Energy Efficient Building Guideline for MENA Region

November 2013

MED-ENEC

Energy Efficiency in the Construction Sector in the Mediterranean

This project is funded by the European Union

The Taparura head-office building is about to be finished. It sets the example for green building in the urban re-development on the coast of the city of Sfax, Tunisia. The following energy saving measures are included: double glazing, window, roof and wall insulation, thermal bridge protection, EE lighting and HVAC equipment. A solar water heater and Photo-Voltaic panels are installed as renewable energy systems. These measures are estimated to generate an energy savings of 33-35%, with a payback time of 4 to 11 years. Developer SEACNVS, www.taparura.com
More info: www.med-enec.eu/sites/default/files/user_files/downloads/Taparura%20Article%20MED-ENEC121010.pdf

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Climate

Courtyard building, New Giza, Egypt

Wall construction, Dutch Embassy, Jordan

Ecolodge Feynan Jordan. In one of the hottest areas in Jordan, and where there is no electricity connection, this environmental project is developed with the following energy saving measures: court yard building, window design (dimensioning and location) for optimal day lighting and minimum cooling (the interior is designed to make use of candle light as an alternative to electrical lighting), improved thermal resistance for walls and roof, shading for windows and elevation in Yemeni tradition, and solar water heaters. A photo voltaic system covers the electricity demand for food cooling. Architect Ammar Khammash.

1.

Introduction

A need to reduce energy consumption!

The building sector is estimated to be responsible for more than one third of global energy consumption, making it the biggest single contributor to total energy consumption[1]. The south-east Mediterranean countries are expected to witness a population growth of 40 million and a related 24 million new housing units by 2030[2]. The increased population, housing stock and better living standards will increase energy demand. Since more households are using electrical appliances such as refrigerators, washing machines, and air conditioners, last of which the main cause of the rapid electricity demand increase. Between 2000 and 2009 primary energy consumption has increased by nearly 50%, final electricity consumption has nearly doubled. A "business-as-usual" approach will, accordingly, lead to another doubling of final electricity demand untill 2020.

Limiting the growth of electricity consumption will not only have economic and environmental benefits, it will also support energy security and a cleaner environment. On a national level, this will free up financial resources for sectors in need, such as health and education. On an individual level, it will ease the household budget. The European Union (EU) has named energy efficiency (EE) as one of the best ways to foster energy security in the long term3, and to create jobs.

In order to minimize the energy demand, cost effective energy efficient building needs to start with the architectural design and the construction of the building envelope.

EE measures in buildings are cost effective with the right approach. When EE is taken into consideration from the beginning of a building project, a construction budget can be released for EE equipment, or renewable energy systems, which further reduces the energy consumption. For other EE measures, the additional investments will be paid back within a few years – depending on electricity prices - as a result of lower energy bills.

The right approach starts from the architectural design, at the preliminary sketches. Only simple strategies such as orientation, size of windows openings, shading, and insulation lead easily to a reduction of the net energy demand of around 30% and, at the same time indoor comfort is improved. This is the passive design approach.

energy efficient building starts with design, Abdali project, Jordan

Reducing energy consumption for cooling, through design and construction measures is the main aim of this brochure. It provides practical guidelines for cost effective energy efficient buildings, to be considered by developers, architects and engineers for new building projects in the southeast Mediterranean countries.

The Energy Efficient Building Design Guidelines are developed for *warm/hot* climates, the prevailing climate in the MENA region. Thus, the approach is for reduction of the cooling demand and the related energy consumption. Where needed a differentiation is made between *warm humid* and *dry hot* climate.

The EE Building Guidelines are based on international best practices and developed in cooperation with the New Urban Communities Authority in Egypt.

MED-ENEC promotes Energy Efficiency in the Mediterranean construction sector to reduce CO_2 emissions, by publication of a series of brochures. Among others the EE Building Code Roadmap and EE Urban Planning Guidelines have been published on MED-ENEC website: www.med-enec.eu

Dr.Kurt Wiesegart,
MED-ENEC Teamleader

Different regions have various vernacular architectural types, which design teams can analyze and learn from. Climate responsive architecture in Yemen includes thick walls as thermal mass, recessed windows that receive less solar radiation, and shading devices that reduce the solar heat gain. These EE measure provide a better indoor climate comfort.

Background of the passive design approach

A 'passive' design approach is most cost effective when it comes to reducing the energy consumption of buildings. Figure 2 shows that the design level, from urban planning to architectural design, is the start for cost effective energy efficient buildings. A good design can even reduce the investment cost of a building, when considering compactness, efficient lay-outs and orientation.

Once a building is designed with an optimal energy demand*, the 'active systems' such as heating, cooling and lighting equipment can be added for indoor thermal comfort.

The passive design approach consist of different climate responsive strategies, to avoid heat transfer through the building envelope:

- **Orientation:** reduce solar radiation on the building envelope.
- **Ventilation:** use airflow to release heat and humidity.
- **Thermal zoning:** allocate functions related to time of use and solar gain.
- **Building form and typology:** reduce the solar radiation on the building envelope and optimize daylight access.
- **Building envelope design** (size and location of windows and shading): provide the minimum required daylight access, together with a minimal heat gain and maximal external reflection.
- **Materials selection:** to reduce heat transfer to the indoor space.
- **Landscaping:** provide shade on the building, reducing the heat gain, and to create pleasant outdoor space.

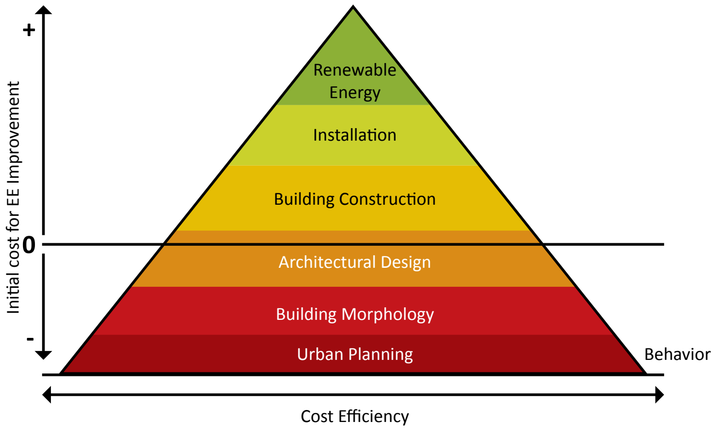


Figure 2: Strategy for Cost Effective Energy Efficient Buildings

In the past traditional, vernacular, buildings in the MENA region were designed and built according to passive design approach as there was no electric equipment to control the indoor climate, see photo page 4.

We can learn a lot from examining such vernacular building concepts. Which measures to use in what climatic conditions, see photo page 2.

In modern buildings these concepts can be applied as well. This does not mean that the building looks like a traditional building. On the contrary, contemporary building design can be very well 'traditional' in their energy concept without noticing it at first sight.

Climate responsive strategies reduce the energy demand of a building based on basic physics, climate and thermal comfort.

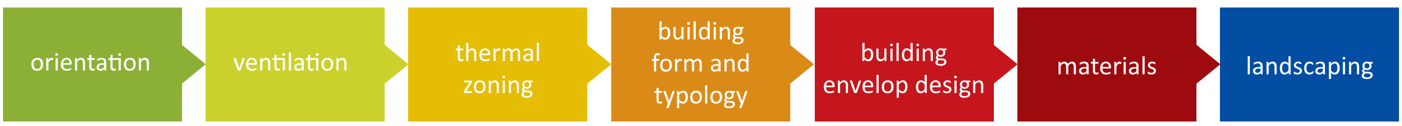
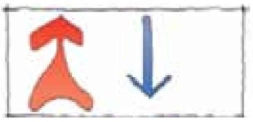


Figure 1: Architectural development of the climate responsive design process

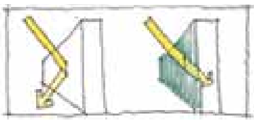
* The energy demand indicates the energy needed to obtain a comfortable indoor climate and depends on the climate condition and building design. The energy consumption is the energy needed to meet the energy demand.

Basic physics

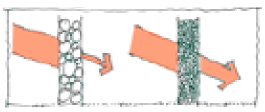
The EE Building Guidelines present climate responsive strategies for architectural design and building envelope construction using the basic principles of physics:



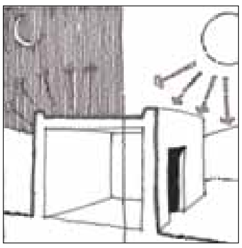
a) Warm and cold airflow
Warm air rises because it is lighter and lower in density than cool air. Cold air moves downward and replaces the warm air.



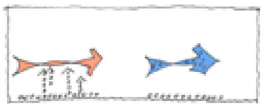
b) Reflection and absorption
Light colors reflect solar radiation. Dark colored materials absorb heat radiation.



c) Lightweight and dense materials
Air reduces energy transfer. When a material contains a lot of air bubbles, it is more resistant to thermal energy heat flow.



d) Thermal storage and release
Mass can store thermal energy. Heavy materials, with high density, have a high capacity to store thermal energy. When ambient temperature drops, this energy is released.



e) Evaporation: dry and humid air
Water evaporation requires energy. When dry air absorbs water vapor, the ambient temperature lowers and humidity rises.

