AZEB – Best Practices Manual for Users

The following manual has been created to help users operate their nZEB in an optimal way (step 15 of the AZEB roadmap). It may also be used for inspiration by professionals and users in the early stages of a project to identify important requirements and parameters to guide the development process (step 2 of the AZEB roadmap). Examples are included to show the effect of the implementation of the recommended practices. It contains the following factsheets:

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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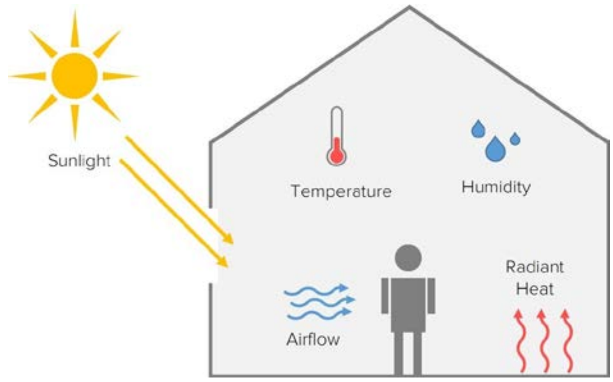
Affordable Zero Energy Buildings

AZEB_Thermal Comfort Guide

It is generally accepted that a comfortable environment affects the occupant satisfaction, well-being and health and in case of workspaces, also their productivity.



Summary

The ASHRAE 55:2017 defines the thermal comfort as “the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.”
The energy consumption of a building strongly depends on the criteria set for the indoor comfort condition.

Discomfort conditions lead the occupants to take actions to restore a state of comfort, which might take the form of better controlling passive or low energy features of the building (e.g. in summer operating solar shading, night ventilation openings, ceiling fans) if those are available or adapting clothing and activity levels.
ASHRAE formed a new standard to stipulate standard methods of testing fans, and its Comfort Standard 55 now has an integrated approach to evaluating comfort effects of air movement ranging from desirable air speeds. However, designers still lack guidance for designing rooms with ceiling fans (spacing, sizing and cooling effect). (He et al. 2019).

But in case adaptation measures have not been provided by the building design or are not allowed, users might choose stricter set-points for active systems or even add individual active systems; these actions may have energy implications.

Consequently, the thermal comfort assessment has a key role in the design process and must be considered together with the energy performance during the assessment of energy-saving measures.

However, the energy consumption of a building strongly depends on the criteria set for the indoor environment; the same level of comfort, can be achieved via various combinations of physical parameters (clothing level, metabolic equivalent, relative humidity and air velocity), each providing different energy need levels. With a correct choice of these parameters the user can therefore achieve the same or better comfort level with lower energy and power demand than other combinations, implying a strong cost reduction.
The combinations of physical parameters leading to comfort are codified into Comfort standards as e.g. EN 15251 and

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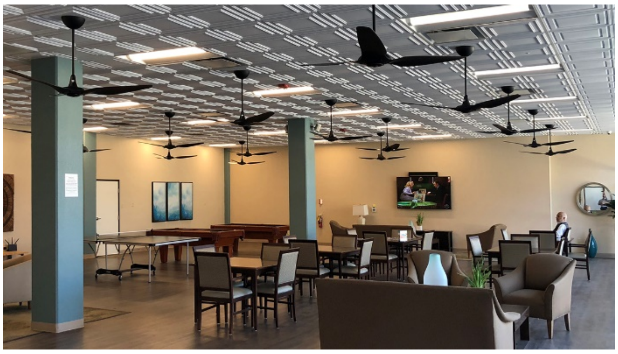

ASHRAE 55. Sometimes in design and operation of heating and cooling systems designers and energy manager choose to aim at values of temperature and humidity within the stricter comfort category I (which is in fact proposed by the standards only for fragile persons in hospitals, care centres for elderly people, etc.) rather than the category II proposed for new buildings or category III proposed for existing buildings. Those choices are often then passed on to users habits. Moving from category I to II implies energy savings of 10 to 40 % and moving from category I to III implies savings of 20 to 66 %, according to (Sfakianaki et al. 2011). The authors find similar savings are obtained by reducing ventilation needs from category I to II or III for ventilation, with the same thermal parameter.

"Analysis is ongoing to ascertain whether people can actually distinguish among the proposed categories. An analysis (Arens et al, 2009) of data from the ASHRAE, SCAT and Berkely databases of field surveys concludes that category A (and possibly B) is too narrow to be discriminated by occupants of buildings.

On the side of possible discrimination via measurement of physical parameters and the calculation of PMV (d'Ambrosio et al, 2006), note that: 'the PMV range required by A-category can be practically equal to the error due to the measurements accuracy and/or the estimation of parameters affecting the index itself' (Alfano et al, 2001); as a matter of fact, the errors accepted by EN ISO 7726 in terms of required accuracy give large errors in the PMV value.

In fact, ISO 7730-2005 acknowledges that: 'Owing to the accuracy of instrumentation for measuring the input parameters, it can be difficult to verify that the PMV conforms to the Class A category (-0.2 < PMV < +0.2). Instead, the verification may be based on the equivalent operative temperature range, as specified in A.2 and in Table A.5.' This is probably equivalent to setting to zero the uncertainties on all the other variables besides temperatures and hence makes little sense.

More fundamentally the question may be posed as to whether it is possible to discriminate a range of 0.2 * 2 = 0.4 points on the thermal sensation scale when the surveys and the judgements of people go in steps of 1.0 point on that scale. McIntyre (1980) suggests that a seven-point (vs 3- or 25-point) scale is appropriate for psychological measurement. He observes that when people are presented with a set of stimuli that vary in one dimension only, the number of stimuli that can be unambiguously identified is relatively small. Subjects can identify about six different tones and five degrees of loudness without error. For several different types of stimuli, Miller (1956) found that people cannot generally deal with more than about seven levels of sensation without confusion." (Pagliano et al. 2010).

Recommendations for users

Choose the correct temperature

- Set thermostat on 19 – 21 °C in winter and on 26 – 28 °C in summer.

- Hot air in winter is dry and irritates mucous membranes. Air that is too cold in summer creates thermal stress and muscular tiredness.

Control ventilation

- With mild weather, during office hours ventilate with a single tilted window. With very hot (> 35 °C) or cold (< 10 °C) weather, lower natural ventilation by fully opening for short periods of 5 min, sporadically every 1-2 hours according to the needs.

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- Excessive ventilation with extreme temperatures provokes excessive energy consumption.
- In case you want a more precise control on Indoor Air Quality levels, install a CO_2 sensor (pay attention to the fact that it should be re-calibrated from time to time according to specifications by the manufacturer).

Use ceiling fans

- When you feel hot, set on in preference the ceiling fan rather than opening the window, when the outdoor temperature is higher than the indoor temperature.
- With a wind breeze or air velocity created by a fan, we feel cool even with temperatures higher than 28 °C because of air movement.

Use a combination of strategies

- When the ceiling fan is not sufficient to provide thermal comfort use in preference the ceiling fan in combination with the air conditioning set to 28 °C rather than the air conditioning alone set to 24 – 26 °C.
- Combined use of ceiling fan with air conditioning provide comfort with 28 °C. 2 °C higher set temperature are equivalent to 15 % less energy consumption for cooling. Comfort with higher temperatures is healthier because it provokes less muscle stress.

Control the windows' opening

- In winter, close the exterior doors and do not leave the windows open when you leave the office. Avoid setting the thermostat to high temperatures, especially in periods when windows are open.
- The worst energy consumption happens with high internal temperatures and window open. When ventilation is not necessary it causes unnecessary energy consumption.

Summer night ventilation

- During summer and shoulder seasons (May to October), leave open all protected windows during night. For the automatic windows, ensure that the mechanism is set to on and the system works.
- If effective solar protections are present and correctly used/controlled and internal loads are not too high, summer night cooling may avoid completely or significantly reduce cooling energy consumption. Natural cooling is also healthier.

Lighten the dress code

In lightweight clothing the body can be refreshed more easily. Linen, silk or cotton fabrics are breathable. On particularly sultry days - or during the entire summer - the company should suspend the obligation to wear the tie and allow pants and short-sleeves clothing.

Reduce physical stress

Physical comfort in the workplace can be improved with ergonomic principles and technical aids, as well as with the distribution of heavy activities on more people. This lightens the work when temperatures are too high.

Work rhythm

- With little flexibility many jobs can be moved to cooler times, in the morning or evening. The company can facilitate flexible work, for example by setting flexible hours, the time of annual work or the recovery of extra hours.
- During particularly sultry days, the company can grant more breaks in cool places and a prolonged lunch break, or allow carrying out the work in cooler places, for example at home.

Plan and inform

It is advantageous for the company to plan measures for the prevention of heat in advance and involve for time the collaborators. For example, by adjusting who ventilates and when, who takes care of shadings or informing about personal behaviour to be adopted.

Drink water and eat light food

During hot periods drink at least 1.5 litre a day and eat food easily digestible. Companies can make available water dispensers on the work place.

