# Urban Energy Technical Note

08

# Passive Cooling

Passive cooling systems use non-mechanical methods to maintain comfortable indoor temperatures and are a key factor in mitigating the impact of buildings on the environment.

Passive cooling seeks to use natural heat flows whenever possible. The purpose of passive cooling is to provide indoor comfort and a healthy indoor environment while reducing the energy costs associated with cooling, thereby eliminating or reducing overall running costs.

In areas where cooling is a dominant problem, passive cooling techniques can be used to reduce or eliminate, mechanical air conditioning requirements. They also reduce the peak cooling loads in buildings, hence reducing the size of the air conditioning equipment needed and the period for which it is generally required.

Many parts of East Africa experience high temperatures in certain periods of the year and therefore cooling is very important. For example in humid, arid and semi-arid climatic regions, cooling is the primary design consideration.

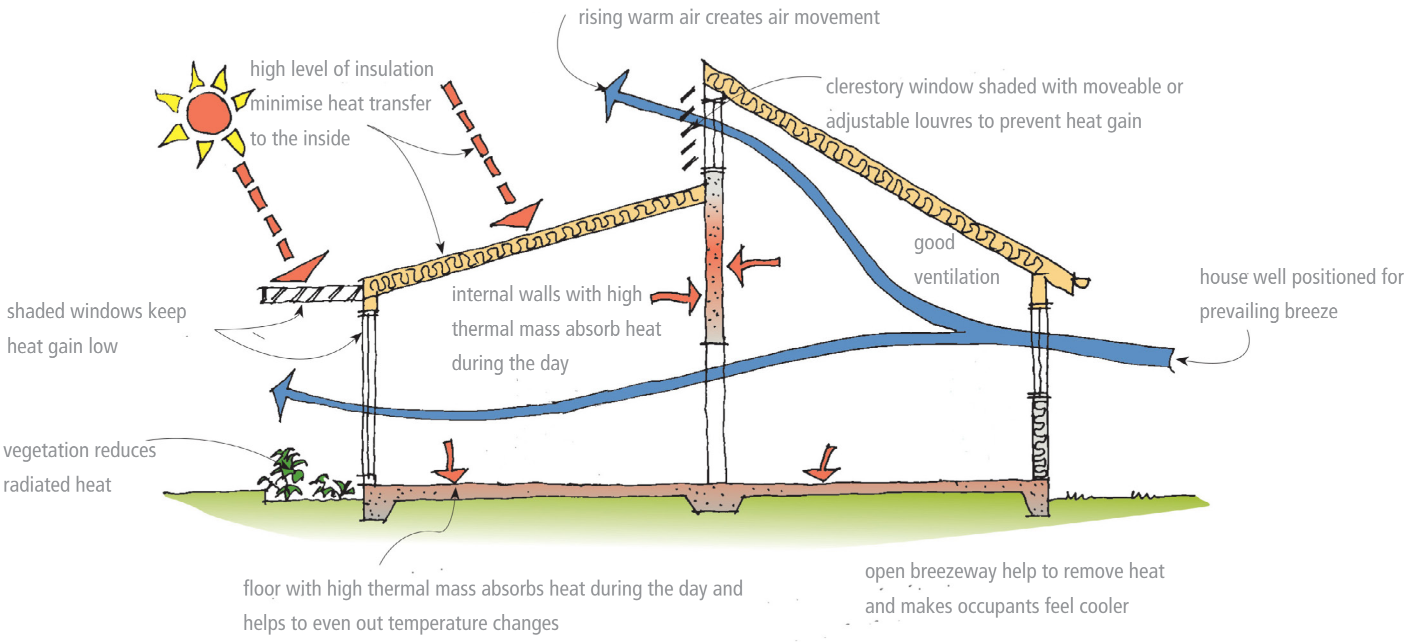
The cost and energy effectiveness of these options are both worth considering by homeowners and builders. By integrating these systems at the design stage, greater efficiency and lower costs can be obtained.

This technical note describes how a building can be effectively cooled using natural means.

## Sources of unwanted heat

- Direct solar gains through windows and skylights.
- Heat transfer – through materials and elements of the structure
- Internal heat generation from occupants, and mechanical and electrical equipment.
- Infiltration of hot air into the building.

Fig. 01: **Features of passive design for cooling**




Adapted from Level, The Authority of Sustainable Building © BRANZ 2011

# Cooling buildings

Passive cooling works by controlling or preventing heat from entering the building (heat gain prevention) or by removing heat from a building (heat dissipation).

## Reduction of heat gains

Cooling requirements for buildings are largely determined by the amount of heat gained from solar radiation. Reduction of solar heat gains can very effectively reduce the energy consumption of buildings.