Figure 3: Basic principles of physics

Climate

A climate responsive strategy is based on the specific climate characteristics. Climate data* needed to determine the strategy to reduce the major specific energy demand of the building, (cooling, heating or lighting):

- Temperature (T - ºC)
- Sun angles** (α - º)
- Solar radiation (horizontal and diffuse) – (Kwh/m^2)
- Relative humidity (RH - %)
- Wind speed and direction (m/s)
- Precipitation (mm/year).

The table below helps to determine the right climatic design strategy, cooling, heating or mixed. A further division can be made depending on the relative humidity, whether the climate is humid or dry:

Average Annual Temperature (ºC)	Humid RH >70%)	Dry RH <50%
Cooling	>18	>21
Heating	<15	<18
Mixed	15-18	18-21

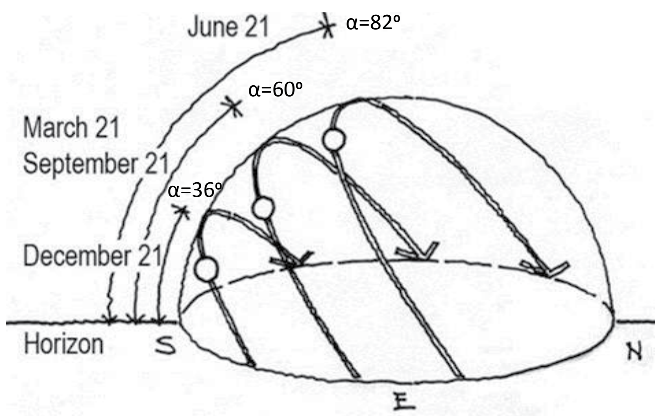


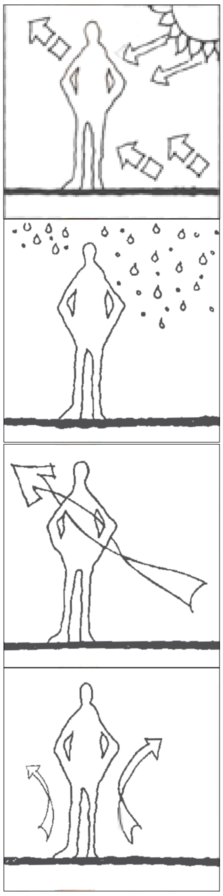
Figure 4: Sun path diagram with sun angles for Egypt

* Climate data, (preferably annual and monthly average, minimum and maximum) can be found on meteorological websites. If possible check data onsite, as specific site factors can influence the local conditions, such as large buildings blocking the wind.
** To calculate sun angles see: http://www.susdesign.com/sunangle/ or use the Ecotect software.

Thermal Comfort

Thermal comfort is an individual perception. It indicates the balance between the energy produced, received and lost by the human body. Factors influencing this state of physical thermal well being are: activity level, age, clothing, culture and human acclimatization.

The following modes of energy transfer, which can be influenced by building design, affect the feeling of thermal comfort as well.



a) Radiation:
emission of thermal energy

b) Evaporation:
phase change from liquid to gas.

c) Conduction:
energy transfer between particles in a substance.

d) Convection:
energy transfer between a solid surface and the adjacent liquid or gas that is in motion.

Figure 5: Different modes of energy transfer

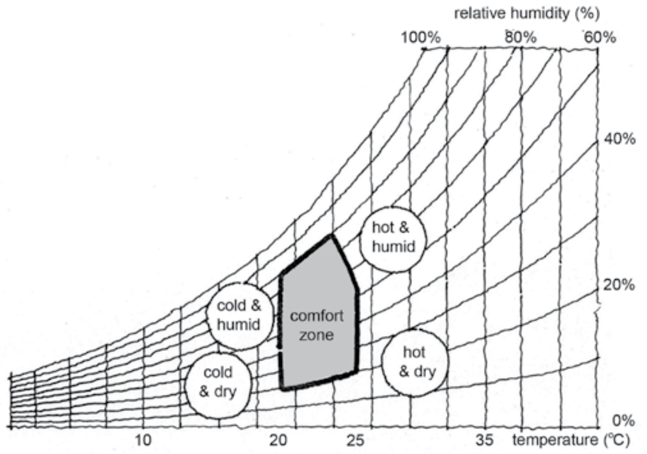


Figure 6: Range for indoor climate comfort

Thermal comfort is a personal perception. However there is a general range or comfort zone in which 80% of the people feel comfortable. This comfort zone is shown in figure 6.

Climate Zone		1: Alexandria	2: Cairo	3: Aswan
Characteristics		Warm Humid	Hot Humid	Hot Dry
Annual temperature °C	Average	19.9	21.9	26.2
	Max.	30.1	43	44
	Min.	9.2	8.1	8.2
	daily ΔT	9	12.1	15.9
Solar Irradiation (kWh/m²)		2000-2200	1900-2000	2300-2500
RH(%)		67	58	27
Wind direction		NW	N/SW	N/NW
Precipitation (mm/year)		138.5	31.2	It seldom rains.

Figure 7: Analyse climate data to determine the climate responsive strategy. Example of data for Egypt

The Aqaba Residence Energy Efficiency project (AREE), Jordan, under construction, was designed according to the passive design approach. The EE measures generated 32% savings on the net energy demand and added 12% to the construction costs, compared to conventional buildings. However, it was calculated that these additional cost would be recovered by a lower energy bill in less than four years. Architect: Florentine Visser

Climate responsive strategies

Orientation

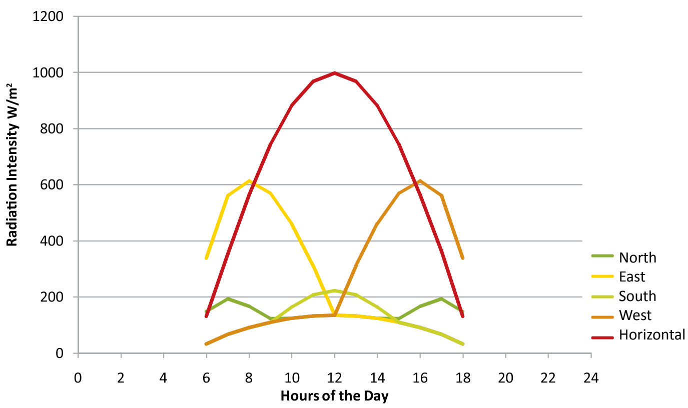
The building orientation towards natural elements such as wind and sun influences energy consumption.

The wind orientation is important to increase natural ventilation, as this can reduce the energy demand for cooling. The natural ventilation needs to make use of the prevailing wind direction, therefore it is important to include options for air inlet on the side of the prevailing wind, see page 10.

Solar heat gain of a building depends on the sun orientation. Reduction of solar heat gain is the key strategy for warm and hot climates. Solar heat that does not enter the building does not need to be cooled, thus a reduction of the cooling load.

The solar radiation on the building elevation is shown for different orientations in figure 8.
The roof receives the highest level of solar radiation. Therefore it is important to reduce the gain, either by shading, insulation, or thermal mass, see pages 15, 19, 21.
On the north and south side the solar radiation is lower than on the east and west side. Therefore, the preferred building orientation is along the east-west axis. This means that the largest elevation surfaces face north and south. On the north side, there is hardly any exposure towards the sun, which results in a minimum heat gain from solar radiation. On the south side where the sun is at its highest angle, it is easy to limit solar heat gain with shading elements for the windows and the facade, see page 2.
Since the largest solar intensities are on the east and west sides, the heat gain is reduced when the smaller facades are on the east and west sides.

Figure 8: Elevation orientation and solar radiation in Egypt



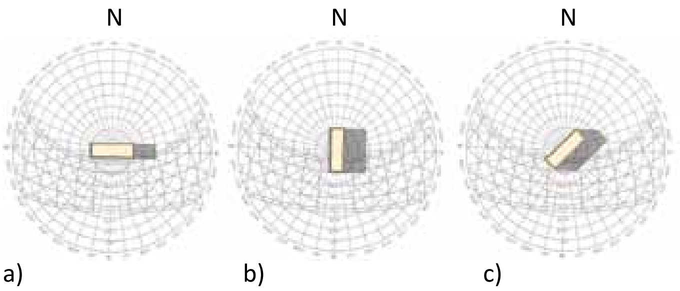


Figure 9: Orientation on the east-west axis (a) reduces cooling load

The shade provided by the building can create pleasant outdoor space. Figure 9 shows the shade of by the building on its surrounding for different times during the day and for different orientations. This should be taken into consideration when making the landscape design, to include nice places to spend time outside, instead of being inside the building.

The roof receives the highest solar radiation, shading is a good solution, office building in Giza, Egypt.

Dry Hot climate: Use evaporation for additional cooling and indoor climate comfort.

Natural ventilation

This strategy uses both wind and temperature differences to cool by ventilation. Ventilation can release heat, and thus reduce the cooling load. A natural air flow contributes to indoor climate comfort. In addition, it improves the indoor air quality however, dust infiltration should be prevented.

