to over 1.2 million btu's / hour. Cost of the unit including duct work, controls and installation will range from 140 Euros/square meter to 187 euros/square meter. Unit cost alone range from 1304 euros for 2 tons to 1739 for 5 tons. This relates to an energy use of 140kWh/square meter/year.

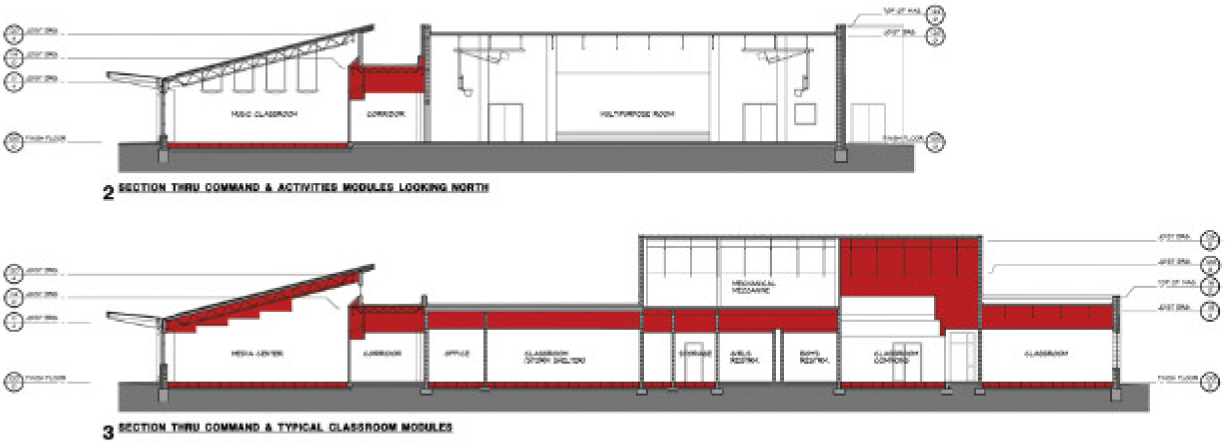
These units have a low initial cost and low cost to maintain with energy costs are higher than average and the life expectancy of the unit is less than 30 years.

Typical Package Roof Top Unit

Displacement Ventilation

Displacement ventilation is one that is different from most used in educational facilities. Displacement systems deliver air near the floor at low velocity and at a temperature between 17.2 to 18.3 C (63-65 F as compared to 55 F with other systems) The goal of displacement ventilation or cooling is not to cool the space but to cool the occupants. When cool air flows along the floor until if finds warm bodies. As the air is warmed by the occupants the air rises and cools the occupants and then is exhausted out of the space. Cooling loads decrease significantly because most of the load is generated by occupants, lights and computer equipment. Air quality is improved since the contaminants are raised out of the breathing zone.

The supply of air has three options: Access floor (raised flooring); Low wall outlets and infloor outlets. See photo below for examples;



Areas is red on floor level are raised floor with vents

Low wall outlets

The best cooling source for displacement cooling is a chilled water system. For this system to operate properly ceiling height should be at least 3.05 m. The cost of this system is initially it about the same as conventional systems, because of the down sizing of the chiller system and motors and fans because of the features of the displacement system.

Hydronic Distribution

Hydronic distribution system describes the transfer of heat by circulating a fluid (as water or vapour) in a closed system of pipes to cool a space. The fluid can be either heated by a boiler or cooled by a chiller or fluid from a Geo-Exhange system. When cooling is required, this distribution system circulates chilled water to either individual unit ventilators, large fan coil units to extract heat from the space and transport is back to the chiller for heat extraction and re-cooling of the fluid. Energy savings can be obtained in the design by using Variable Drive Pumps (VDP). Hydronic systems can be designed for either 2–pipe or 4-pipe operations.

Two pipe systems are less expensive and complicated to design and build but only allow for either cooling or heating at one time. Four pipe systems allow for cooling and heating at the same time. Four pipe systems are more complex in design and control and more costly to operate but allow for extreme flexibility.
These systems are common in school construction because of its simplicity and use of common equipment, materials and controls for maintenance personnel. The cost effectiveness of this system is dependent on it initial design and depends quantity, size and type of piping, valves and pumps. The system properly sized and installed will provide a quiet, efficient and virtually maintenance-free operation at minimal cost. Oversized piping will not only reduce the need for pumping power required but will also for increase in load requirements when additions or renovations are needed without a complete system overall. Energy used for these systems range from about 130 kWh/square meter/year for a two pipe system to 180 kWh/square meter/year for a two pipe system.