Unwanted solar energy can be excluded by using various techniques that can be generalised as follows:

1. Correctly designed shading devices deflect the sun's rays;
2. Proper orientation of the building with the longer facades facing the north and south prevents overheating in the tropics;
3. Minimizing glazed surfaces on the east and west facing sides of a building reduces heat gains;
4. Light coloured paints and materials on the roof and walls effectively reflect unwanted solar radiation;
5. Building materials affect heat gains and should be chosen with respect to the local climate.

- Heavy weight materials (suitable for hot and dry climates) absorb heat, slowing the increase in internal temperatures on hot days. At night, they then release the heat absorbed earlier in the day.
- Light weight materials do not store heat and are ideal for use in hot-humid climate.

## Heat dissipation strategies

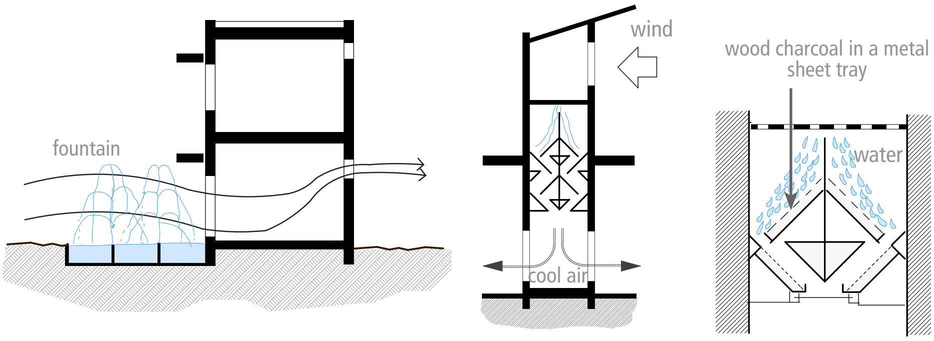
The cooling strategies chosen for a project should suit the specific characteristics of the climate and also enhance the architectural design solution. Varying degrees of cooling in a building can be naturally achieved using the following strategies:

1. **Evaporative cooling**

- This technique cools outdoor air by channelling it over water before it is introduced into the building thereby cooling the indoor spaces. This method is effective in hot

Fig. 02: **Vegetation and outdoor areas enhance shade and cooling breezes**

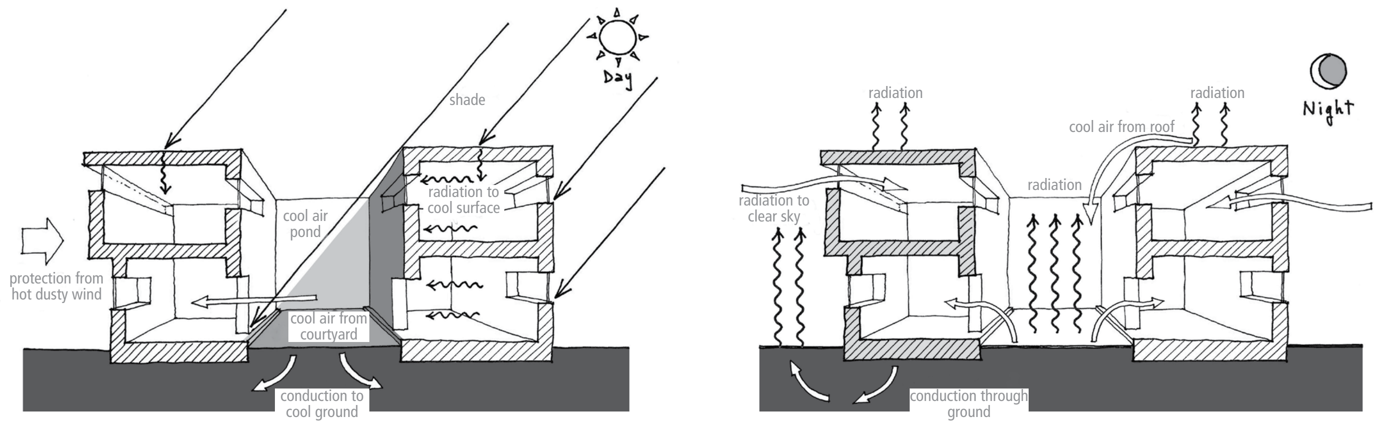
Fig. 03: **Evaporative cooling strategies**




Fountains, sprays, pools and ponds are particularly effective passive cooling techniques. Hot air is channelled over the water before it enters the building.

Passive downdraft evaporative cooling (PDEC) technique incorporates towers that are equipped with evaporative cooling devices at the top to provide cool air by gravity flow.