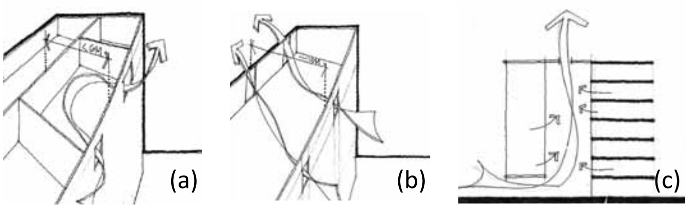


Figure 10: Ventilation strategies: Single sided (a), cross ventilation (b) and stack ventilation (c)

Single sided ventilation

This strategy is applicable when a space has only one side along the elevation. Key considerations include:

- **Building orientation** toward the prevailing wind direction.
- **Location of openings**, windows, towards the prevailing wind direction.
- **Elevation features** ("brise vent") to create the required negative pressure zone.

Cross ventilation

Natural ventilation is enhanced when the inlet and outlet are placed at the diagonal of the indoor space, for both plan and section. Key considerations include:

- **Building orientation** toward the prevailing wind direction.
- **Size of the inlet and outlet openings**. See Annex for calculation of the needed sizes and proportions.
- **Depth of the space:** limit to 12 to 14 meter for a space with a height of 3 meter.

> In Cairo the prevailing wind direction is North, in the summer. Capturing these winds with passive strategies improves indoor comfort conditions.

Stack effect

When hot air rises, it creates a natural draft, removing the heat in a building, see figure 10. Key considerations include:

- **Height of the stack,** the vertical air column that induces wind flow, should be at least 2 meters above the space it is ventilating. See Annex for calculation of the basic proportions of the stack.
- **Areas of the inlet and the stack outlet** should be equal, to maintain a comfortable flow.
- **Material and color of the stack** on the outside. Dark colors absorb heat, the air indoor warms up and induces natural ventilation.
- **Unobstructed wind flow** inside the stack to avoid reduction of air speed.

The wind catcher is an architectural element that captures the prevailing wind at a high level, above adjacent obstructions, and redirects the air flow into the indoor space. Key considerations include:

- The wind catcher inlet needs to face the prevailing wind direction.
- Height of the wind catcher should be above adjacent elements, as obstructions could reduce or stop wind flow.
- The inlet is to be designed and sized in relation to the indoor space it is serves.
- Maintain unobstructed wind flow.

Wind catcher in a house in Fayoum, Egypt

Thermal zoning

The occupancy patterns and thermal zoning determine the building layout. The location of the building functions should relate to the solar radiation and the users' occupancy patterns. The spaces are positioned in relation to the time of use, and, as required, the need to gain or to be protected from solar radiation.
This strategy can be used for the floor plan layout, and the building section, see figure 11.

The following considerations are recommended for a climate sensitive layout[4]:

- Arrange indoor living areas along the southern side of the building, and bedrooms along the northern side.
- Use rooms that do not need a lot of cooling and heating in the 'sun exposed' areas of the house, eg garages, storage rooms, corridors.
- Gather different uses into zones with separation doors. This allows control of the cooling (and heating) 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 losses from the pipes and consequently the hot water use.

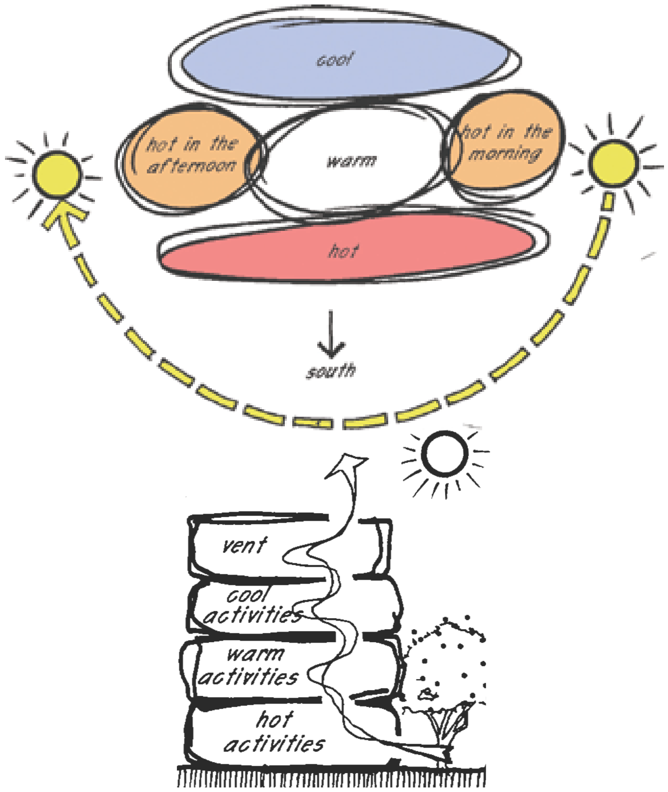


Figure 11: Thermal zoning in floor plan and section

"Full time buildings" are used day and night, such as residences, hotels, hospitals.
Spaces with short term use, such as bathrooms, can be placed on the hot side of the building, the south west. This way they also function as buffer zones to protect other spaces. While the bedrooms are best located on the north-east side, to stay cool and avoid the need for cooling in the evening.
"Part time buildings" are usually occupied for a part of the day, such as offices. Functions with a short terms use, such as meeting rooms or spaces with low occupancy by people, such as storage rooms, can be placed on the hot side of the building, see figure 12.

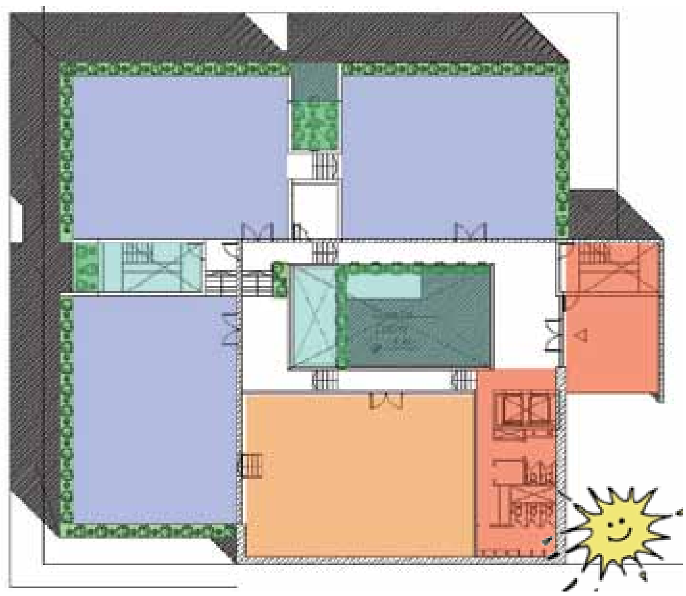


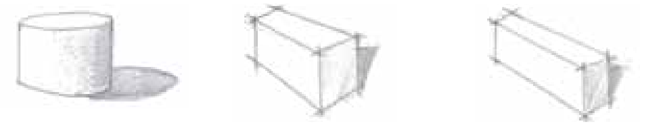
Figure 12: Organise space according to time of use and sun exposure

Short term use on the hot side: bathroom on the west side

Building form and typology

The form of the building mass influences the energy consumption. A compact building has a lower surface-volume-ratio (S/V), and thus a smaller surface area to absorb solar heat compared to a building with a higher surface-volume ratio, see figure 13. All the shapes have the same foot print and volume, while the elevation area differs, and this influences the surface-volume ratio.

Consequently, the internal cooling loads will be lower for the building with the lower ratio, see figure 15. A compact building mass is strongly recommended.



Envelope = 63m² S/V = 1.2 | Envelope = 71m² S/V = 1.35 | Envelope = 81.5m² S/V = 1.55

Figure 13: Compactness of building mass

A flat roof is exposed to the sun all day long, see figure 8. Therefore, to reduce the roof surface other roof forms could be considered as they have a smaller surface exposed to sun such as a vault, dome or pitched roof.

The courtyard building offers the possibility to make use of daylight without solar heat gain, see figure 14. At night the cool night air descends into the courtyard. Sun heats up the air in the courtyard which creates an upward draft during the day. In the late afternoon the air rises up, supporting the natural ventilation in the building. At night the courtyard cools down again.