Examples

According to the PMV-PPD model due to Fanger, there are six primary factors that directly affect thermal comfort that can be grouped in two categories:

- personal factors, which are characteristics of the occupants: clothing level and metabolic rate;

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- environmental factors, which are conditions of the thermal environment: air temperature, mean radiant temperature, humidity and air speed.

In the following examples, we highlight the effect of the different parameters on the thermal comfort, using the free online *CBE Thermal Comfort Tool* (Sfakianaki et al. 2011; Pagliano et al. 2010). The examples report the variation of the comfort category as a function of PMV and PPD indexes, according to EN ISO 15251 [Table 1].

Table 1 Examples of recommended categories for design of mechanical heated and cooled buildings.

Category	Thermal state of the body as a whole	
	PPD %	Predicted Mean Vote
I	< 6	-0,2 < PMV < + 0,2
II	**< 10**	**-0,5 < PMV < + 0,5**
III	< 15	-0,7 < PMV < + 0,7
IV	> 15	PMV<-0,7; or +0,7<PMV

The clothing level

The clothing level is the thermal insulation provided by clothing (ASHRAE 55:2017). Having the same dimension of the thermal resistance, it's expressed in clo units where 1 clo is equivalent to 0.155 (m^2K)/W and represents the insulation capable to maintain the human body in thermal equilibrium with the environment at 21 °C and 0.1 m/s as air velocity. The comfort temperature ranges are calculated in the EN 15251 considering 0.5 clo for summer and 1 clo for winter.

A typical summer condition has been considered: 26 °C operative temperature, 50 % RH, 0.1 m/s air speed and 1.2 met (standing, relaxed).

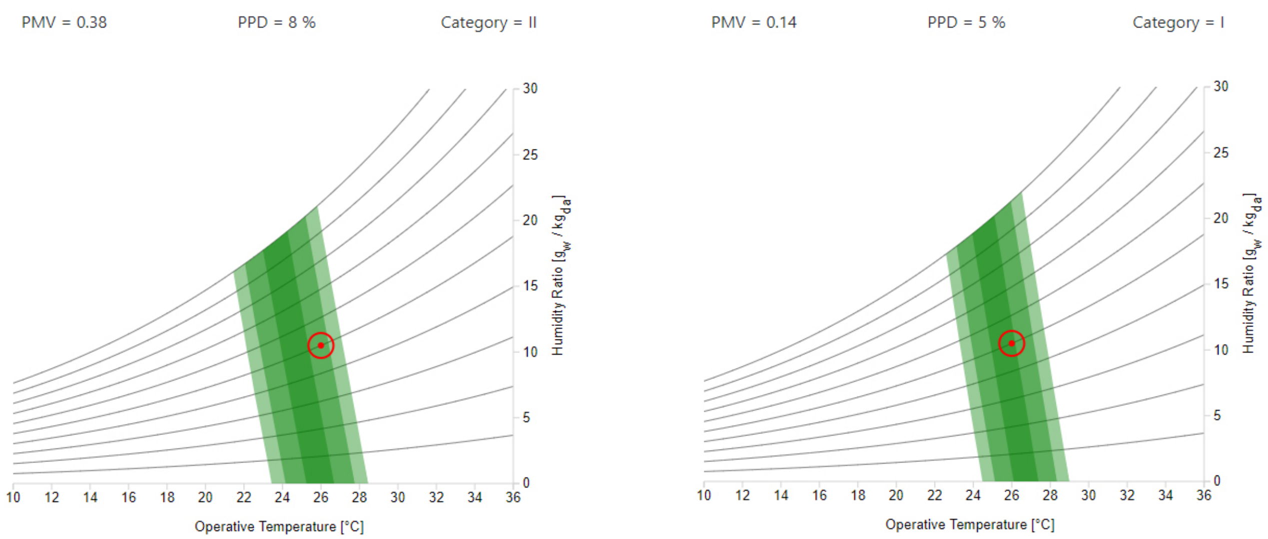

Figure 1: Comfort temperature ranges for different clothing levels. In the example: 26 °C operative temperature, 50 % R.H., 0.1 m/s air speed and 1.2 met (standing, relaxed), 0.5 clo (left), 0.36 clo (right).

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The graphs in Figure 1 show the variation of the comfort range in relation to the change in the clothing level. On the left the graph considers typical summer indoor clothing (0.5 clo) while on the right it corresponds to walking shorts and short-sleeved shirt (0.36 clo). The decrease in the clothing level resistance moves the comfort range to higher temperatures: using a clothing thermal resistance equal to 0.5 clo the comfort category reached is the II (PPD = 8%); under the same thermo-hygrometric conditions using 0.36 clo it is possible to move even more towards the center of Comfort category II (PPD = 5%). This improvement obviously comes at zero energy cost.

The same clothing change, assuming an operative temperature of 27 °C, would bring an improvement from the III category (PPD = 15 %) to the II category (PPD = 10 %) [Figure 2].

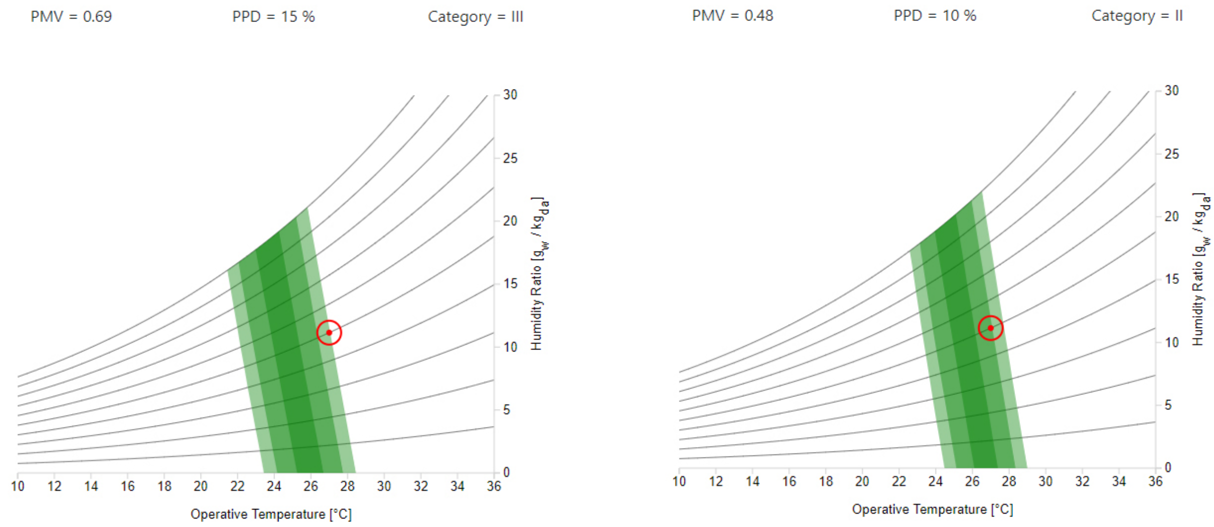

Figure 2: Comfort temperature ranges for different clothing levels. In the example: 27 °C operative temperature, 50 % R.H., 0.1 m/s air speed and 1.2 met (sedentary occupancy), 0.5 clo (left), 0.36 clo (right).

Metabolic equivalent of task

The activity level or the metabolic equivalent (met) is a physiological measure expressing the energy cost of physical activities, set as the ratio of metabolic rate during a specific activity to a reference metabolic rate. 1 met is equivalent to the rate of energy produced per unit body surface area of an average person seated and quiet (ISO 7730:2005).

In the standard, several values of metabolic equivalents are assumed for the evaluation of the comfort temperature range, depending on the predicted activity. Considering the same situation described for clothing levels comparison (i.e. 26 °C operative temperature, 50 % R.H., 0.1 m/s air speed and 0.5 clo), the current variation [Figure 3] is the decrease in the metabolic rate from 1.2 (left) to 1 met (right); 1.2 met is referred to standing relaxed (office, dwelling, school, laboratory). The change in the metabolic activity shifts the condition from the border of II category (PPD = 8 %) more towards the center of the same category (PPD = 5 %).

We are aware that it is difficult to adjust the activity because it changes in relation to the necessity; however, it is important to reduce the physical stress, distributing if possible heavy activities on more people.

