How Can a House Be Energy Efficient?

Center for the Study of the Built Environment (CSBE)

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Energy consumption in residential buildings in Jordan amounts to 22% of the total energy consumption in the country, so applying energy efficient principles in these buildings is of major importance. However, the design of most residential buildings in Jordan does not take into account energy efficient principles such as proper orientation and layout, and the need to maximize the benefits from natural elements such as sun and wind, which can lead to much more effective heating and cooling.

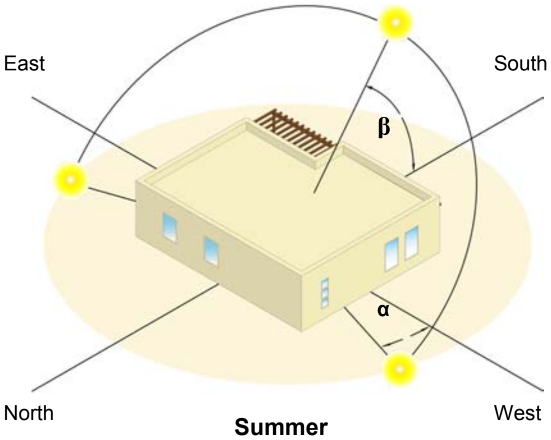
This booklet has been developed especially for householders living either in individual houses or apartment blocks. This booklet can also help those looking to build or buy a residence to select suitable and appropriate means to make their home energy efficient, and will also help the residents of existing homes to enhance the energy performance of their house.

Features of an energy efficient house:

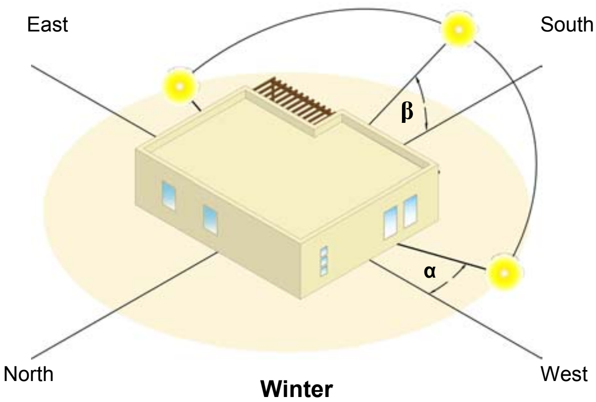
1. <u>Building orientation</u>

The movement of the sun is the most important natural element to take into account when designing an energy efficient house. Since the sun is the main source of heat, a major principle of energy efficient design is to allow that heat into the house in the winter, and exclude it in the summer. Fortunately this is easily achievable since the angle of the sun changes from season to season. During the summer months the sun rises in the north east and ascends slightly southwards until it becomes almost perpendicular to the earth's surface at noon, after which it descends again towards the North West. The main heat gain of a house during the summer comes from the roof, as well as from the east and west facades. Therefore it is important to shade and obscure the roof and any east and west facing windows and walls. During the winter months the path of the sun is much shorter - it rises in the south east, and remains at a low angle as it moves towards the south before setting again in the south west. As such, the main heat gain during the winter comes from the south façade of the house. South facing windows and walls, therefore receive maximum warmth during the winter.

Wind is the other element that is important to control during the design, as shall be seen below.



Summer



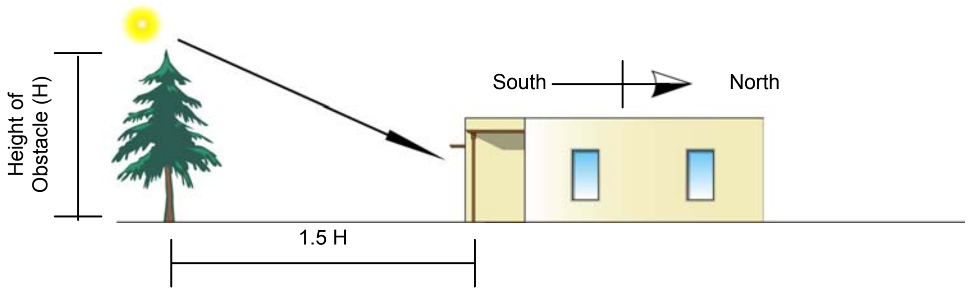
Winter

Season	Day	Horizontal Rise (α)	Noon Altitude (β)
Summer	June 21 (longest day of the year)	28° South	82°
Winter	December 21 (shortest day of the year)	28° North	35°

- When choosing a site, ensure that there are no obstructions such as buildings or trees in front of the south façade. The distance between the south façade and obstacles should be at least 1.5 times the height of the obstacle.