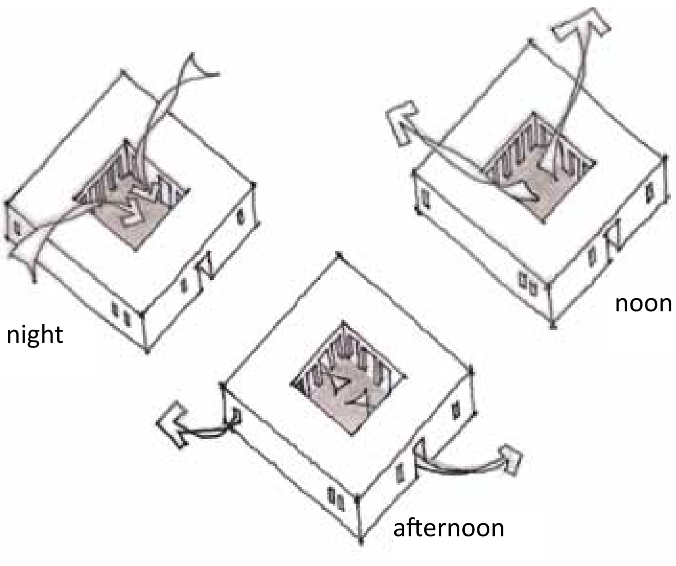


Figure 14: Courtyard for a pleasant in and outdoor climate

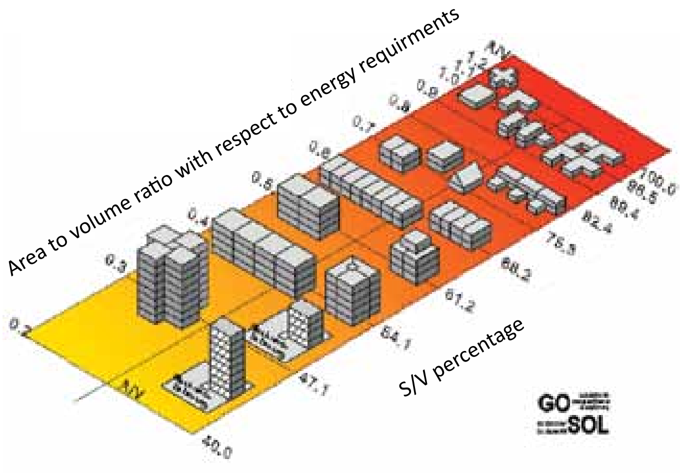
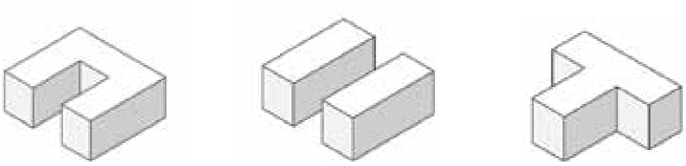


Figure 15: Energy consumption related to building form

Different examples of building mass configurations can support daylight access, while limiting direct solar radiation, see figure 16:

- The U-shape building creates a comfortable shaded courtyard, especially when the open side is oriented to the north.
- Parallel blocks, oriented along the east west axis, offer also shaded outdoor space.
- The "T" shape building offers two outdoor spaces with different orientations, thus having different climates when the leg of the 'T' is oriented in the north-south direction.



U-shaped block | Parallel blocks | T-shaped block

Figure 16: Energy efficient building typologies

A courtyard brings daylight deep into the building

Building Envelope Design

The challenge for the building envelope is to design it in such a way that there is an optimal balance between sufficient day light in the building, and a minimal heat transfer through the envelope. The transparent parts of the envelope, such as windows or doors, can transfer heat around five times faster than the closed, or opaque, part of the envelope. This means for a warm/hot climate that the size of the windows and doors has an effect on the cooling load. The larger the openings the more likely it is to have a higher cooling load.

The window to wall ratio (WWR) is an indicator which is used to check the optimal balance. WWR is the ratio of the window area related to the total wall area (opaque and window surfaces), see figure 17. In the calculation only the walls above ground are considered.

WWR = Windows Area / (Total Wall Area)

When designing the window openings, the following key issues should be considered:

- A maximum WWR of 18% building envelope[5].
- A maximum of 10% glazed area for a room with south orientation[4].
- Large glazed areas are preferred on the north side, since the north has the lowest radiation of all elevations, see figure 8.
- Reduce windows area on west, east and south-oriented facades.
- Large window areas, exposed to direct solar radiation, should have exterior solar shading devices, see page 15.

Large windows on the north side, in Feynan Ecolodge, Jordan

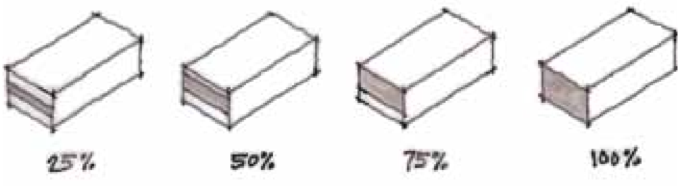


Figure 17: Window Wall Ratios of an elevation

When, due to the need of daylight access, a relatively high WWR ratio is the outcome, the heat transfer through the windows can be reduced by window shading, see page 14.
A more cost effective option is to make use of indirect daylight access. Then the need for artificial lighting is reduced, while the heat transfer is also kept at a minimal level, see page 14.

WWR ratio's: 10% on south facing facade,

and 18% for total building envelope

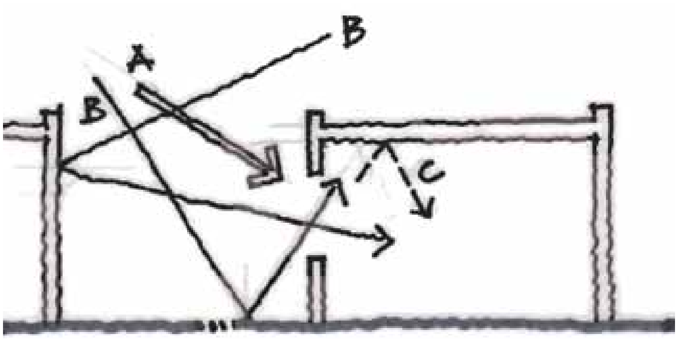
Window design

Adequate natural daylight has a positive effect on human wellbeing and energy consumption. Daylight access reduces the need for artificial lighting, and consequently the electricity bills. However, the design of window openings in the building envelope needs to be done properly, as these transparent parts of the elevation also allow for solar heat gain, which can increase the cooling demand.

When designing daylight access (window openings, skylights, etc) the following needs to be considered:

- **Strategic positioning of windows and envelop openings;** where lighting is needed.
- **Visual comfort;** avoid excessive contrast and glare*.
- **Avoid direct sunlight acces;** small windows in thick walls could be efficient, and openings oriented to the courtyard are a good solution.
- **Shading elements or screens;** provide diffused light and reducing heat gain such as the traditional mashrabiya, see page 15.

There are different ways of 'insolation', sunlight access into the interior, direct and indirect, see figure 18.



A: Direct skylight
B: Externally reflected light
C: Internally reflected light

Figure 18: Possibilities for daylight access

Direct sunlight, during hot summer months should be avoided in a climate responsive strategy. It is easy is to apply window shading on sun facing elevations, see page 15.

Indirect day lighting has the benefit of daylight access to indoor space while avoiding the heat gain. This strategy is to be considered in warm/hot climates.

Good window design provides daylight without additional heat gain

Architectural elements that re-direct daylight, can be on the inside or outside of the building envelope, see figure 18 and 19. These elements include reflectors, straight or curved louvers.
In some cases, adjacent buildings reflect light onto other buildings and/or adjacent areas.
Ceilings with a light color and smooth texture can reflect more light and enhance the quality of natural light in a space.

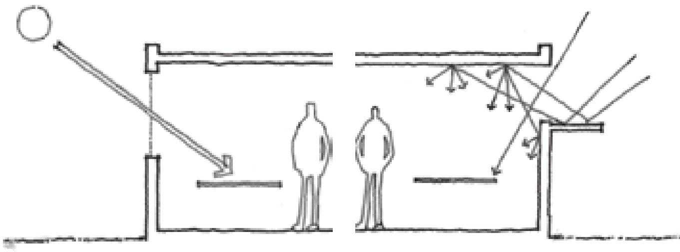


Figure 19: Indirect daylight access reduces glare (right)

* Avoiding glare is important for office spaces since it creates reflections on computer screens, which can reduce employees' efficiency.

Shading

The solar heat gain through windows can be excessive in the MENA region and creates uncomfortable high interior temperatures. This increases the cooling load for air conditioning systems as well. The most efficient way to protect a building from the solar radiation is by window shading.

Exterior window shading reduces or can even prevent the direct solar radiation from entering the interior space. When designed in a proper way the sun is blocked in summer, while during winter, when the sun is at a lower angle, solar heat can warm the interior space, and reduce the heating load, see figure 20.

The type and angle of the shading device depends on the orientation and position of the sun during the year:

- **South:** a horizontal shading device to block the solar radiation, since the sun angle is high, see figure 4. This allows heat gain in winter when the sun is at a lower angle.
- **East and West:** vertical shading devices are most effective, see figure 22.

Any type of shading device should be:

- placed on the outside of an opening, to reflect the 'sun radiation', see figure 20, 21 and 22;
- designed to prevent reflection on other parts of the building, especially windows;
- detailed in a way to avoid hot air being locked in, such as the open louver system, see figure 21b;
- made of reflective materials to avoid absorption and re-radiation of the heat through the opening.