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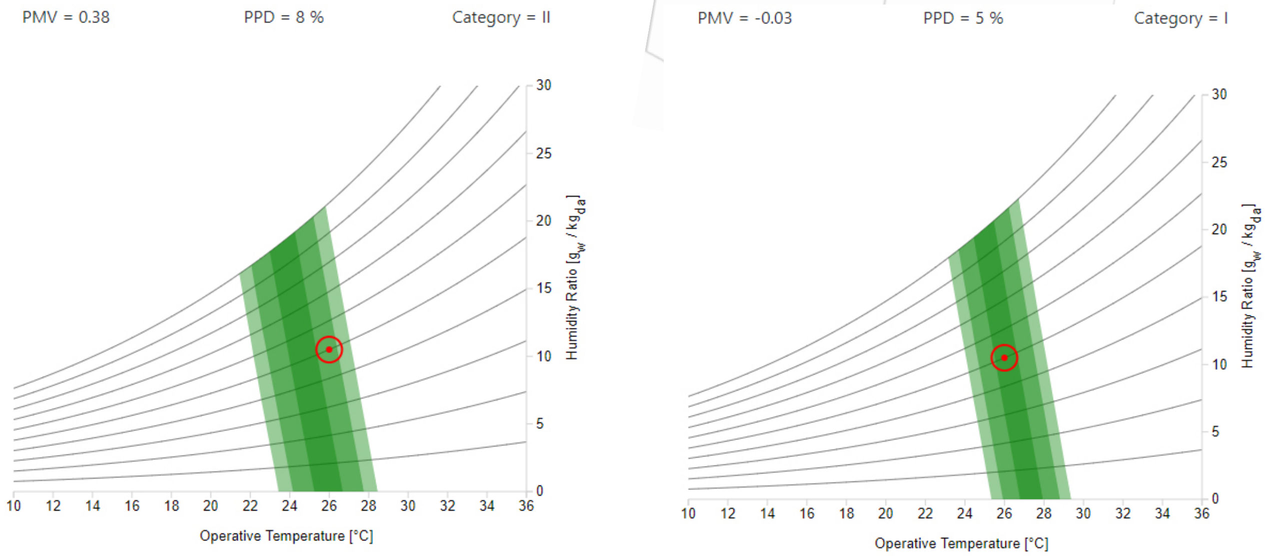

Figure 3: Comfort ranges for different metabolic rates. In the example: 26 °C operative temperature, 50 % R.H., 0.1 m/s air speed and 0.5 clo, 1.2 met (left), 1 met (right).

Relative humidity

According to Fanger's model the humidity inside the space has only a small effect on thermal comfort. The thermal sensation, for sedentary occupancy, is just slightly influenced by the humidity if the temperature is below 26 °C. When the operative temperature is higher, the heat balance of human body at high metabolic rate is more significantly influenced by relative humidity. As a general rule of thumb, the relative humidity may stay within the range 20 – 70%: below this range, it may cause dryness and irritation of eyes while above the range it increases the risk of mould growth (in winter or in summer only if cold surfaces are present, e.g. diffusion elements of air conditioning not accurately designed). The graphs in Figure 4 compare summer condition with 26 °C of operative temperature, 0.1 m/s air speed, 0.5 clo, 1,2 met and respectively 30 % RH (left) and 60 % RH (right). The change in the relative humidity causes a shifting of the point in the psychrometric chart, but the movement does not affect the comfort category (II category in both cases) and only slightly the thermal comfort condition (RH = 30 % and PPD = 6 %; RH = 60 % and PPD = 9 %). However, keeping a value of RH equal to 30 % has a large energy cost since it requires the use of an active system able to remove vapour from the air.

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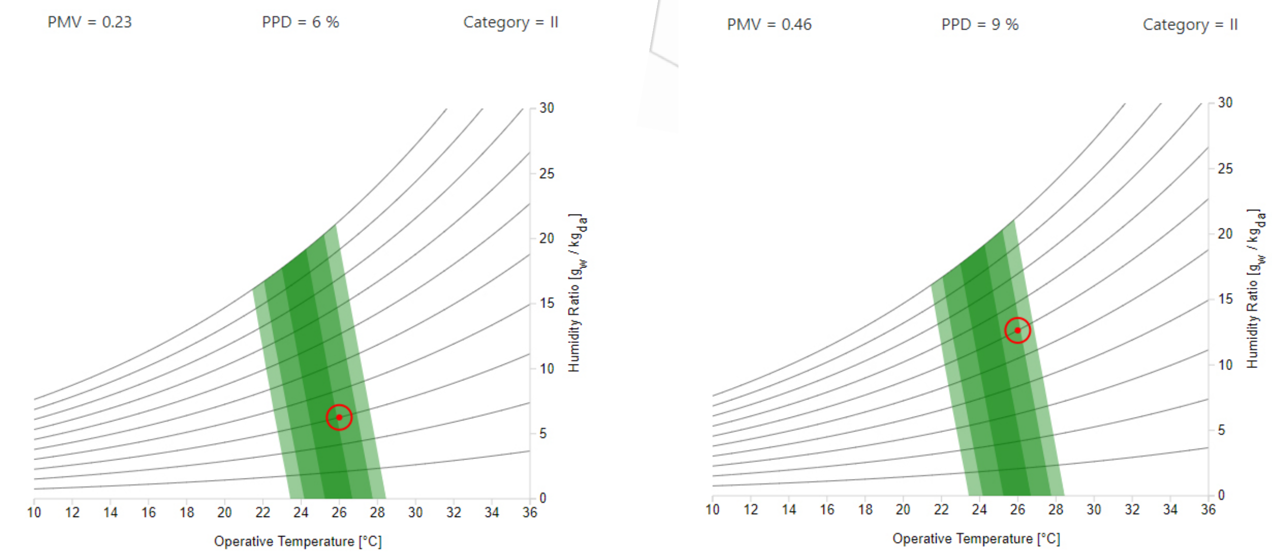

Figure 4: Comfort ranges for different relative humidity. In the example: 26 °C of operative temperature, 0.1 m/s air speed, 0.5 clo, 1.2 met, 30 % RH (left), 60 % RH (right).

Air velocity

The increase in the air velocity can extend by some degrees the upper limit of the temperature comfort range. The cooling perception with improved air movement is due to the rise of the heat leaving human body; the movement of air accelerates the process of sweat evaporation from the skin that requires heat: faster is the process, more is the heat leaving our body. In addition, if the air temperature is lower than 38 °C, the air movement improves the heat transfer from the skin trough convection.

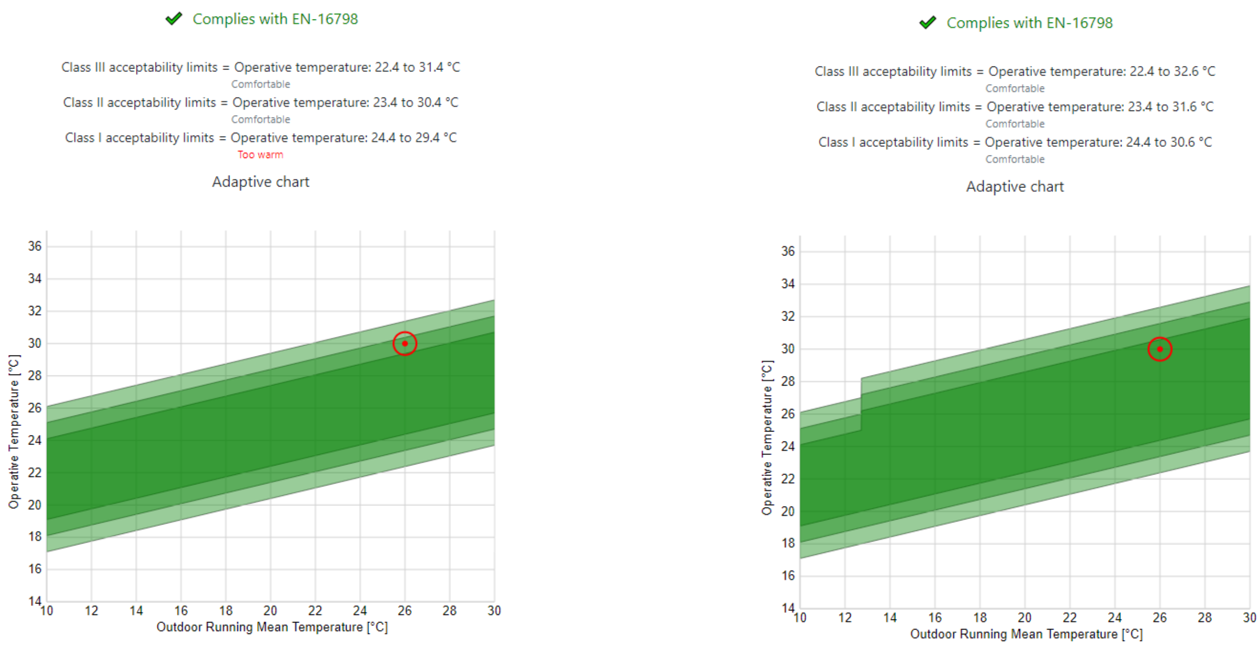

Figure 5: Comfort ranges for different air velocities according to the adaptive model, compliant with EN 16798. In the example: air speed lower than 0.6 m/s (left), and equal to 0.6 m/s (right).

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Figure 5 shows, according to the adaptive model compliant with EN-16798, a summer condition characterized by an operative temperature of 30 °C, an outdoor running mean temperature of 26 °C and an air speed lower than 0.6 m/s (left). The point is within Class II acceptability limits for the adaptive model. If the air velocity is increased up to 0.6 m/s (right) the upper boundaries move, and the point is now more towards the center of class II. In the adaptive model, the change in the air velocity doesn't vary the lower comfort limits.