Fig. 04: **Cooling system in a courtyard house**




Courtyards are excellent thermal regulators. High walls cut off the sun, except for around midday, and large areas of the inner surfaces and floor are shaded during the day. During the night the heat accumulated during the day is dissipated by re-radiation.

and arid climates or where relative humidity is low (70% or less during the hottest periods); the drier the air, the greater the cooling potential.

2. **Natural Ventilation**

- When properly used, this strategy contributes to the improvement of thermal comfort and indoor air quality leading to a significant reduction in energy consumption for the cooling of buildings.
- Orienting the building to take advantage of the prevailing wind aids in natural ventilation, which is a very important aspect of natural cooling.

3. **Solar chimney**

- This technique enhances stack ventilation by the thermal-buoyancy effect. The chimney's structure absorbs heat during the day, hence heating the air enclosed within, causing it to rise. As indoor air escapes via the chimney, cooler outdoor air flows into the building.

4. **Wind turbines**

- The use of turbine vents at the roof peak can be used to improve the cooling rate by enhancing the air flow.
- When the surface of the turbine is heated, it creates a low pressure zone at the outlet thereby drawing indoor air upwards where it escapes to the outside.

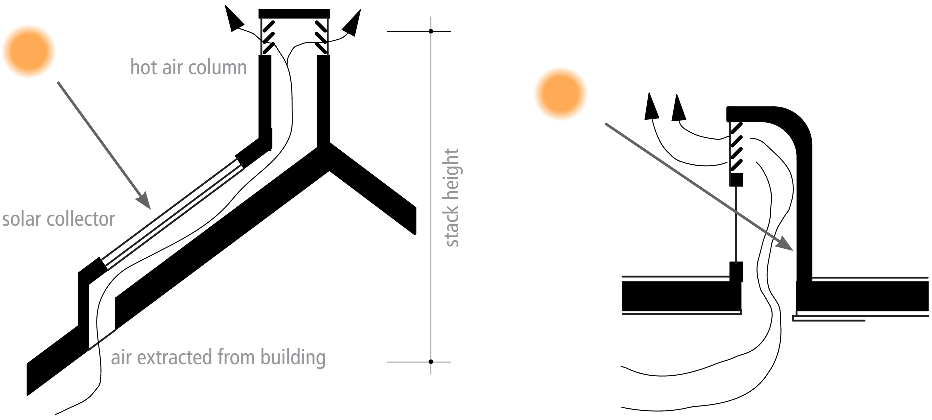
5. **Air vents**

- Curved roofs with air vents at the top are suitable for hot and dry climates. The air vent in the apex of the domed or vaulted roof provides an escape path for the hot air that accumulates at the top.

6. **Rock bed heat exchanger**

- In this system, during the day, outdoor hot air is drawn through the (night-cooled) rock bed where it is pre-cooled before entering the building.
- At night, cool night air is blown through the building via the rock bed, thereby cooling the rocks.

Fig. 05: **Examples of solar chimneys**




The heated air rises and escapes to the outside. This causes internal air to be pulled into the heated space and expelled thus enhancing airflow.

Fig. 06: **Examples of air vents and wind turbines**

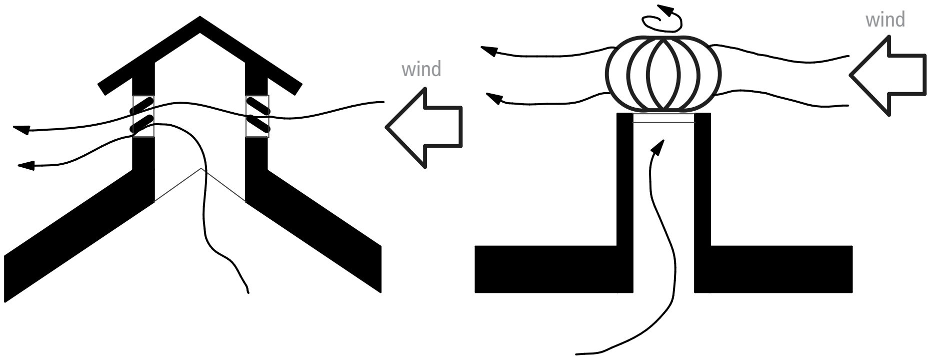
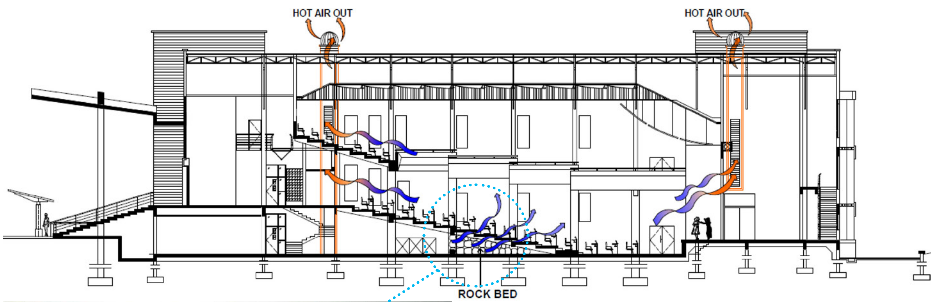