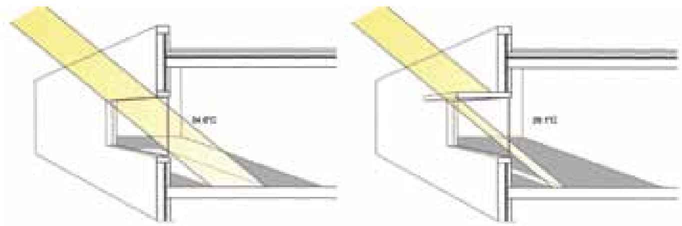


Figure 20: Reduction of solar heat gain due to window shading

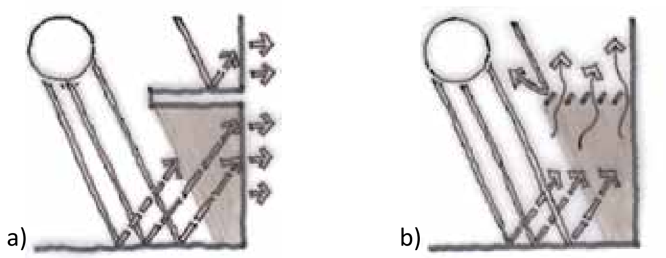


Figure 21: Shading for mixed (a) and warm/hot climate(b)

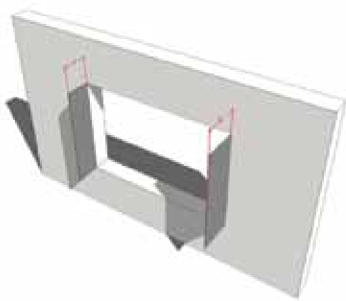
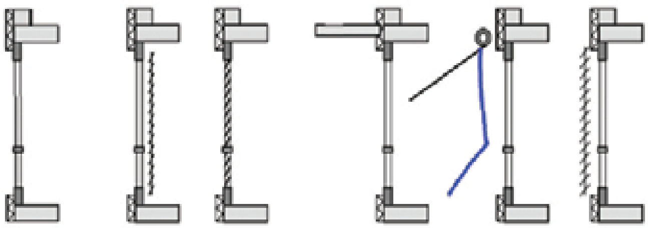


Figure 22: Vertical shading for the east/west side

Horizontal window shading in Abdali, Jordan

Different types of shading devices have different levels of solar protection, indicated by the shading coefficient (SC), see figure 23.The lower the shading coefficient the more solar radiation is blocked.



1,0 0,90 - 0,75 0,50 0,40 - 0,50 0,25 - 0,40

Figure 23: Shading types and Solar Coefficient (SC)

Materials

For a climate responsive strategy, the properties that each material has and the properties that the combined materials have together are important. These properties are a function of the material's composition and characteristics. Depending on the type of the material, it can reduce the flow, storage and release of heat.
In warm, hot climates the thermal resistance, reflection, absorption and emissivity coefficients are important factors, to reduce the energy demand for cooling.

Thermal resistance of the building envelope is determined by the detailing and the specifications of the materials, indicated by the U-value. Materials with a low density also usually have a low thermal conductivity, these are the insulation materials.
Materials that are heavy, with a high density usually have a high capacity to store heat, see page 19 and 26.

Reflection determines the amount of radiation that is reflected by a surface. Light colored surfaces reflect radiation, whereas dark colored surfaces absorb more heat.
The climate responsive strategy is to select light colors for the exterior building envelope*.

Absorption of thermal energy takes place when radiation on an opaque surface is not reflected. Instead it is absorbed by the material and heat is gained. Dark, heavy materials, such as concrete, absorb more heat and should be avoided, unless shading is applied on the sun exposed elevations.

Emissivity indicates the capacity to emit heat. Wood and stone have a low emissivity and can feel comfortable when exposed to the sun. While shiny metal has a higher emissivity, and thus feels much hotter when exposed to direct sun.

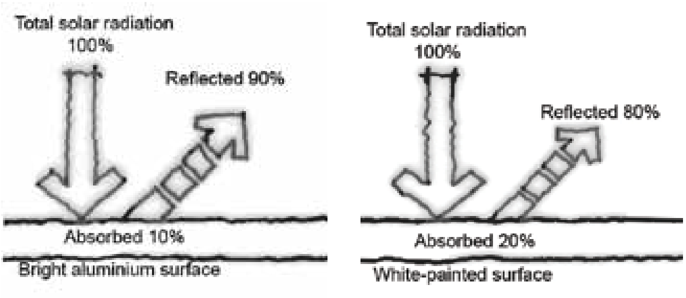
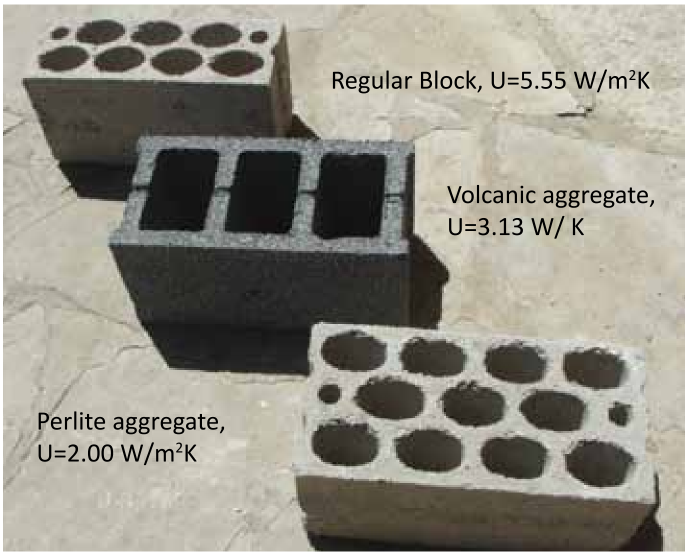


Figure 24: Reflection and absorption for aluminum and white painted surface



Concrete block with different U-values (the lower, the better)

"Full time buildings" (see page 10) are usually constructed with reinforced concrete, plastered masonry, or clad with natural stone.
This thermal mass help to reduce the cooling load when there is a difference of 14ºC between day and night temperatures.
In summer, during the day, the thermal mass of the external walls absorbs heat from the sun, keeping the interior spaces comfortable. At night, the heat in the external walls will dissipate to the cooler outside environment.
In cold, winter weather, due to the low sun angle, the internal thermal mass stores the heat from the sun during daytime and releases it into the interiors.
This helps reduce energy consumption of heating equipment.

"Part time buildings" (see page 10) usually have various construction methods, from masonry to curtain wall systems (glass or aluminum).
In summer, the masonry building behaves like the "full time building". An important factor to consider is that the thermal mass also helps to absorb the heat generated from the appliances, such as computer monitors, hard drives, artificial lighting systems and others.
In the afternoon and evening, when the occupants leave the building, ventilation can help to release the stored heat.

* **The Solar Reflectance Index (SRI)** indicates the reflection capacity. SRI for a black surface is 0 and for a white surface SRI is 100.
The albedo or reflection coefficient is another indicator of the reflection capacity. On a scale from '0' to 1, 0 is for no reflection, or a perfectly black surface, and 1 is for total reflection, or a white surface.

Landscape design

Landscape design can provide shade for buildings and outdoor spaces. Trees and shrubs protect building parts from direct solar radiation. And thus, contribute to a reduction of the energy consumption needed for cooling.

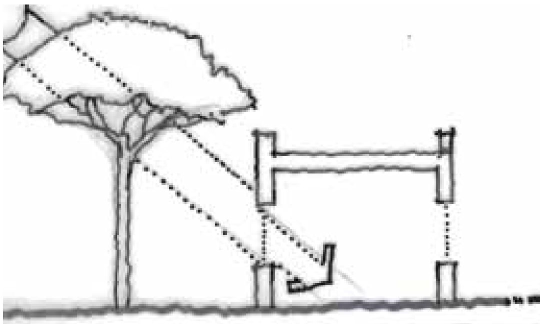


Figure 25: A canopy tree shading a window

Different types of trees and vegetation provide the following shading possibilities:

- Evergreen trees provide shade throughout the year, and reduce the dust infiltration.
- Shrubs and bushes can be used for shading the east and west sides, since the solar angles are lower at that side.
- High trees that have a canopy effect can protect elevations from the high south sun angle, see figure 25.
- Vines reduce the heat transmission through the wall or roof by shading it.
- Deciduous trees, losing the leaves before the winter, do not block the winter sun and prevent the summer sun from reaching a building.

Landscape design can support cooling reduction

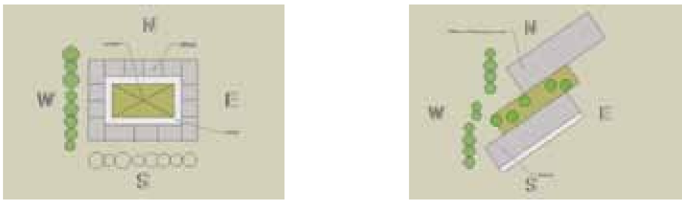


Figure 26: Shading by shrubs is effective on the east and west side (a). Use existing trees to create shade on the building (b)

For dry hot climates: the evapo-transpiration of leaves cool the surrounding air through evaporation.

Green walls are covered with vegetation. The plants, or vines that shield the building offer protection from direct sunlight, and also cooling, due to evapo-transpiration. Also they reduce air pollution and contribute to lowering the urban heat island effect[6] as the temperature of building walls is lowered.

A green roof works as a cooling element, Aqaba Jordan

Green roofs are roofs that are partially or completely covered with vegetation. Green roofs reduce the cooling load by heat accumulation, insulation, and the shading effect of the plants. The thickness of the green roof can range from 15 to 25 cm, and determines which types of plants can grow on the roof*. Important issues to consider when designing a green roof are weight, waterproofing and the access for maintenance.