Typical Unit Ventilator Used in Retro-fits

<u>Variable Air Volume (VAV) System</u>

VAV is a general term for a type of HVAC system supplying on the amount of air needed to satisfy the load requirements of a building zone or room, and can supply different volumes to different zones at the same time. The result is the total supply of cool air changes over the course of the day, depending on the heat gains in different building areas at different times.
In a VAV system, a central supply fan sends air through medium-pressure ductwork to terminal units (VAV boxes) throughout the building. The airflow to each zone or classroom is controlled by the VAV box (a smart damper), which varies the airflow in response to the space temperature. As cooling loads in the zone drop, the damper continues to close until it reaches a minimum position. The minimum position provides the occupants of the zone with adequate ventilation air. Some VAV boxes, especially those in perimeter zones, contain a reheat coil for times when the minimum airflow provides too much cooling. The reheat coil provides heat in the winter. A duct mounted pressure sensor that decreases the fan output as the VAV box dampers close controls the main system fan.
The overall efficiency of VAV systems depends on the diversity of zone heating and cooling loads. This system is best used in a large school building that is multi-story and a large number of classrooms and varied uses. The typical VAV reheat system costs between 145 to 164 euros per square meter to install.
Advantages of the VAV system include:

1. Better comfort control results from steady air temperature
2. Moderate initial cost for buildings that require multiple zones
3. Better de-humidification control
4. Energy efficient
5. Centralized maintenance
6. Relatively simple to add or rearrange zones

Disadvantages of the VAV system include:

1. Requires more sophisticated controls than a single zone
2. VAV box can generate noise that radiates out of the sheet metal walls and travel down the supply ducts

The above described air conditioning installation system use varying sources or systems to supply the cooling medium. Some of these sources are reviewed and addressed in the Section 5.3 Cooling Systems.

5.5. Solar control systems

5.5.1. Glazing with solar optical control

Today, a large variety of glazing or selective coatings is proposed by the manufacturers, some of them devoted to protect internal spaces from excessive light, reducing the brightness glare of the glazing and heat with respect of luminous performance. Three innovative trends are particularly attractive [3]:

- An active control of transmittance, eg. thanks to a varying dc voltage/current which may be controlled manually or automatically (electrochromic glazing) or thanks to a temperature dependent properties layer or deposit (thermotropic or thermochromic glazing) in order to switch from a transparent state to a lower transmitting state when indoor temperature is likely to exceed overheating limit.
- An angular selective coating, obtained thanks to anisotropic coatings. Previous work in this field has considered metallic or cermet films obliquely deposited by thermal or filtered cathodic arc evaporation.
- A light scattering or deviation surface eg. prismatic surfaces which displace the incident light sideways, arrays of microlens which act as controlled diffusers, etc

Among these innovative trends, switchable glazing technology can be used to control the amount of solar energy passing through windows. The use of switchable glazings should reduce the peak electricity demand and the cooling, lighting, and total electricity consumption associated with windows, compared with all other window technologies currently available. The maximum benefits can be obtained when the glazings are used in conjunction with dimmable electric lighting controls. These technologies are still in the field of research at this date and consequently they may be difficult to find, to implement and to justify economically.

Other less advanced technologies proposed in most manufacturers catalogues are:

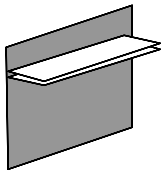
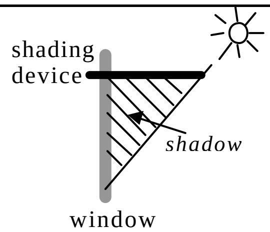
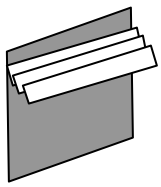
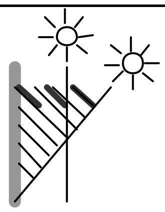
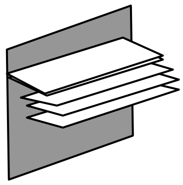
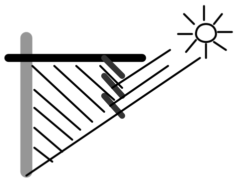
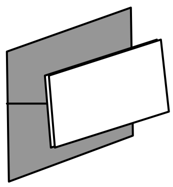
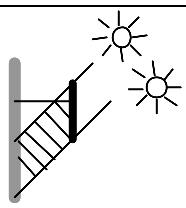
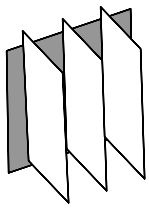
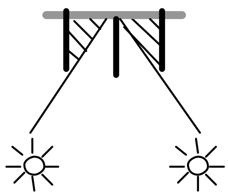
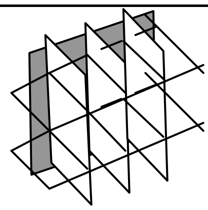
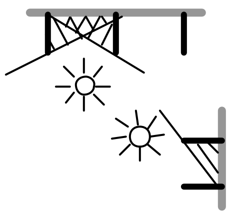
- the coloured panes, that lower the daylight and solar transmittance
- the reflective coatings, that increase the reflected part of sun radiation
- the sealed blinds between panes, whose blades tilt is calculated depending on the orientation and the shading requirement of the window, in order to reflect incoming sun light
- the transparent insulation

First two types of glazings should be used with caution: the associated reduction in daylighting is quite important for a solar gains reduction that varies a lot depending on the type of device. Furthermore, they are not adapted to variability of the solar gains depending on the season. Documentation must be found directly at the manufacturers’ to use such king of glazing or coatings.