According to the Fanger model, considering 50 % RH, 1.2 met, 0.5 clo, 0.1 m/s air velocity and an operative temperature equal to 27 °C, the condition is at the upper border of category III (Figure 6, left). The rise of the air velocity from 0.1 m/s (PPD = 15 %) to 0.5 m/s (PPD = 6 %) (Figure 6, right) allows to move towards the center of category II.

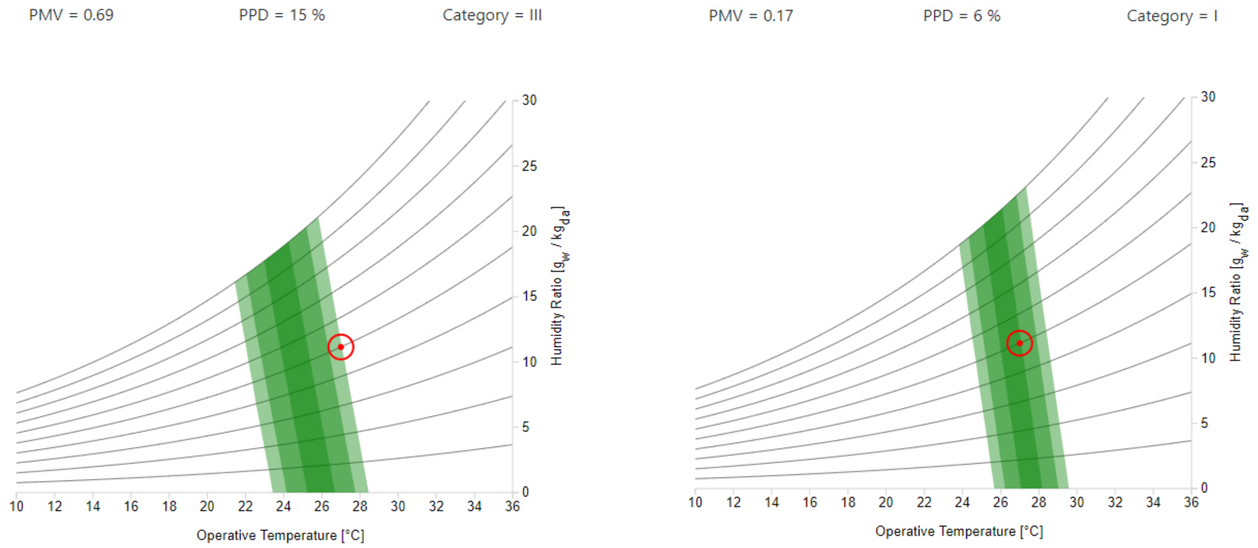
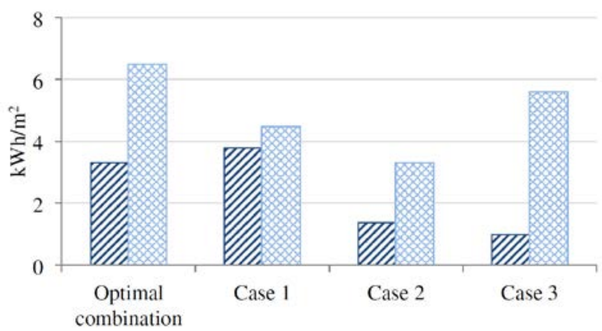


Figure 6: Comfort ranges for different air velocities according to Fanger model. In the example: operative temperature 27 °C, 50 % R.H., 1.2 met, 0.5 clo, air velocity 0.1 m/s (left), 0.5 m/s (right).

The examples provided above show the possibility to modify the PMV and consequently the comfort category through simple changes in the base parameters.
The energy consumption of a building strongly depends on the criteria set for the indoor environment; the same level of comfort, as measured e.g. via the index PMV, can be achieved via various combinations of physical parameters, each with different energy need levels, resulting in energy savings and consequents costs reductions (Figure 7, Dama et al. 2014).



SIM.	T_{op}	R.U.	v	PMV	clo	met
	°C	%	m/s	-	-	-
Optimal combination	26	60	0.01	0.5	0.5	1.2
Case 1	25.7	70	0.01	0.5	0.5	1.2
Case 2	27.3	70	0.5	0.5	0.5	1.2
Case 3	27.6	60	0.5	0.5	0.5	1.2

Figure 7 Influence of comfort set point on sensible (dark blue) and latent (light blue) energy needs for cooling [Dama & al. 2014].

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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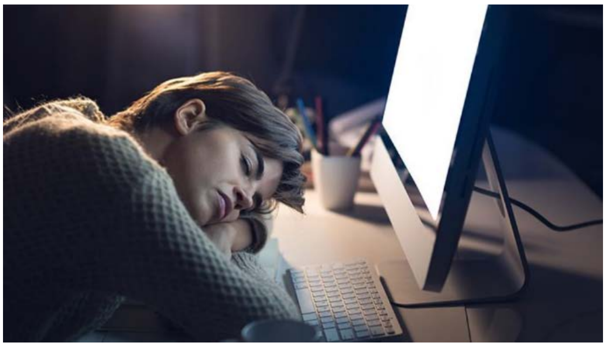
AZEB_Guide to control lighting and equipment

Electrical equipment and lighting emit heat and contribute to the rise of the intern heat gains, which can be a useful source in winter but an additional load in the summer.



Summary

It is common practice, especially in large offices and public buildings, such as universities, to leave the light on during the night. Literature suggests possible causes such as the diffusion of responsibility to others and authorities, people forget to turn lights off because they are stressed and a lack of motivation. In addition, many people leave their computer on and other equipment such as printers.
This behaviour contributes to increase the internal heat gains, which in summer causes a rise in the energy need for cooling with consequent additional costs. In addition, the costs associated to the electric energy required for their functioning during the night or the unused periods cannot be neglected.

Different automatic solutions are available for modern lighting installation: they are driven by sensors, which turn off after a certain period of no movement being detected in the zone, after business hours.

Recommendations for users

Switch off lighting

Switch off the lights when natural lighting is sufficient. Position correctly the offices in relation to light direction and glare of the glazed windows. Glare makes eyes tired provoking headaches.

Switch off equipment

When possible, remember to switch off equipment, screen and unused lamps. To make this process faster use smart master-slave plugs. Alternatively, you can use timers or related apps and you can use the power saving mode offered in many devices.

Pay attention to energy efficiency

Modern equipment and lighting systems are characterised by a high level of efficiency, which is guaranteed by labelling. When you choose a new device or you have a very old equipment, evaluate to change it with a new one, which offers a great potential of energy costs reduction and helps to prevent the production of unused heat gain.

Locate strategically the appliances

If possible, place the appliances that emit heat in the rooms that are not used. Printers, router and similar can be placed for example in the corridors or in other rooms which don't need to maintain a certain comfort temperature.

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Consider health

VOCs in high concentration are bad for heath. By putting printers in a well-ventilated area, office staff is less exposed to this pollution.

Consider the energy used

Although electrical power of stand-by mechanisms and battery chargers is low, they are on 24 hours.

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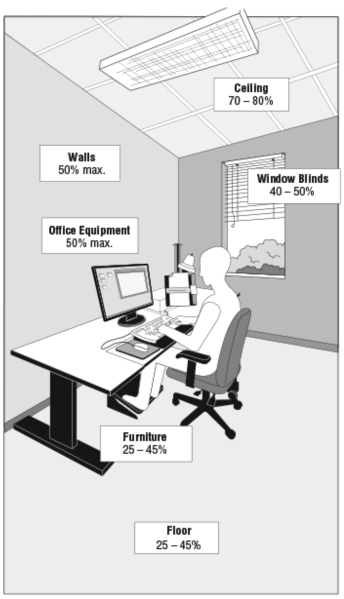
Table 2 reports examples of industrial and office tasks and the recommended light levels.

Table 2 Recommended Illumination Levels [IESNA Lighting Handbook. 9th ed. Illuminating Engineering Society of North America, 2000. p. 10-13]

Recommended Illumination Levels*	
Type of Activity	**Ranges of Illuminations (Lux)****
Public spaces with dark surroundings	20-50
Simple orientation for short temporary visits	50-100
Working spaces where visual tasks are only occasionally performed	100-200
Performance of visual tasks of high contrast or large scale	200-500
Performance of visual tasks of medium contrast or small size	500-1000
Performance of visual tasks of low contrast or very small size	1000-2000
Performance of visual tasks of low contrast and very small size over a prolonged period	2000-5000
Performance of very prolonged and exacting visual tasks	5000-10000



To reach proper light levels and uniform light distribution in the visual environment, many light fixtures are designed to reflect light off walls, ceilings and objects. The amount of light reflected off a surface can be measured. Suggestions for the percent of light reflected off surfaces in a typical office include:

- Window blinds (40-50%)
- Walls (50% maximum)
- Business machines (50% maximum)
- Ceiling (70-80%)
- Floor (20-40%)
- Furniture (25-45%)

The percent value refers to the amount of light that a surface reflects relative to the amount that falls on the surface.