*For more info see: http://new.csbe.org/assets/e-publications/AREE-Specification-final-versionTE.pdf (figure 38).

The Crystalle building in Amman, Jordan, here under construction, is designed as a Green Building. It includes the following energy saving measures: insulation on the interior side of walls, (5cm polystyrene and 10cm light weight concrete blocks) and on the roof (5cm of polystyrene), windows with double glazing, window frames with thermal break, shading devices, best practice efficient HVAC systems and solar water heaters. Delivery is planned for 2015. Architect: Maisam.

4.

Energy efficient building envelope

The building envelope* regulates the heat transfer between outdoor and indoor spaces (see figure 3.b, c and d on page 6). The two main strategies to reduce this thermal transfer are thermal mass and the insulation.

Thermal mass is effective when the difference in temperature between day and night is more than 14ºC[5]. Materials with high thermal mass have a great capacity to store heat. These materials have a high density and are heavy in weight, such as natural stone or clay bricks. They can absorb and store heat during the day, which will be released at night.

Insulation materials reduce heat transfer through the building envelope due to the low thermal conductivity (less than 0.1 W/m.K), see figure 3c. Many small air bubbles reduce the heat transfer, so insulation materials are light in weight, and have low density.

In hot regions well insulated buildings have a lower cooling load due to the reduced heat transfer from outside to inside. This provides a better indoor quality, enhancing peoples' comfort and productivity as there is less need for additional cooling.
Insulating materials can be classified as fiber or cellular insulation and are required to last as long as the building's lifetime (up to 50 years).

Positioning of thermal insulation
Insulation can be applied at different positions in the building envelope; on the inside, outside and between two layers.

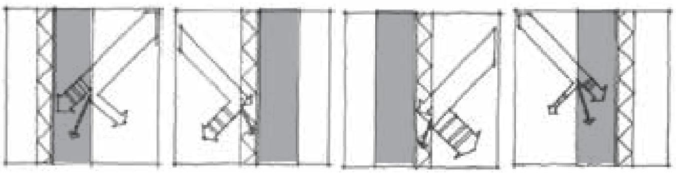


Figure 27: Effect of thermal insulation interior (a) and exterior (b)

Interior insulation allows the solar heat to penetrate through the external wall, absorbing part of the solar energy. At the insulation layer the thermal transfer rate drops significantly. From the thermal point of view this option is efficient in cold climates with heating as the major energy demand. Since, in case of heat transfer from the inside to the outside, the indoor heat will not be absorbed by the wall.

Exterior insulation good for warm hot climates housing project in Syria

Exterior insulation reduces the heat flow already on the outside of the building envelope. The interior side of the envelope can absorb indoor heat. Therefore this solution is preferred for hot climates, from a thermal point of view.

Insulation placed in between two layers of thermal mass, is a mix of the above options, and most suitable for mixed climates that require heating and cooling. From a construction point of view, it is a good solution, since the insulation material is enclosed by two solid elements, providing durability. However it is also very difficult to replace.

The simplest way to select a proper insulation material is by comparing U-values.
This is an indicator of a material's heat transfer capacity. The lower the U-value, the better the insulation capacity.
See page 25 for the U-value calculation.

* The building envelope, walls, roof and ground floor, includes closed, opaque, and transparent elements, such as windows and doors.

Wall construction

The material selection for the walls must ensure the required energy performance of the building. Since the walls are usually the largest surface of the building, their thermal transmittance (U-value) has a major influence on the cooling demand*.
This includes the opaque (closed) walls, the window and door components (glazing and frame).

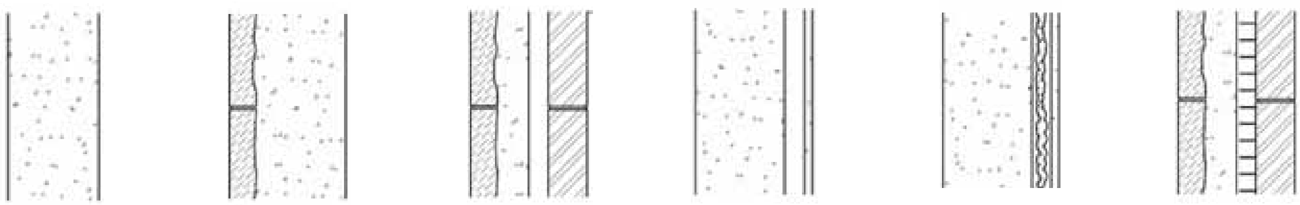
Cavity wall with 3cm polystyrene insulation in Jordan

Examples of wall sections, their U-values and material composition, listed from inside to outside, are provided in figure 28.
The lowest U-value, on the right, this is the wall with the lowest thermal conductivity and the lowest rate of thermal energy transmission.

Element	Thickness	Thermal Conductivity λ	Thermal Resistance
	(m)	(W/mK)	(W/m²K)
External Surface (Rso)	-	-	0.05
External Brick (R1)	0.1	0.96	0.10
Cavity filled with foam (R2)	0.1	0.04	2.50
Internal Block (R3)	0.1	0.55	0.18
Plaster (4)	0.01	0.48	0.02
Internal surface (Rsi)	-	-	0.12
Total Termal Resistance			2.97
U-value			**0.34**

Figure 29: U-value of an insulated cavity wall (Egypt)

Beside the thermal conductivity of the wall, also the texture and color influence the internal cooling load, see page 16.
A light colored wall reflects more energy than a dark wall.
A very rough texture creates shade on itself and thus reduces the heat absorption.
In both cases the thermal transmission is reduced as well as the cooling load.



a) Solid wall	b) Un-insulated wall	c) Cavity wall	d) Un-insulated wall	e) Insulated wall	f) Insulated cavity wall
U=3.03 W/m²K	U=2.6 W/m²K	U= 2.02 W/m²K	U= 1.73 W/m²K	U= 0.61 W/m²K**	U= 0.49 W/m²K
20 cm concrete	23 cm concrete 7 cm stone cladding	10 cm hollow concrete block 5 cm air gap 8 cm concrete 7 cm stone cladding	1.5 cm gypsum board 5 cm air gap 23 cm concrete	1.5 cm gypsum board 5cm rockwool 23 cm concrete	10 cm hollow concrete block 5 cm polystyrene 8 cm concrete 7 cm stone cladding

Figure 28: Examples of wall constructions

* For calculation of the U-value see page 25.
** Most suitable for thermal renovation.

Roof construction

The building roof receives the most direct solar radiation per m². Therefore, it is necessary that the roof has a high thermal capacity and is thermally insulated.
Similar to the wall, the thermal transmittance indicator for the roof is the U-value*.

Figure 30 below shows two roof constructions; one is insulated and the other not. When comparing the U-values of these roofs it is clear that the roof with the insulation material has a much lower U-value and thus a higher thermal resistance. Therefore, roof insulation is preferred for all climates. It reduces both the cooling and heating load!

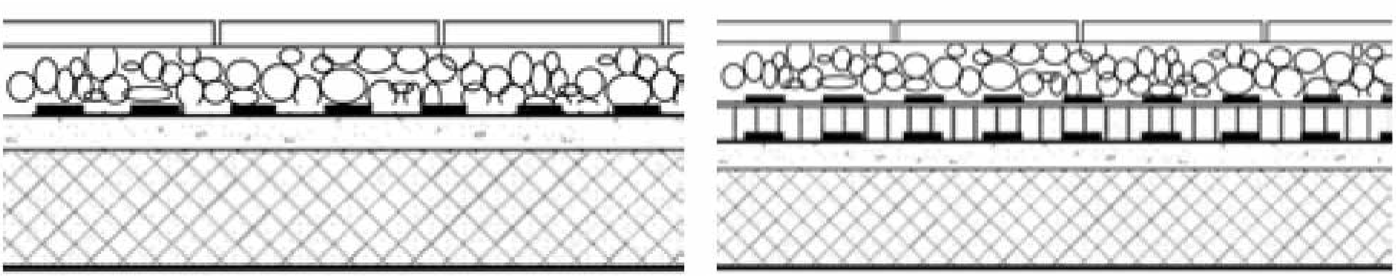
Shading elements on the roof, such as pergolas, solar thermal, etc. reduce the solar radiation, and therefore the heat load on the roof.

Apply roof insulation to reduce the cooling load.

A white roof reduces the cooling load

A relatively simple way to reduce the cooling load is to give the roof a light color, for instance by painting it white. A light color reflects more solar heat and therefore it takes longer for the roof to warm up. Thus it takes longer before the indoor space gets warmer, the so called the time lag.

> In an office building in Amman the roof was painted white, this delayed the incoming heat for two hours. Instead of 2 pm, the heat came in as a warm blanket at 4 pm ! When starting at 8 am and leaving the office at 4 pm, there is no need to use air-conditioning. Night ventilation cooled the office space to be comfortable again in the morning.



a) Un-insulated roof, U = 1.89 W/m²K
2 cm tiling
3 cm gravel
0.5 cm waterproof membrane
5 cm screed
20 cm reinforced concrete roof slab

b) Insulated roof, U = 0.46 W/m²K
2 cm tiling
3 cm gravel
0.5 cm waterproof membrane
5 cm extruded polystyrene thermal insulation
0.5 cm damp proof membrane
5 cm screed
20 cm reinforced concrete roof slab

Figure 30: Roof construction examples

* See page 25 for calculation method

Thermal bridges

The problem of a thermal bridge is that it interrupts the insulation layer. This creates a higher heat transfer at the connection of different building elements, such as floor-wall, and window-wall connections, see figure 31.