- A building should be designed just a bit longitudinal with an east-west direction. The longer side towards the south will allow for more sun to enter the house during winter. However the ratio should not exceed 1.5 because the more longitudinal the building, the greater the surface area subjected to external weather - the sun in the summer or wind in the winter. The best ratio for a building would be 1:1.2 in all areas of Jordan.

- An orientation perpendicular to true south is best. If there is a deviation, it should ideally not be more than 15 degrees.



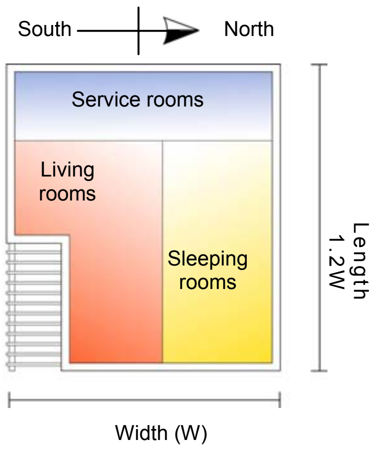
2. Internal room layout

- Arrange indoor living areas along the southern side of the home, where possible, and bedrooms along the northern side.

- Use rooms that do not need a lot of cooling and heating in the most exposed areas in the house, e.g. garages, storage rooms, corridors.

- Gather different uses into zones with separating doors. This allows control of the heating and cooling of each zone separately depending on the needs.

- Group hot water-using services together, e.g. Kitchen, laundry, and bathroom. This will minimize the need for long hot water pipes, and will reduce the amount of heat lost from the pipes and consequently the hot water use.

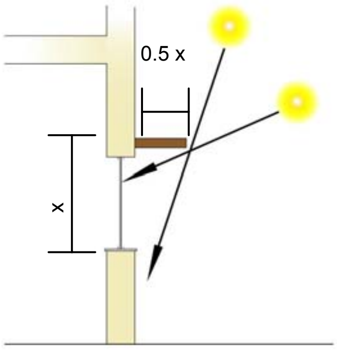


Plan

3. Window placement, sizing and shading

Windows should be carefully designed as they serve several functions in an energy efficient house. They act as solar collectors, trapping heat from the sun. They also act as ventilators, providing cross ventilation. They are also important lighting tools. However, a window can loose heat five to ten times faster than an equivalent area of wall. Therefore the design of windows should achieve a balance between its functions.

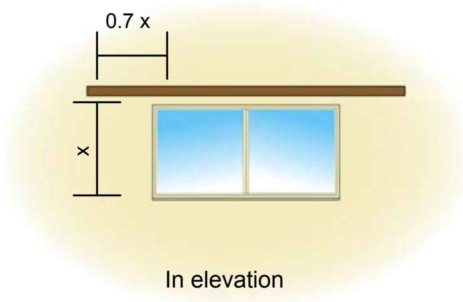
- South-facing windows: The best size for south facing windows largely depends on the location of the house. In cooler, hilly areas, larger window sizes are more suitable, provided they are double glazed and air-tight. In warmer areas, smaller window sizes are better, and shading overhangs become important. For example in Amman, 20-30% of the elevation area should be glazed. This can go up to 40% if the windows are double glazed and shaded. In Aqaba, the smaller the area of window openings, the better. Around 10% of the elevation area is best.



In section

- Calculate the best depth of the shading overhang, to allow winter sun to pass through while shading the summer sun. The shade depth should be 0.5 times the window height. The shading should then extend beyond the edges of the window on both sides, with the extension equaling 0.7 - 0.8 of the window height.

- Deciduous trees or creepers may be grown on the southern side of the house to provide good shade in the summer. But ensure that shading devices do not block the sun during the winter.