5.5.2. Fixed shading control systems

An important advantage of fixed shading devices is that they are passive or self operating. However they have an impact on the aesthetic of the facades and must be robust enough to resist snow loading. Large horizontal overhang can also reduce in a significant way the availability of daylighting in deep plan school resulting in a need for permanent artificial lighting.
Design of fixed shading device depend on the seasonal angle of incidence of the direct solar radiation to permit some selective control to be achieved. Orientation, inclination and geometry of fixed overhangs and fins must be carefully analysed [4].

Table 5.2: Examples of fixed shading devices and their protection against direct sunlight [5]

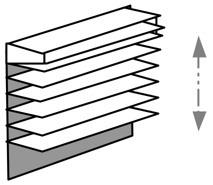
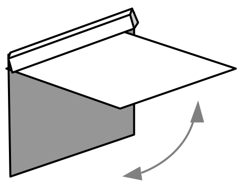
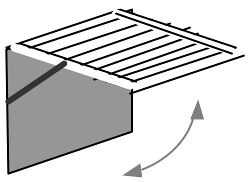
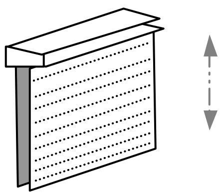
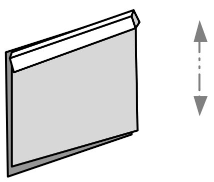
		Horizontal overhang is more efficient around southern orientation.
		Louvers parallel to the wall allow air to circulate. Slanted louvers offer better protection.
		Where protection is needed for low sun angles, louvers hung from horizontal overhang are more efficient.
		A solid or perforated screen parallel to the wall can block lower rays of the sun.
		Vertical fins serve well towards east and west and near these orientations. They may be oblique for more efficiency and detached from the wall to avoid heat conduction.
		“Eggcrates” or any combinations of horizontal and vertical fins are also possible to benefit of previous advantages.

Landscaping is also a natural means to protect facades against direct sunlight. Vegetation needs no specific device and is naturally adapted to the season climate (the choice of a vegetal specie with deciduous leaves is of main importance). It is however uncontrollable upon time and can reduce daylighting more than expected.

5.5.3. Movable shading control systems

They are more responsive than the fixed shading devices, but their movement mechanisms can present installation and maintenance problems. For external ones, weather implies some robustness constraints and sometimes some control implications (eg. awnings might be withdrawn if the wind is too strong).
Combination of a movable outdoor shading device and an indoor light blind offers best opportunities to control solar gains all year long.
A wide range of blinds is available at the manufacturers' documentation. Robustness is an important factor to take into account in addition to the daylighting and energy performance.

Table 5.3. Examples of outdoor movable shading devices

	Movable horizontal louvers can change their mask characteristics according to their position. Ventilation through the blades avoids overheating. Low security protection, bad night insulation (same idea with movable vertical louvers).
	Canvas canopies have the same characteristics as solid slanted overhangs but may be retractable and not completely opaque to light.
	Bahamas shutters offer a sun obstruction whatever is their position. With disjointed slats, they can be not completely opaque to light. Manual control only.
	Roller blinds offer good protection against night heat losses and sometimes allow infiltration through it in a specific position. However possibilities to control simultaneously solar gains and daylight are very limited.
	Screens can be used indoor and outdoor, but will be more efficient outdoor. Usually made of PVC covered material with a wide range of solar factors. Not completely opaque to light. Air infiltration somehow allowed to pass through it.

Indoor shading devices includes: screens, horizontal or vertical venetian blinds, and curtains. Usually they are not as efficient as outdoor shading devices unless they have a high reflective property.

Most of the shading devices presented in this paper could be motorized and automatically controlled. Combined with a control system for electric light, the energy consumption could significantly be reduced.
The shading devices can be classified on the basis of their adaptation to the seasonal requirements and to the climate conditions as fixed/movable, or on the basis of their position as internal / external / interpanes. External shading devices provide more effective shading because the solar energy is rejected before it can enter the building. However, they tend to be expensive due to the need for weather resistance and maintenance. Shading devices can also be classified on the basis of their construction features: horizontal axis slat/fin, vertical axis slat/fin, blind, awning, screen, curtain, shutter, coatings, tints, film, opaque pattern, integrated louvers.
Venetian blinds, vertical fins, screens and slatting shutters permit simultaneous shading and ventilation on the contrary of roller blinds and curtains that can be an obstacle if maintained in operation.
Finally, they can be classified on the basis of the material, as metallic/plastic/wooden/glazed.

The shading devices options can be classified following a more architectural point of view:

- Special solar optical properties of the glazing : reflective, selective, thermochromic, etc Architects often appreciate the potential of aesthetics offered by the large choice of glazing and films manufacturers. Spectrally-selective tints and spectrally-selective low-E coatings have entered the market more recently. Solar control retrofit film is widely available.
- Fixed external solar obstruction: overhang, vertical fin, eggcrate, etc They can also be integrated to the facade as part of its aesthetic by the architect.
- Movable external or internal shading devices: screen, blind, louver, awning, etc They are only considered as necessary appendices by most architects. Integrated louvres and silk-screened glazing are available from specialised window manufacturers.

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