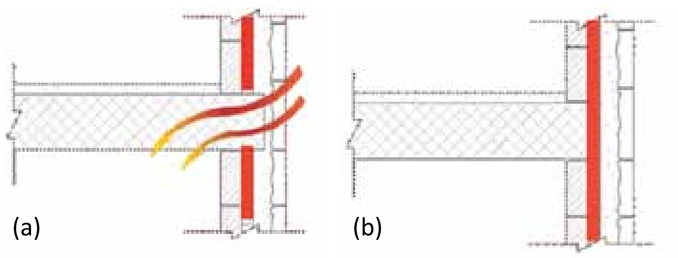


Figure 31: The floor-wall connection as thermal bridge (a) and with good insulation (b)

In a building that is not properly insulated, thermal bridges represent low losses (usually below 20%) compared to the total energy losses through the building envelope. However, in humid areas thermal bridges may cause condensation problems during winter. This condensation is the breeding ground for mold, see figure 32.

When the walls and roof are well insulated, the percentage of losses due to thermal bridges becomes high (more than 30%), compared to the losses through the envelope. Therefore, thermal bridges need to be avoided in energy efficient buildings*.

The common construction method in the MENA region is the reinforced concrete structure (columns, beams and floor slabs), filled in with block work or brick walls, thus thermal bridges are very common.

Solving a thermal bridge: 3 cm polystyrene in the formwork before pouring concrete

How to solve thermal bridges:

- For interior insulation, the solution for the thermal bridge is complicated as the roof and wall need to be wrapped with insulation material for around 60 cm from the wall.
- Continuous exterior insulation is a good and simple solution to solve thermal bridges at the wall–floor connection, see photo page 19.
- When insulation is placed in between two construction layers, thermal bridges can easily be solved by adding 3 cm polystyrene to the form work edge, before pouring concrete, see photo above.

Thermal bridges are very common in the MENA region

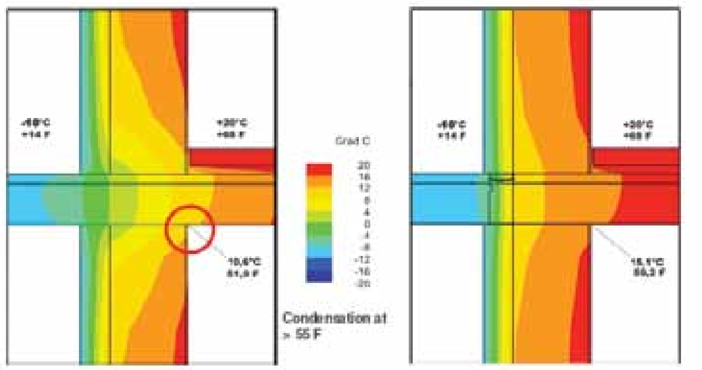


Figure 32: Temperature flow at the wall-floor connection

* Source: http://www.isover.com/Q-A/Implementation/What-is-a-thermal-bridge.

Glazing

A window can lose heat around five times faster than a wall of the same area. Therefore it important to improve the thermal transmittance of the window glazing. In other words, glazing with a low U-value has to be considered.

Glazing types

- Single glazing is the common type in the MENA region, as it is the cheapest, however it also has the highest U-value. Thus, it provides a large heat transfer.
- Double glazing is usually used for sound reduction, as in Egypt. However, it also contributes to a reduction of the heat transfer, which results in a lower cooling load. From a construction point of view it is relatively easy to apply double glazing.

Double glazing: effective to reduce the cooling load

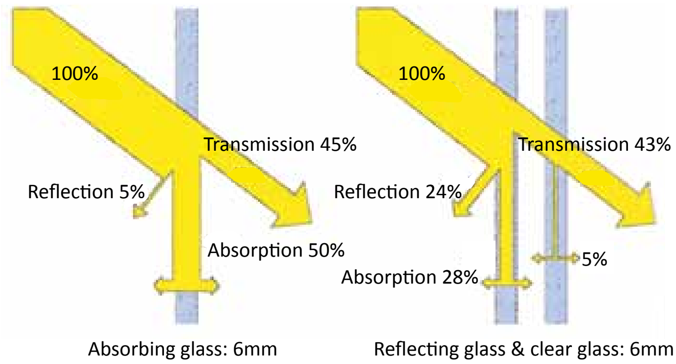


Figure 33: Solar radiation to glazing is transmitted, reflected and absorbed

Glazing specifications

Thermal transmittance of glazing is indicated by the U-value, which is similar for walls and roofs, for example:

- Single glazing: U=5.88 W/m^{2}K
- Double glazing U= 2.88 W/m^{2}K. The U-value of double glazing can be lower by adding gas to the air cavity, as argon.

For the calculation of the total U-value of the window, the window frame needs to be considered too.
A very low thermal transmittance reduces the daylight access. The lower the U-value the higher the reduction of light*.

The g-value indicates the energy transmission through the glass, see figure 33. To reduce artificial light the g-value should be as high as possible. However in area with a very high outdoor light level, a lower g-value could be selected to reduce glare.

The emissivity is the amount of thermal radiation that is emitted from the glass. Glass performance can be substantially improved by the application of special low emission coatings. The resulting product has come to be known as “Low-E” glass:

- Normal clear glass has an emissivity of approximately 0.84.
- Pyrolytic coating can achieve an emissivity of approximately 0.40[7].

When selecting the glazing the cost efficiency of the glass and frame combination has to be taken into consideration. Suppliers can provide the specifications and technical information of different glazing and window types.

*The outside surfaces of glazing with a very low U-value can have a mirror-like appearance. This may restrict it’s use to special applications or to specific parts of buildings only.

Air tightness in buildings

Heat gain and heat loss also takes place due to small air gaps between building components or elements such as walls and windows and in movable windows. Therefore a reasonable level of air tightness is important for all buildings.

Air tightness should be addressed during the detailing and the material selection of the connection between the building elements. This should ensure that the sealing can be done properly, and in line with the workflow of the construction process.

The construction supervisor should be aware of the importance of air tightness and supervise accordingly during the different construction phases.

During the design phase the air barrier should be identified on drawings to make clear to the site supervisor where the critical points are located, see figure 35.

During the construction phase attention should be paid to the following points:

Walls

- Make sure mortar joints are fully filled.
- Avoid gaps around elements that go through wall and roof constructions.

Windows and external doors

- Make sure that windows and doors include air strips, to provide a proper airtight seal when closed.
- All seams in the building must be sealed with durable materials such as plaster, rubber or foam ribbons, or tape.

Window sealing is very easy

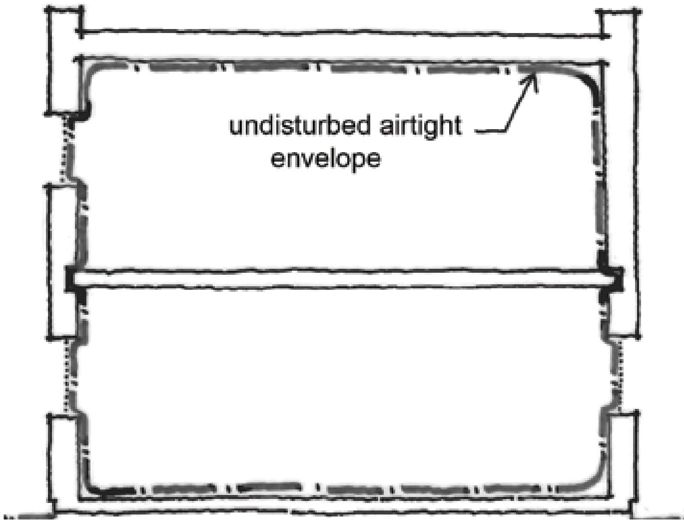


Figure 34: Avoid air infiltration through a window

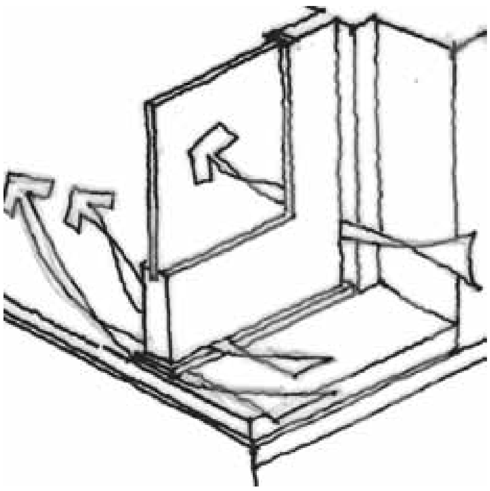


Figure 35: Avoid air infiltration through a window

Air tightness should not be mistaken for insulation. Both have to be achieved independently. A well insulated construction is not necessarily airtight. Air can easily pass through insulation made from coconut, mineral or glass wool. These materials have excellent insulation properties, but are not airtight. On the other hand an airtight construction is not necessarily well insulated. For example aluminum foil can achieve excellent air tightness, but has no relevant insulation property.