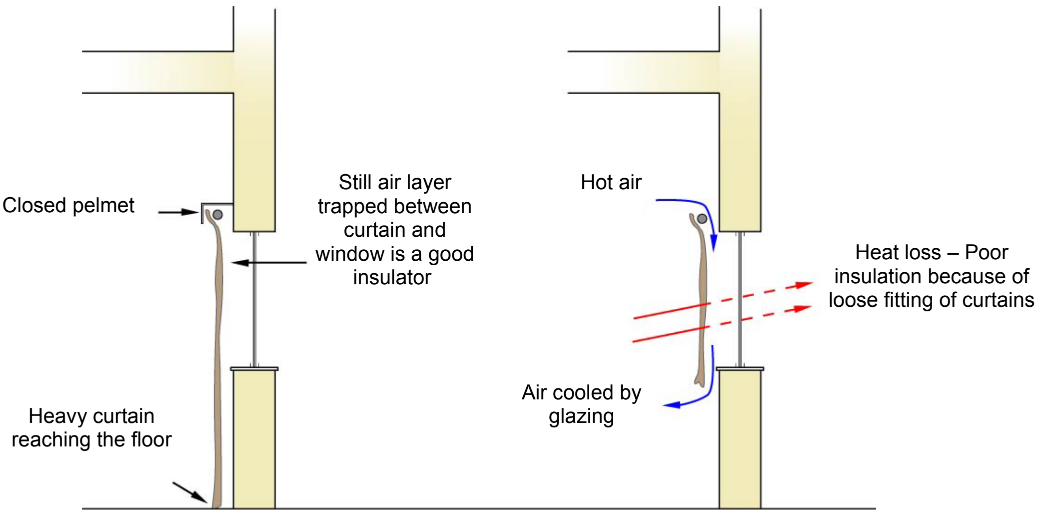


In elevation

- East and west-facing windows: The area of these windows should be kept to a minimum. Full vertical screening (external shutters) or deciduous trees are the only shading devices that can block low sun in the early and late summer. However, western windows are also important for cross ventilation in some Jordanian cities (e.g. Amman) because of the direction of the prevailing summer breeze.

- North-facing windows: These lose considerable heat during winter, but only need minimal vertical shading and internal blinds to block out the summer sun. The use of double-glazed windows for northern windows is most important as it minimizes heat loss during the winter.

- Internal window treatments - curtains/blinds: These are important in reducing winter heat loss, but are not effective in blocking the summer sun. In order for curtains to act as an insulator, they should be made of a heavy fabric with insulating backing. They need only to be long enough to reach the ground, and they should include a closed pelmet to minimize air circulation between the curtain and the glazing. However, often in Jordan, radiators are placed underneath the windows, and in this case, the use of long curtains is not recommended, since it would prevent heat from the radiator from reaching the room.



Demonstration of using curtains to reduce heat loss in section

Demonstration of heat loss in section

- Skylights: Even though skylights reduce the need for artificial lighting, they cause significant heat loss in winter and heat gain in summer. To limit these effects, skylights should be double-glazed, and should be shaded in the summer.

- Tinted glass: Tinted glass is effective in reflecting heat in the summer, but also reduces the amount of light and heat entering the room in the winter. It may be useful where large areas of glazing in western and eastern facades are unavoidable. However, they do not substitute for external shading.

- Double-glazing: Such glazing works both to prevent heat loss and gain, but does not substitute for external shading. Also, it is cost effective only where there are high heating requirements (it therefore would not be effective in Aqaba, for example, where winters mild).

The installation of double-glazing is one effective solution for improving the energy efficiency of existing houses. If the budget available for double-glazing is limited, then focus on the northern elevation, and the large windows on other elevations.

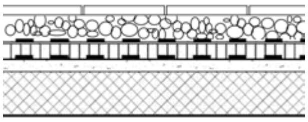
4. Insulation

- Most heat is lost or gained through the roof. It is therefore absolutely necessary that the roof of a house or an apartment building is thermally insulated. Thermal insulation of the roof could simply mean a 5cm layer of insulation material applied over the roof slab. This is different from the water insulation typically used in buildings in Jordan.

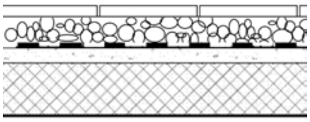
- It is recommended that external walls are also insulated. A standard way of doing that in Jordan is the sandwich-insulated wall, see below.

- To select a proper insulation material, the simplest way is to compare the U-values. U-value is a measure of a material’s ability to transfer heat. The lower the U-value, the better an insulator the material is.