In addition, light fixtures that are too widely spaced or wrongly positioned can create shadows. Objects between the light fixture and work being done can block the light and cast shadows. Likewise, workers sitting with their backs to windows, with light fixtures directly overhead or to the rear, cast shadows on their own work surfaces.

Figure 8 Examples of surface reflectance of objects.

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How do you correct glare problems?

To correct glare, try:

- Using several small low-intensity light fixtures rather than one large high-intensity light fixture.
- Using light fixtures that diffuse or concentrate light well. Indirect light fixtures or direct light fixtures with parabolic louvres are two possibilities.
- Covering bare bulbs with louvers, lenses or other devices to control light.
- Increasing the brightness of the area around the glare source.
- Using adjustable local lighting with brightness controls.
- Positioning light fixtures to reduce reflected light that is directed toward the eyes.
- Using low gloss paper or applying flat or semi-gloss paint and matte finishes on 'offending' surfaces. Removing highly polished and shiny objects.
- Keeping general lighting levels at recommended levels.
- Positioning the work station so that windows and fluorescent light tubes are parallel to the worker's line of sight.
- Position the work station so that the light fixtures are NOT in the front or directly overhead.

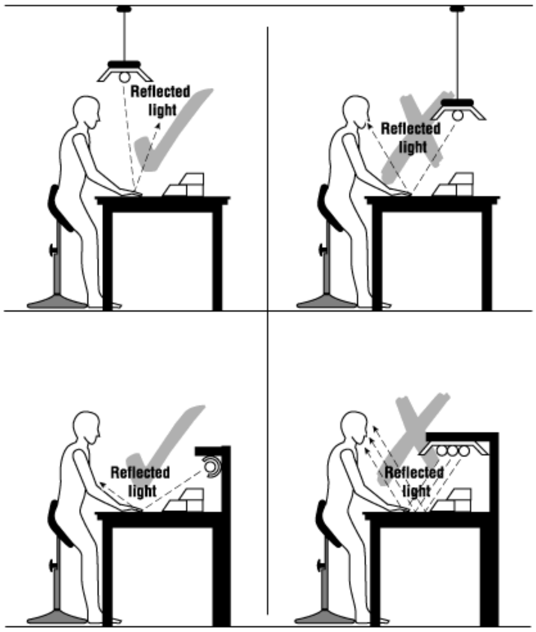

Figure 9 How to correct glare problems?

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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AZEB_The potential of the shading systems

Solar shading systems are an effective measure in buildings both in summer to reduce the energy need for cooling and in winter to reduce the energy need for heating.

Summary

Solar shading systems prevent solar radiation entering the building and control natural light in the indoor environment to avoid glare. They can have a significant impact on the energy need of the building as well as on the thermal and visual comfort of occupants. In particular, externally adjustable solar shading can mitigate the window surface temperature, improving the indoor thermal conditions and reducing the temperature difference between perimeter and interior areas, increasing the usable area. Finally, they can also provide privacy.
Their use is different in relation to the season: in summer, the occupant should close the shading to avoid solar gains and consequent cooling loads. In winter these systems should be open, to let solar radiation and natural light enter the building.

Solar shading can be fixed or moveable. Adjustable shading is usually preferred for most applications, but it's more expensive and needs more maintenance because of its moving parts. If the changing seasons are the only factor, then fixed shading may be enough. Its geometry is designed to block out high-angled summer sun, but allow low-angled winter sun.

Among the moveable systems, the cheapest solutions to mention are:

1. external slat blinds, best with dual tilting
2. tilting shutters
3. sunshades
4. rolling shutters

Recommendations for users

Use the shading systems since the early morning

In summer, remember to use the shading systems since the early morning before the entrance of sunlight. If you wait until the afternoon, when you start to feel uncomfortable, the heat has already entered inside the room and it is too late to achieve comfortable temperatures.

How to position the blinds

In summer, with the blinds tilted up and the rounded side facing out, the heat in the room moves toward the ceiling. In the winter when the sun is out, open the blinds to bring sunlight into the room, or set them so the rounded side

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faces the room to move warmer ceiling air closer to where it is needed. With the blinds facing up, outside sunlight and radiant energy are deflected skyward, and heat is directed away from the living spaces of the room.
In case of dual tilting, the upper part can be used to deflect light towards the ceiling and the lower part to shade the floor/desk close to the window.

How to exploit the potential of shading systems in the night

In winter, during the night, remember to close the shutters to reduce the heat loss. The contribution of the solar shading improve the thermal resistance of the glazing alone. In summer, position the blinds horizontally in order to allow the exploitation of night natural ventilation.

Make the most of natural lighting

Physiological and psychological benefits for occupant's health and workers' productivity are linked to daylight. Make sure to correctly address the light inside your room through a proper use of shading systems and switch off the artificial lighting if not necessary.

Define the roles

Especially in large buildings, such as companies, schools, etc. it is important to identify a person, which has the task to control the shading systems in the conference and meeting rooms, common areas or unused spaces. In case of large buildings characterized by many windows, evaluate the installation of automatic controls.

Maintenance for sunshades

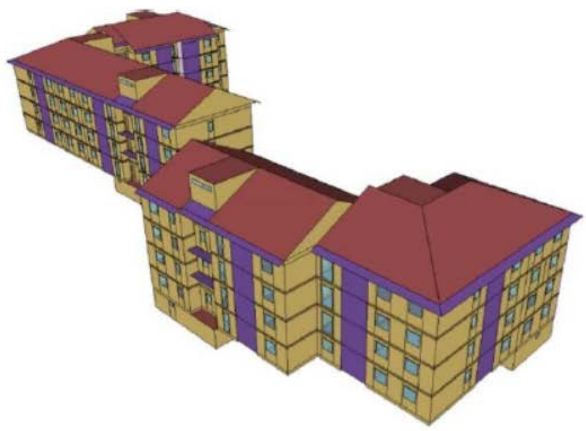
- Both during the installation and in the use phase make sure that the curtain is always tight, so as not to encounter problems in handling and, in case of rain, to avoid the creation of water puddles that can deform the fabric.
- Grease periodically the moving parts (e.g. joints and winch).
- Close the shading in case of strong wind, rain and snow. In case you have forgotten the sunshade open under the rain, make sure not to close it when it is wet: mould and bad odours can damage the system.
- Clean the sunshade periodically or at least at the end of the summer season.
- Consider the use of a canopy, box or protective cover to protect the shading from dirt and atmospheric agents when it is not used.

Choice of the shading system

Remember that internal solar shadings are not as effective as external shadings because they offer visual comfort to occupants but they allow that solar radiation enters in the interior space.

Example

The following example (Erba et al. 2017) aims to highlight the effect of the use of solar shading systems on summer thermal comfort.



Reference Building	
Heating Setpoint Temperature [°C]	20
Cooling Setpoint Temperature [°C]	n.a.
Weather file (source)	ITA_Milano-Linate.160800 (IGDG)
Number Thermal Zones	41 (Building 1) + 66 (Building 2)
Gross Floor Surface [m²]	4633
Gross Volume [m³]	13823
Window-to-Wall Ratio [%]	14
Surface-to-Volume Ratio	0.55

Figure 10 Sharing Cities_EU Project: Energy simulation of a public social housing block located in Milan (Erba et al. 2017).

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The analysis focuses on a case study of a public social housing block located in Milan, consisting of two L-shaped buildings with four stories each and a total of 66 flats. The project of solar shading devices in the dynamic model deserves particular attention because its control can substantially affect building thermal and lighting performance both from an energy and comfort point of view. Solar shading systems influence daylight levels in a building; they control solar gains and affect the thermal exchange through the glazed building envelope. Several studies about the shadings' effect on yearly energy use demonstrated that shading devices may decrease the cooling requirements, but at the same time, they may increase the heating demand, due the reduction of solar gains during the heating season. In EnergyPlus settings, the function Shading Control Types allows to specify a schedule that determines when the control is active. It can be seasonal, when the incident solar radiation is high enough, or it can be set on fixed period, or depending on other drivers such as outdoor air temperature or glare, etc. After a sensitivity analysis, the activation of the shading device in the model has been set for values of irradiance, on the component' surface, higher than 200 W/m2. Comfort evaluations have been performed in reference flats according to the standard EN 15251 approach under two different weather conditions (MI_Linate_1951-1970, older and colder weather dataset and MI_City_2006-2015, updated and warmer weather file). Acceptable summer indoor conditions have been assessed as a function of the outdoor running mean temperature, defined as the exponentially weighted running mean of the daily outdoor temperature, and the indoor operative temperature.

Figure 11 shows the model of one of the buildings and it highlights, as an example, one of the flats in which the analysis of acceptable indoor conditions has been carried out.