Fig. 07: **Rock bed heat exchanger**




Rock bed cooling system used at The Learning Resource Center Conference hall, The Catholic University of Eastern Africa, Nairobi, Kenya © Architect Musau Kimeu

7. **Other cooling strategies include:**

- **Ground (earth) cooling -** During the hot periods, the soil temperature at a certain depth is considerably lower than the ambient temperature. Hence, the ground offers an important sink for the dissipation of the building's excess heat.
- **Wind towers -** Hot outside air enters the tower through the upper opening of the tower, gets cooled, becomes heavier and flows down the tower and into the living area through the lower opening.
- **Radiative cooling -** This technique works by covering the roof or externally insulating the roof during the day in order to minimise heat gains from solar radiation and

ambient air. At night, the roof is uncovered / exposed to the cool night sky, thereby losing heat via long wave radiation and convection.

## Active cooling systems

These systems can be used in climates where the average daily temperatures and humidity levels lie beyond the passive cooling strategies.

The following strategies can be used:

1. **Evaporative coolers** - These are very effective and energy efficient in hot-arid and hot semi-arid climates. In these climates, there are seasons and periods of the day in which air humidity is very low and air temperature very high.

- Fans in the unit force hot outdoor air through water-soaked pads, filtering and cooling it before driving it into the building thereby causing warm inside air to be expelled through windows or vents.

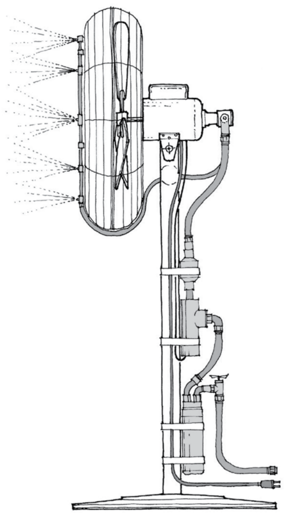
2. **Air conditioning systems** - These systems can be used in hot and humid climates during periods of high humidity.

- They can be used in conjunction with other cooling methods, such as ceiling fans, for energy improvements.

Fig. 08: **Evaporative cooler**

Evaporative cooling systems as used at the students' center building, Strathmore University, Nairobi © UN-Habitat / Jerusha Ngungui

Fig. 09: **Misting fan**



3. **Ceiling fans** - These are effective in spaces with no air conditioning and where air movement is not sufficient.

4. **Misting fans** - These are normal fans equipped with fog nozzles, which are designed to produce a very fine mist so that the water evaporates quickly. They are effective in hot-arid climates.

### Tips for using air conditioning systems

- Correct sizing and selection of air conditioning equipment is key to achieving optimum energy efficiency.
- A good energy efficient air conditioner should have a high energy rating.
- The use of air conditioning should be limited to the rooms where it is most needed.
- Air conditioned rooms should be thoroughly insulated, have reduced glass areas and preferably be located in the coolest part of the house in order to reduce the cooling loads.
- Regular maintenance checks will ensure your air conditioning system operates as efficiently as possible.
- Keep windows and doors shut when units are operating. If you open windows in a space you are cooling, the unit will try to cool down the outside air!

***REFERENCES***


*Gut, P. and Ackerknecht, D. (1993).* ***Climatic Responsive Building: Appropriate building construction in tropical and subtropical regions.*** *Switzerland: SKAT.*

*Koeningsberger, O.H., et al. (1973).* ***Manual of Tropical Housing and Building.*** *London: Longman.*

*Konya, A. (1980).* ***Design Primer for Hot Climates.*** *London: The Architectural Press Ltd.*

*UN-Habitat and Politecnico de Milano (forthcoming).* ***Sustainable Building Design for Tropical Climates: Principles and Applications for Eastern Africa.*** *Nairobi*



**For more information, please contact:**

The Urban Energy Unit
Urban Basic Services Branch
United Nations Human Settlements Programme (UN-HABITAT)
P. O. BOX 30030 - 00100 Nairobi, Kenya
Vincent.Kitio@unhabitat.org
www.unhabitat.org/urban-themes/energy/



*Executed by UN-Habitat with the support of GEF and UNEP*

*The purpose of this Technical Note is to call reader's attention to new technical issues in the field of sustainable human settlements development. They are not meant to be final or exhaustive. For more information, contact the Urban Energy Unit. Prepared by Vincent Kitio and Jerusha Ngungui*