Roof sections:

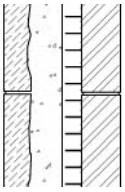


An insulated roof comprised of 20cm reinforced concrete roof slab, 0.5cm water barrier, 5cm extruded polystyrene thermal insulation, 5cm screed, filter membrane, 0.5cm gravel and 0.2cm tiling
U-value = 0.455

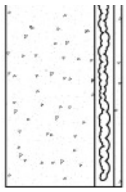


By contrast, an un-insulated roof comprised of 20cm reinforced concrete roof slab, a 5cm screed, 0.5cm water barrier, 0.5cm gravel and 0.2cm tiling
has a U-value of 1.885

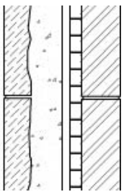
Wall sections:



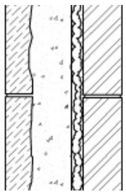
A cavity wall comprised of 7cm stone, 8cm concrete, 5cm polystyrene, and 10 cm hollow concrete blocks. U = 0.49



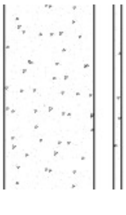
An un-insulated wall and a gypsum board, with 5cm rock-wool separating the two layers.
U = 0.61



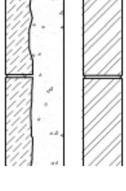
A cavity wall comprised of 7cm stone, 8cm concrete, 3cm polystyrene, 2cm air gap, and 10 cm hollow concrete blocks. U = 0.69



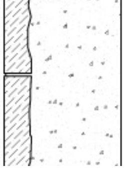
A cavity wall comprised of 7cm stone, 10cm concrete, 3cm rock-wool, and 10 cm hollow concrete blocks. U = 0.88



An un-insulated wall with 1.5cm thick gypsum board, separated by 5cm cavity. U = 1.73



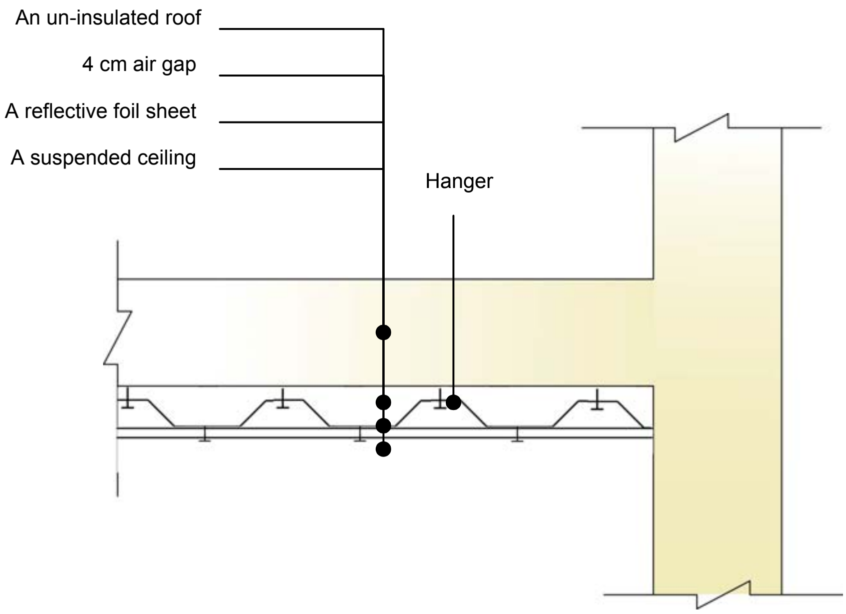
A cavity wall comprised of 7cm stone, 8cm concrete, 5cm air gap, and a 10cm hollow concrete blocks.
U = 2.02



An un-insulated 23cm concrete wall with 7cm stone veneer.
U = 2.60

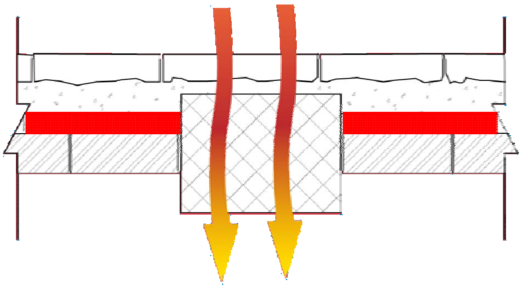
An un-insulated 20cm concrete wall.
U = 3.03

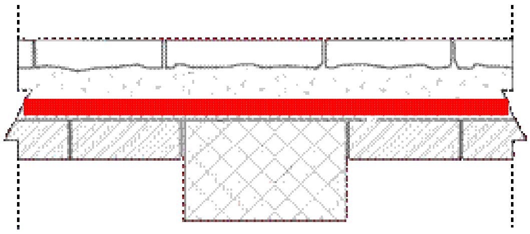
- To improve the insulation of an existing house, you can add a gypsum board at a distance of 5cm from the internal surface of the walls and you can also fill this cavity with insulation materials. Typical U-values for different wall make ups are demonstrated above. As for insulating the roof, individual house owners or those who own apartments at the top floor can suspend a false gypsum board ceiling with a reflective foil sheet covering the internal surface of the roof, as explained in the following figure.