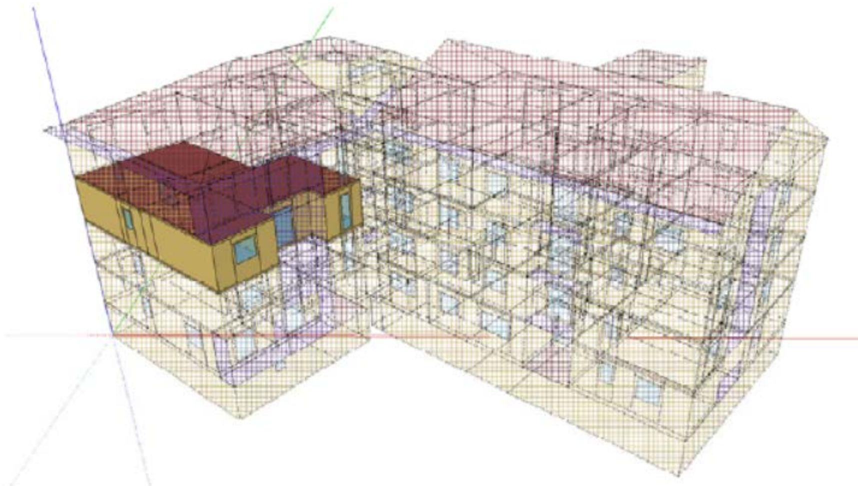

Figure 11 Geometric model of one building highlighting the flat considered for comfort analysis.

Results reported in Table 3 show the effect of the activation of solar shading devices on the indoor comfort during the cooling season. Although the role of solar shading in improving comfort is obvious, the values reported in the table show that its effect may be massive in the climate of Milan.

Moreover, Table 3 also reveals that the use of different weather files may have a much higher impact on the simulation results of a building without solar shading, than of a building provided with it. The results highlight the necessity to activate solar protections especially when a dataset based on values gathered in recent years is chosen, i.e. the MI_City_2006-2015 weather file. The number of hours inside category II is dramatically reduced passing from 65.3%, when shading systems are in use, to 13.5%, when they are not used. It means that if old datasets are adopted, the need for a proper solar shading control may be substantially underestimated.

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Table 3 Percentage of time during which the indoor operative temperatures are in or out of the different categories, according to the standard EN 15251.

	MI_Linate_1951-1970		MI_City_2006-2015		
	% in	% out	% in	% out	
cat I	74.6 %	25.4 %	19.3 %	80.7 %	including the shading device operation
cat II	97.0 %	3.0 %	65.3 %	34.7 %	
cat III	100 %	0.0 %	97.9 %	2.1 %	
cat I	60.0 %	40.0 %	10.7 %	89.3 %	without the shading device operation
cat II	86.9 %	13.1 %	13.5 %	86.5 %	
cat III	98.8 %	1.2 %	49.6 %	50.4 %	

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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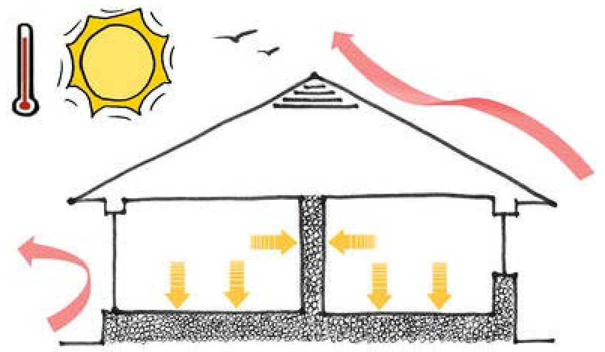
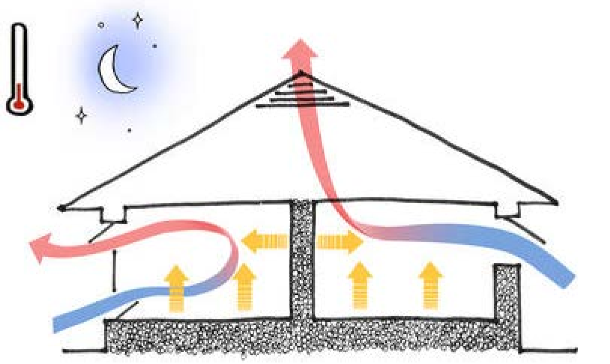
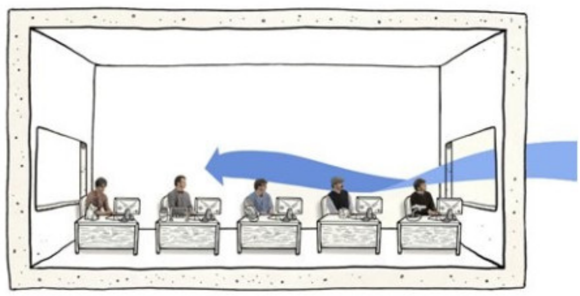
AZEB_Natural ventilation and fans

Natural ventilation is a well-known strategy to guarantee thermal comfort and indoor air quality and it is considered one of the most effective passive techniques to reduce the energy need for cooling. If coupled to the use of ceiling fans, these strategies can reduce significantly the cooling load of the building.







Summary

The implementation of passive cooling strategies such as natural ventilation since the very beginning of the project, can lead to considerable energy and costs reductions due to the decrease in the use of air conditioners thus reducing electricity consumption. This strategy can also guarantee adequate comfort conditions and improve the air quality of the room.

Natural ventilation is strongly affected by outdoor temperature: in particular, focusing on night ventilation, the higher the temperature difference between indoor and outdoor during the night, the greater will be the potential to cool down the structures during those hours, allowing the building to act as a heat sink for the following day (Erba et al. 2019). However, great importance is linked also to the correct positioning of openings, which should be placed, where possible, in order to guarantee cross ventilation and in order to make the most of it.

Strategies for wind ventilation include operable windows, ventilation louvers, and rooftop vents, as well as structures to aim or funnel breezes. Windows are the most common tool. Advanced systems can have automated windows or louvers actuated by thermostats.

The possibility to exploit NV is strictly linked also to the interaction between the building and the district, the air quality, the acoustic quality and usability issues: presently cities create constraints and buildings' geometries prevent air movement and pollutants from dissipating.

In support of NV can be adopted ceiling fans. They extend the range of comfort temperature during the hot season reducing the need to install active cooling systems or otherwise increasing the set point temperature for the air conditioning system.

Also during winter, they may be useful to reduce vertical stratification of temperature and make the heating system more effective.

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Recommendations for users

Ventilate during the night and in the early morning

In summer, remember to keep the windows open during the night and position the blinds of the shading systems horizontally or open the lower part in case of tilting shutters. If the openings are placed to allow cross ventilation, open the windows on both the side of the room to allow fresh air enter the building and cool down the structures.

Use the refreshing effect of the airflow

When the temperature inside the building has reached the temperature of the external environment, allow the passage of airflow. The increased movement of air accelerates the rate at which perspiration evaporates from our skin: since evaporation requires heat, more heat is leaving our body. Although it cannot decrease the temperature of the inner space, it can make people feel cooler.

Define the roles

It is important to identify a person, which is in charge of opening the windows in the evenings or in the early mornings and closing them after. In large buildings, a system of automated ventilation vent can be integrated in the window to control night-time cooling or sensor-controlled ventilation.

Ventilate during the day

Sometimes could be necessary to open the windows also during the day to improve air quality. Remember to close the windows as soon as possible to avoid the overheating of the building.

Choice of the ceiling fan

Larger diameter but slower fans are generally preferable respect to smaller but faster ones. In addition, the best effect is given by ceiling fans. If possible, check the noise done by the ceiling fan before choosing the type, especially if you need silence while working.

Use the fan

Place the fan so that the airflow provides a pleasant sensation and it does not hit and fresh a unique part of the body. In case of portable fan, place the device on the floor so that the fresher air is brought upward and the air mixture is improved.

Tools and physical mechanism

To evaluate the potential of natural ventilation in buildings, different tools are available depending on the design phase when they are applied. For the conceptual design phase are suggested two simplified methodologies for the calculation of the cooling potential (Erba et al. 2019). Both of them are preliminary evaluation methods to estimate the potential for passive cooling of buildings by natural ventilation just analysing climatic data, without considering any building-specific parameter. The first tool is based on the calculation of the index CPNV (Climatic Potential for Natural Ventilation) defined as the number of hours in a year when natural ventilation could be performed, divided by the total number of hours in a year. The second tool calculates the average daily Climatic Cooling Potential (CCP) for night natural ventilation over a certain period (e.g. 1 month), as the sum of the degree-hours between the indoor building temperature T_B and the outdoor dry-bulb air temperature T_E, divided by the considered number of nights, *N* (example in Figure 12).

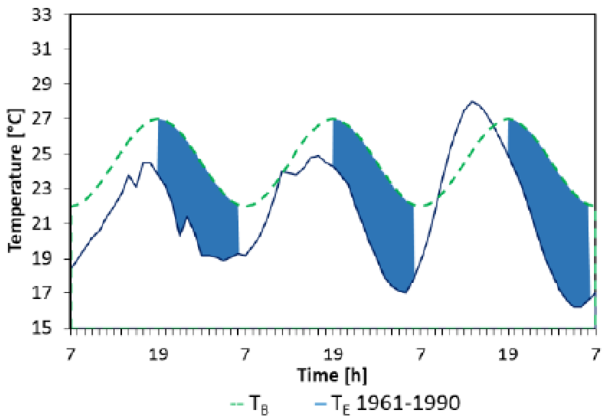

Figure 12 Comparison between the building temperature T_B (in green, dashed line) and the outdoor dry-bulb air temperatures T_E. Blue areas show graphically the climatic cooling potential between 7 p.m. and 7 a.m.