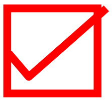
- Ensure that insulation materials are properly installed. Pay special attention to moisture bridging, damp proofing, air gaps and provide continuous insulation even around columns and roof slabs. Thermal bridges need to be prevented as they can cause several problems such as cracking and moulding of walls, due to the inconsistent temperatures of internal surfaces on the same wall.

Wall plans:



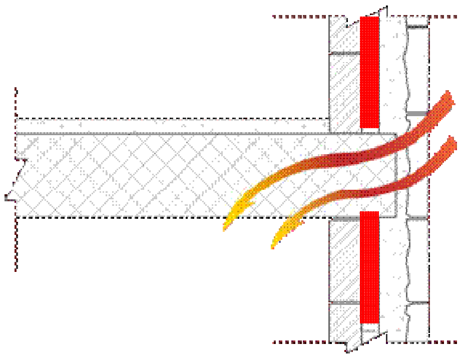


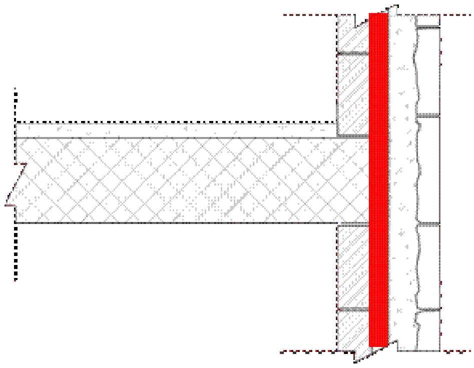
The insulation layer stops when it reaches the columns and roof slabs, forming thermal bridges at these places. This causes several problems such as cracking, moulding as well as heat loss through these bridges.



The insulation layer turns around the column and the slab, ensuring a continuous layer of insulation around the external shell of the building.

Slab sections:





The typical method of building a wall is by first building the internal block-wall (three rows at a time), placing the insulation material, and then pouring concrete in the remaining gap. This is fine if the insulation material is rigid. However, if it is flexible, build the stone facing first, then fix the insulation, and finally build the block wall. This will maintain the insulation thickness.

5. Use of heat absorbing materials

Thermal mass is the concept that defines the material's ability to absorb and store heat. Dense materials such as stone, concrete, and brick heat up and cool down very slowly. They have a high thermal mass, which means that they store heat for longer hours before starting to radiate it again. Lightweight materials such as fiber concrete, metal sheets, wood, and gypsum board have a low thermal mass, and accordingly heat up and cool down quickly.

- Having internal walls and other internal surfaces (floors, counters, furniture, etc.) comprised of materials with a high thermal mass is most beneficial for homes which have good solar access from southern facing windows. For example, laying dark tiles on the floor where the low angle winter sun hits will maximize the absorption of heat. However, if solar access is limited, large amounts of thermal mass can increase the building's heating requirements in winter. This would be a problem in areas like Amman and the northern highlands, like Ajlun. Thermal mass also helps in keeping the home cool during summer days, provided there is adequate ventilation during the night. This is most important in hot areas like Aqaba. Do not use thermal masses at locations that receive direct sun light during the summer.

- If high thermal mass materials are used for the external walls, make sure to provide proper sandwich insulation separating external wall surfaces from internal ones. Otherwise they will cause overheating of the interior spaces during summer and will require considerable energy to cool them down. In general, higher thermal masses on external walls are recommended in cooler climates (e.g. the northern highlands).

- Using low thermal mass materials for external walls would also require insulation to stop heat loss through the walls during the winter. In general, lower thermal mass external walls are recommended in hot areas (e.g. Aqaba and the Ghors).

- Color: lighter colors reflect heat. Using light colors for the external walls will therefore reflect solar heat during the summer and keep the home cooler. On the other hand, using darker colors where there are internal thermal masses with direct access to the sun during the winter will improve the heat storage capacity of those masses.

6. Draft proofing

- It is very important to make sure there are no air leaks and gaps in walls and around doors and windows. These leaks cause major heat loss in winter and heat gain in the summer. To prevent these leaks, seal window and door frames with sealing strips, and install draft excluders at the bottom edge of doors. Draft excluders are available in different shapes and forms that are available in most hardware stores.

7. Ventilation

- Doors and windows should be positioned to allow for cross ventilation. The best distribution of cross ventilation cooling is achieved by allowing air through an opening at least as big as the opening through which the air leaves.

- If this has been considered in the design of your home, it is best to open doors and windows late on a summer's day and through the night to deploy the cooler air and allow the building to cool off. It is also recommended to close doors and windows during the day in order to trap the cooler air inside for as long as possible. To substitute for cross ventilation cooling during the day, use a fan instead of opening windows. This way, the cooler air is circulated, achieving the same cooling results of cross ventilation, but with cooler air.

8. Landscaping

- Deciduous trees shade the house during the summer, but allow the sun through during the winter.

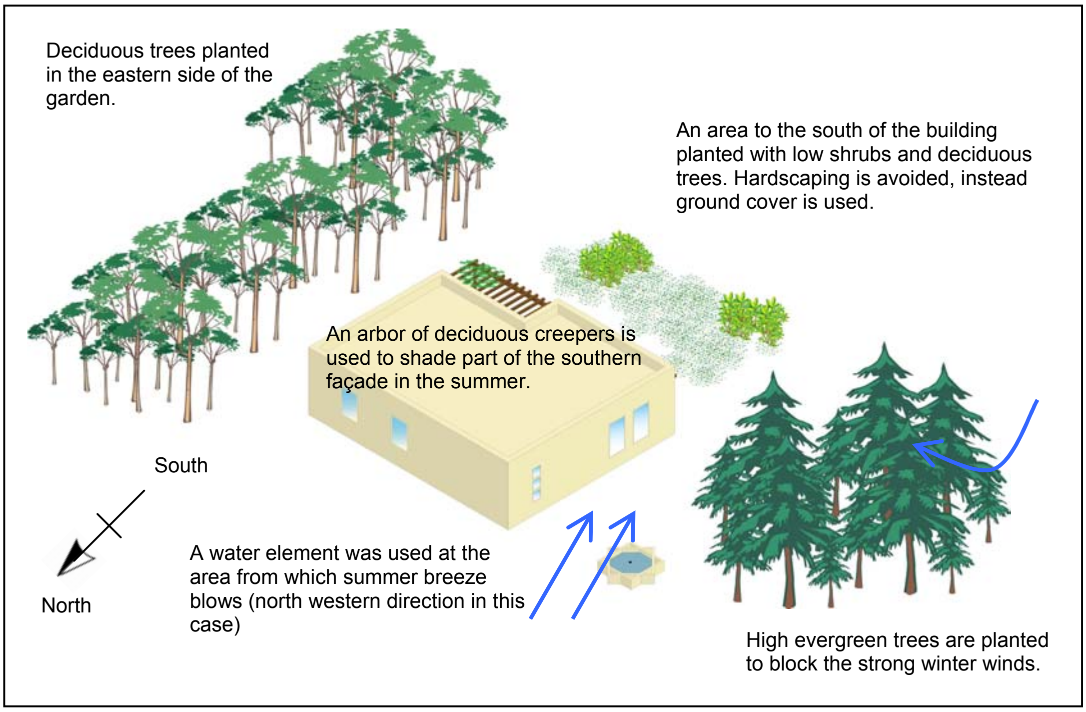
- Using deciduous creepers to shade west facing walls provides a cooling effect on hot summer afternoons, but be careful to plant them in a way that does not block summer breezes (as is the case of some cities in Jordan like Amman).

- Plantings evergreens in the direction from which cold winter wind comes would help shield the building. These winds come from western and south western direction in Amman.

- Un-shaded paving to the south, east and west of the house should be avoided as it can cause heat to be reflected into windows during the summer. Ground covers (plants or mulches) can help reduce this problem.

- If using a water element such as a fountain or pool, try placing it to the side from which breezes come in before entering the house. This will help cool the air before it reaches the inside of the house.

- Investigate the 'wind regime' that is particular to your location to make the most of desirable cooling summer breezes, or to reduce the impact of hot summer or gusty winter winds.



Landscape design to reduce the energy needs of the house

9. <u>Use of energy efficient systems and appliances</u>

- Systems such as lighting, heating, cooling, hot water, and other appliances should be energy efficient. This can be done by carefully selecting highly efficient and performance systems that do not waste energy.