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Ceiling fans

The increase in the air velocity can extend by some degrees the upper limit of the temperature comfort range. The cooling perception with improved air movement is due to the rise of the heat leaving human body; the movement of air accelerates the process of sweat evaporation from the skin that requires heat. Some standards specify the relationship between the air velocity and the upper temperature limit increase. For example, EN 16798-1:2019 states that "Under summer comfort conditions with indoor operative temperatures > 25 °C artificially increased air velocity can be used to compensate for increased air temperatures according to Table B.4 only if the increased air velocity is under personal control. The correction value depends on the air speed range of the appliance." Figure 13

Table B.4 — Indoor operative temperature correction ($\Delta\theta_o$) applicable for buildings equipped with fans or personal systems providing building occupants with personal control over air speed at occupant level

Average Air Speed (v_a) 0,6 m/s	Average Air Speed (v_a) 0,9 m/s	Average Air Speed (v_a) 1,2 m/s
1,2 °C	1,8 °C	2,2 °C

Figure 13 Relationship between air speed and indoor operative temperature correction. Source: EN 16798-1:2019.

Example

The following example shows the improvement in indoor thermal comfort after activating natural night ventilation. The building is a primary school located in Italy (climate zone E); it is characterized by an L-shape, with a covered surface area around 1970 m^2 and a total volume of 20685 m^3 (WP3_Italian case study); the presence of 15 classrooms allows a maximum capability of 375 students.

Figure 14 shows the comfort condition for the scenario without natural night ventilation (S0) in the classroom oriented towards south (t_o is the operative temperature while t_{rm} is the running mean temperature), while Figure 15 represents the scenario where natural night ventilation is provided. It is possible to observe a significant improvement of thermal comfort.

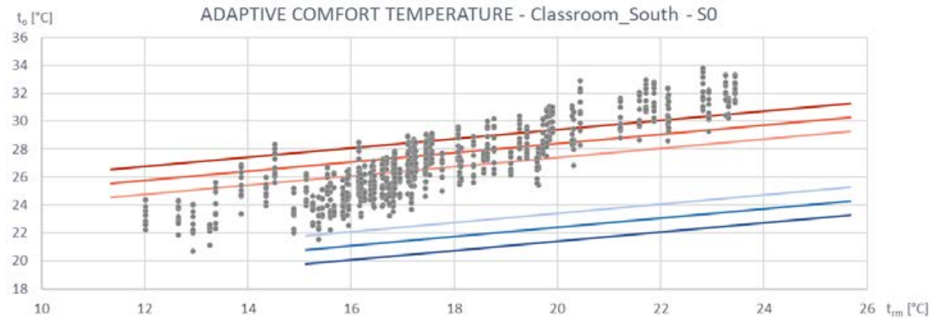

Figure 14: Hourly operative temperature - single classroom_South – Scenario without natural night ventilation (S0).

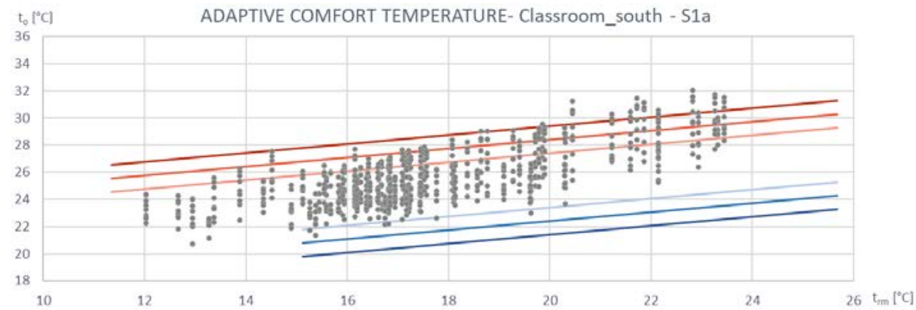

Figure 15 Hourly operative temperature – classroom_South – Scenario with natural night ventilation considerng stack effect and top-hung configuration (S1).

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The configuration with fully opened window [Figure 16], considering average air change rate due to wind and stack effect, brings an important shifting throughout all the hours of the period when night ventilation is applied. The discomfort temperatures during hot days is limited to a few number of hours.
It's important to underline that together with the improvement of thermal conditions, the activation of natural night ventilation reduces the energy need for cooling and costs savings will be achieved.

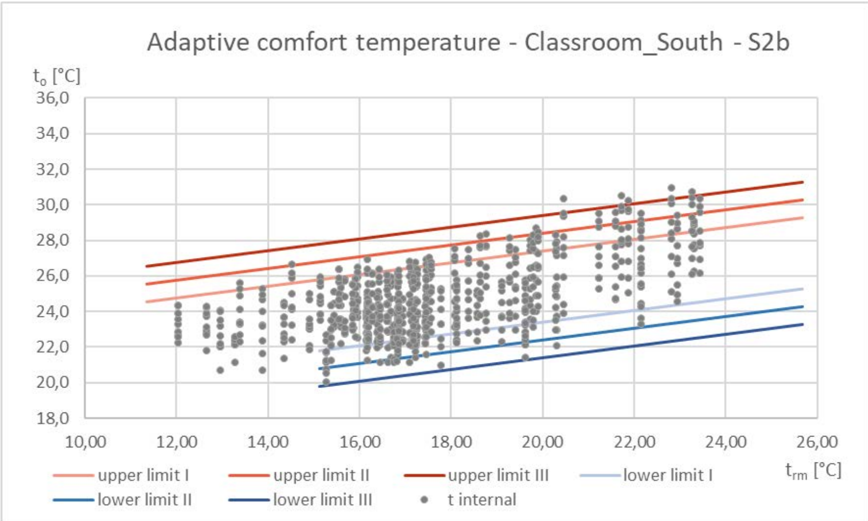

Figure 16 Hourly operative temperature – classroom_South – Scenario with natural night ventilation considering average air change rate due to wind and stack effect and fully opened window (S2b).

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
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e-mail: lorenzo.pagliano@polimi.it

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Affordable Zero Energy Buildings

AZEB_Air conditioners Tips

Using air conditioners and electric fans to stay cool accounts for nearly 20 % of the total electricity used in buildings around the world today.

Summary

Despite the costs associated to the installation of air conditioners, space cooling is the fastest-growing use of energy in buildings, both in hot and humid emerging economies where incomes are rising, and in the advanced industrialised economies where consumer's expectations of thermal comfort are still growing. Final energy use for space cooling in residential and commercial buildings worldwide more than tripled between 1990 and 2016 to 2020 TWh of electricity. The share of cooling in total energy use in buildings rose from about 2.5 % to 6 % over the same period. For commercial buildings, the share reached 11.5 % in 2016, up from 6 % in 1990. Cooling accounted for 18.5 % of total electricity use in buildings (up from 13 % in 1990) and is expected to reach about 37 % in 2050.

Consequently, it is highly suggested to give priority to the suggestion provided in the factsheet "Natural ventilation and fans". If it is still necessary to install an air conditioner, it is advisable to follow the recommendations specified under.

Recommendations for users

Choose the correct dimension

The air conditioner should be properly dimensioned: an oversizing is counterproductive: as the appliance manages to cool the air faster than it manages to dehumidify it, a wet cold sensation will result. Furthermore, these are linked to higher costs for the investment and the energy used.

Adjust as necessary

- If the room is heavily shaded, reduce capacity by 10 percent.
- If the room is very sunny, increase capacity by 10 percent.
- Consider where you install the unit. If you are mounting an air conditioner near the corner of a room, look for a unit that can send the airflow in the right direction.

Choose labelled products

Choose to buy air-conditioners that are energy-efficient labelled.

Guarantee the free movement of the air

At the moment of the installation, you should verify that the fresh air entering the room can circulate without obstacles (such as furniture, walls or curtains).

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Choose a shaded place

If possible, install the external unit of the appliance in a shaded place. Also, pay attention to leave enough space for the free circulation of air around the device.

Check that is waterproof

Who uses a compact device should absolutely check that the air expulsion tube is well waterproofed. Don't leave open windows nearby and close even small cracks! Otherwise, the hot air expelled will be directly reintroduced into the room. Fresh air should possibly be sucked in a controlled manner from the north side.

During the use

- With splits, you should keep doors and windows closed when the air conditioner is on. With the compact appliances, you should verify that the opening, from which the air enters, faces north.

- Generally, it is sufficient to lower the temperature of the rooms of a maximum of 6 degrees compared to the external one. A greater cooling fatigue the body and increases the risk of colds.

- Turn off the air conditioners if there is no one in the rooms. Switch off the air conditioning as early as starting from an absence of one hour. Use eventually a timer not to forget the evening shutdown.

- Do not direct the air conditioning outlet directly on people, because they could get cold. The air flow should also not be hindered by any object.

- Keep the air conditioners following the indications of the producers. Regular cleaning of the heat exchangers, the condenser and the evaporator are particularly important. Otherwise the performance of the device can also reduce about 50 %. Regular maintenance is important also for hygiene reasons.

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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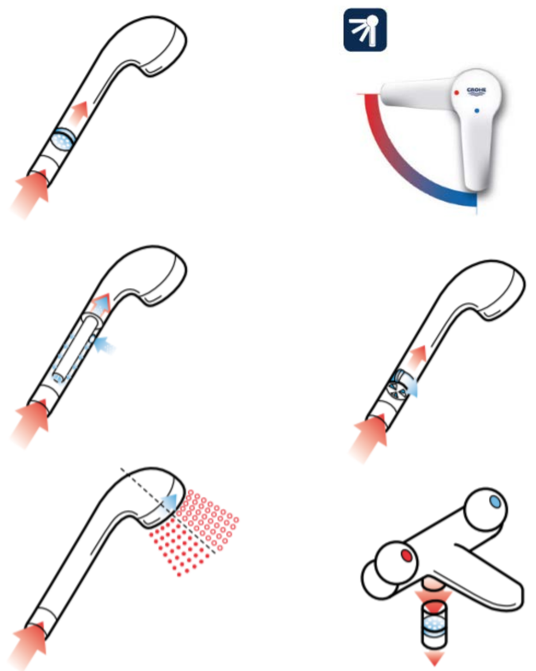
AZEB_Domestic hot water & sufficiency actions

While moving to high performance buildings, the energy needs for heating and cooling is greatly reduced, so the energy and economic costs connected to domestic hot water assume a large fraction of total energy expenditure.



Summary

Nearly Zero Energy Buildings (nZEBs) are buildings which consumes very little amount of energy for heating, cooling, domestic hot water production, ventilation and lighting. These results can be reached through a conscious management of the DHW and using very simple but effective devices, which reduce and regulate the water flow. The reduction of the water consumption allows saving drinking water but also the energy needed to warm it up, with a consequent energy and economic saving, a reduction of the air pollution and of the greenhouse effect.

There are existing voluntary labelling schemes available for taps and showers (e.g. the Water Efficiency Label, the Swiss Energy Label for Sanitary Fittings, the European Water Label scheme) which could potentially apply to almost all products used in domestic and non-domestic applications. The purpose of the energy label is to raise awareness in the consumer on the use of hot water, highlighting environmental and economic benefits.

Different saving devices are available on the market:

- low flow shower dispenser
- shower head with integrated flow regulator
- flow regulator
- special taps

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Recommendations for users

Reduce the unnecessary water consumption

- Turn off the tap while brushing your teeth.
- Avoid leaving the tap open while shaving.
- Turn off the tap while soaping up.
- Use a tray to place the dishes for soaping and then use a weak stream of water to rinse them.
- Use the pasta cooking water to wash the dishes; this has in fact a strong degreasing power and thus allows a saving of water and detergents.

Choose labelled products

If possible, choose to buy sanitary products, which are energy-efficient labelled.

For example in educational buildings, choose special taps in which the possibility of opening the tap in hot and cold water mixing mode is eliminated. This will avoid the useless heating of water for daily rituals such as washing hands or cleaning teeth.

Control the duration of your shower

The standard duration for a shower is around 5 minutes. Teach your children not to spend more than this time under the water and remember to close the water while soaping up.

Physical mechanism

Low flow shower dispenser

Figure 17 Low flow shower dispenser Turbojet, (http://www.jditems.com/turbojet).

It is composed mainly by two devices:

- The flow reducer, which decreases the section for the passage of water, having a lower water flow with the same pressure. It can be rigid or elastic with difference performance.
- The water regulator, which guarantees the quality of the water flow and the capacity of washing also with low flows. Among the different options, the aeration mechanism/filter makes use of the Venturi principle: thanks to its shape, the water passing through brings a depression that sucks air inside [Figure 17].The air is mixed with the water, increasing its apparent volume.

As an order of magnitude, the water consumption is reduced by 40 % to 50 % with respect to a traditional shower.
According to PAEE 2011, in Italy the use of this device has saved 5878 GWh/year just for the residential sector (energy savings reached until 2010).

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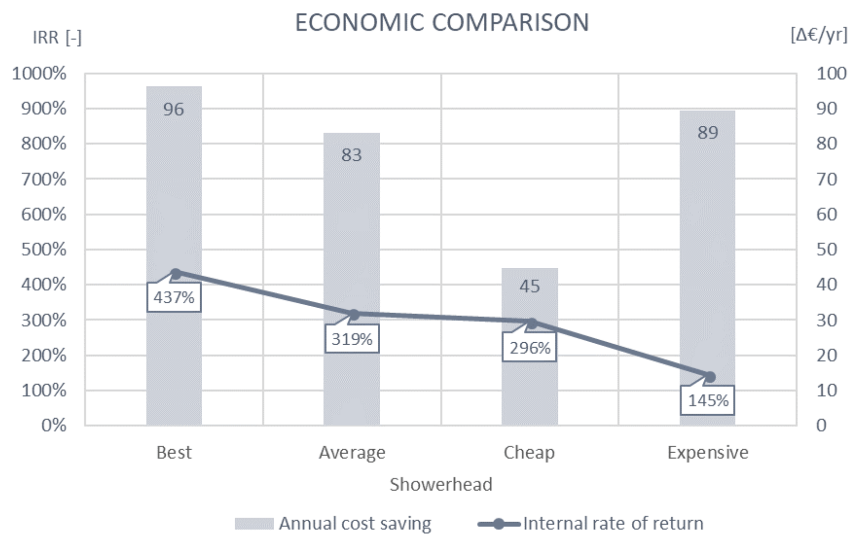
Examples



LOW-FLOW SHOWERHEADS		
Name	V' [l/min]	CO_{inv} [€]
Best	5,7	22
Average	6,3	26
Cheap	8,0	15
Expensive	6,0	61

Figure 18 Economic comparison between different types of showerhead available on the market, highlighting annual cost saving and internal rate of return.

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Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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AZEB_Sharing the common spaces

Common spaces favour conviviality and cohesion and may reduce the need for excessively large private (conditioned) spaces.

Summary

Sharing spaces can be a way to reduce the energy consumptions and the costs associated to the use of the building. To deepen the potential linked to this approach we take advantage of some practices popular in the collaborative living style known as *cohousing*, which favours good neighbourly relationships to ensure high quality of life.

Cohousing is an intentional community of private homes clustered around shared space. Each attached or single family home has traditional amenities, including a private kitchen. Shared spaces typically feature a common house, which may include a large kitchen and dining area, laundry, and recreational spaces.

Shared outdoor space may include parking, walkways, open space, and gardens. Neighbours also share resources like tools and lawnmowers. They tend to keep cars to the periphery, which promotes walking through the community and interacting with neighbours as well as increasing safety for children at play within the community.

Shared green space is another characteristic, whether for gardening, play, or places to gather. When more land is available than is needed for the physical structures, the structures are usually clustered closely together, leaving as much of the land as possible "open" for shared use.

Throughout the years, it has become apparent that, in addition to its social advantages, cohousing offers numerous environmental benefits. On average, residents of cohousing communities consume less energy, own fewer cars and drive less than people who do not live in a cohousing.

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The main practices for common areas are:

- common areas for the differentiated waste;
- availability of parking space for bicycle storage;
- availability of space for pushchairs storage;
- common areas for clothes drying;
- storage of materials and tools;
- common external spaces, possibly equipped, with presence of trees and greenery;
- playground;
- permeability of walkable surfaces;
- favour the construction of buildings in proximity to services and to the access to the public services to encourage their use.

Recommendations for users

Line drying requires infrastructure and clean air

A provision for spaces adequate to line drying outdoors (on facades, balconies, roofs) and well designed for convenience and aesthetic can enable this practice, very relevant in terms of energy saving (drying a kg of clothes indoors or with a drying machine can be 3 to 5 times more energy expensive than washing it).

Use the common spaces

Common spaces favour conviviality and cohesion and may reduce the need for excessively large private (conditioned) spaces.

Maintain the common areas

Organize the shifts to clean periodically the common spaces so that you can take benefit for long.

Bike to work or to school

If possible, favour the use of the bike instead of the car. This will guarantee money savings, fresh air, brain power, fitness and fun!

Car sharing

Organize to share the use of the car if you need to reach the same place (e.g. to bring the children living in the same district together to school).

Contacts

Silvia Erba, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: silvia.erba@polimi.it

Prof. Lorenzo Pagliano, PhD
eERG (end-use Efficiency Research Group) www.eerg.it
Energy Department, Politecnico di Milano
e-mail: lorenzo.pagliano@polimi.it

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