Material specifications

The selection of building materials is an important part of the passive design. In addition to the architectural aspects, the thermal characteristics should be considered when selecting and specifying building materials. To improve the energy performance of a building, the following characteristic need to be assessed.

Different types of insulation: XPS, cork, mineral wool, and cellulose

The thermal transmittance is indicated by the U-value (W/m²K). This is the inverse sum of the resistances (R_c) of each building material and the surface resistances of the outer (R_{so}) and inner faces of the envelope, see figure 36.

The R-value (m²K/W) is the thermal resistance of a material and is calculated as follows:

$$R = t / \lambda \ (m^2.K/W)$$

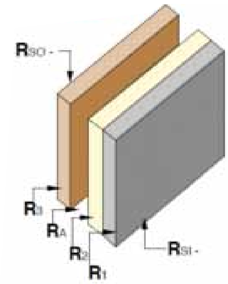
t is the thickness of the material in meters.

λ* is the thermal conductivity** of the material.

$$U = 1/R_c$$

$$R_c = R_{so} + R_1 + R_2 + R_3 + R_x + R_{si}$$

Figure 36: U-value calculation



Orientation		External Surface Absorptivity (α)	Required Min R-values of external walls insulation				Max. SHGC Values for Fenestration (%)				Min. SGR Values for Shading devices (%)			
			Assembly Min R-value	Min R-value of insulation (m²°C/W)			WWR							
							<10	10-20	20-30	>30	<10	10-20	20-30	>30
			(m²°C/W)	0.4	0.6	0.8	SHGC				SGR			
Roof		0.7	2.7	2.3	2.1	1.9								
Walls	N	0.38	0.70		NR	NR								
		0.50	0.74	0.34	0.14	NR								
		0.70	0.82	0.42	0.22	NR								
	NE/ NW	0.38	0.89	0.49	0.29	NR								
		0.50	1.00	0.60	0.40	0.20	0.65	0.50	0.45	0.35	60	80	90	90
		0.70	1.18	0.78	0.58	0.38								
	E/W	0.38	1.07	0.67	0.47	0.27								
		0.50	1.23	0.83	0.63	0.43	0.5	0.4	0.35	0.27	70	80	90	90
		0.70	1.50	1.10	0.90	0.70								
	SE/ SW	0.38	0.97	0.57	0.37	0.17								
		0.50	1.23	0.83	0.63	0.43	0.5	0.4	0.35	0.27	70	80	90	90
		0.70	1.32	0.92	0.72	0.52								
	S	0.38	0.82	0.42	0.22	0.02								
		0.50	0.90	0.50	0.30	NR	0.71	0.64	0.55	0.5	60	70	90	90
		0.70	1.04	0.64	0.44	0.24								

Figure 37: Building envelope requirements for conditioned buildings in Cairo, Egyptian EE Building Code

*λ is the Greek letter lambda

**This is the quantity of energy that passes in a time unit through a particular area (W/m.K). This thermal conductivity is also expressed as k (W/m.K).

Annexes

Thermal conductivity of typical building materials*

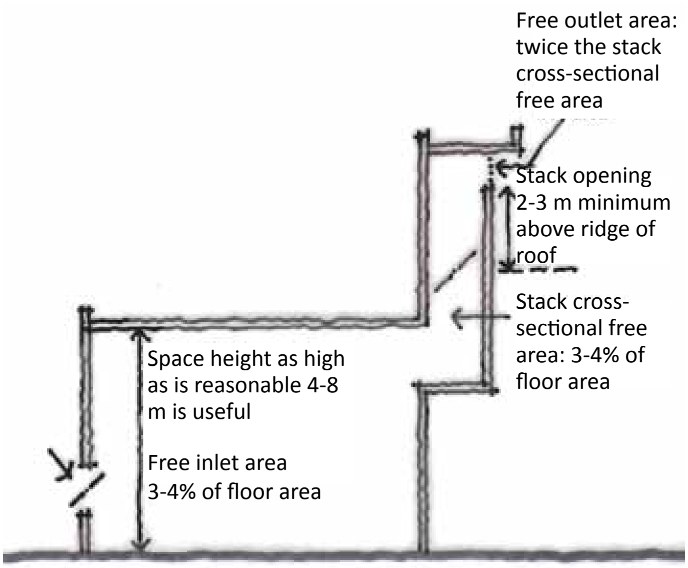
commonly used in Egypt[8]

Description	Conductivity, k (W/m.°C)	Density (kg/m3)	Thermal Resistance for Different Thickness (mm) R_c (m².°C/W)				
1: Bricks (mm)			120	150	200	250	380
1.1 Clay Bricks	0.6	1850	0.37	0.42	0.50	0.59	0.80
1.2 Solid Cement Bricks	1.4	2000	0.26	0.28	0.31	0.35	0.44
1.3 Heavy Sand Brick	1.7	2000	0.24	0.26	0.29	0.32	0.39
1.4 Light Sand Brick	0.35	650	0.51	0.60	0.74	0.88	1.26
1.5 Shall Clay & Hollow	0.6	1790	0.37	0.42	0.50	0.59	0.80
1.6 Cement & Hollow	1.6	1140	0.25	0.26	0.30	0.33	0.41
2: Tiles (mm)			10	20	30		
2.1 Cement Tiles	1.4	2100	0.18	0.18	0.19		
2.2 Ceramic Tiles	1.6	2000	0.18	0.00	0.00		
2.3 PVC	0.16	1350	0.23	0.00	0.00		
2.4Rubber Tiles	0.4	1700	0.20	0.00	0.00		
2.5 Mozaico Tiles	1.6	2450	0.18	0.18	0.19		
3: Wood (mm)			10	20	30	40	50
3.1 Beech	0.17	700	0.23	0.29	0.35	0.41	0.46
3.2 Spruce	0.105	415	0.27	0.36	0.46	0.55	0.65
3.3 Oak	0.16	770	0.23	0.30	0.36	0.42	0.48
3.4 Mahogamy	0.155	700	0.23	0.30	0.36	0.43	0.49
3.5 Pitch Pine	0.14	660	0.24	0.31	0.38	0.46	0.53
3.6 Plywood	0.14	530	0.24	0.31	0.38	0.46	0.53
3.7 Chip board	0.17	400	0.23	0.29	0.35	0.41	0.46
4: Gypsum & Cement Materials (mm)			20	30	40	50	60
4.1 Gypsum	0.15	320	0.30	0.37	0.44	0.50	0.57
4.2 Gypsum Boards	0.39	950	0.22	0.25	0.27	0.30	0.32
4.3 Portland cement	0.175	1335	0.28	0.34	0.40	0.46	0.51
5: Stones (mm)			120	150	200	250	380
5.1 Sand Stone	1.6	1800	0.25	0.26	0.30	0.33	0.41
5.2 Lime Stone	0.79	1600	0.32	0.36	0.42	0.49	0.65
Insulation (mm)			20	40	60	80	100
6.1 Expanded polystyrene	0.034	35	0.76	1.35	1.93	2052	3.11
6.2 Extruded polystyrene	0.03	30	0.84	1.50	2.17	2.84	3.50
6.3 Polystyrene beads	0.045	15	0.61	1.06	1.50	1.95	2.39
6.4 Polyurethane	0.026	30	0.94	1.71	2.48	3.25	4.02
6.5 Perlite loose	0.055	120	0.53	0.90	1.26	1.62	1.99
6.6 Verniculite Loose	0.065	100	0.48	0.79	1.09	1.40	1.71
6.7 Verniculite cement	0.22	650	0.26	0.35	0.44	0.53	0.62
6.8 Celton	0.17	480	0.29	0.41	0.52	0.64	0.76

*PLEASE NOTE: the R_c-value in the table includes R_{SO} and R_{SI} which is usualy only applied for a wall construction, see figure 36. When considering the R-value of one material layer only R_{SO} and R_{SI} should not be taken in account, then the values in the table are to be deducted with 0.127, since R_{SO} = 0.04(m2.°C/W) and R_{Si}=0.123 (m2.°C/W).

Ventilation opening calculation

Figure 38: Design of stack driven ventilation



Procedure to calculate the cooling capacity of stack ventilation:

1. Calculate the ratio of the stack area to the floor area of the space that the stack is cooling.
2. Draw a vertical line up to intersect the height of the planned stack, see figure 39.
3. At the intersection of the vertical line and the diagonal line indicating the height, draw a horizontal line towards the left.
4. The intersection of this line with the vertical scale indicates the cooling capacity of the stack ventilation.

Procedure to calculate the inlet area:

1. Calculate the ratio of the inlet area (opening area of a window) to the floor area of the space that the window is cooling.
2. Draw a vertical line up to intersect the wind flow velocity that is assumed in the design, see figure 40.
3. At the intersection of the vertical line and the diagonal line indicating the wind velocity, draw a horizontal line to the left.
4. The intersection of this line with the vertical scale indicates the cooling capacity of the cross ventilation.

In both cases, the reverse procedure can be applied to calculate the dimensions of the component (stack or window opening) based on a required cooling capacity.

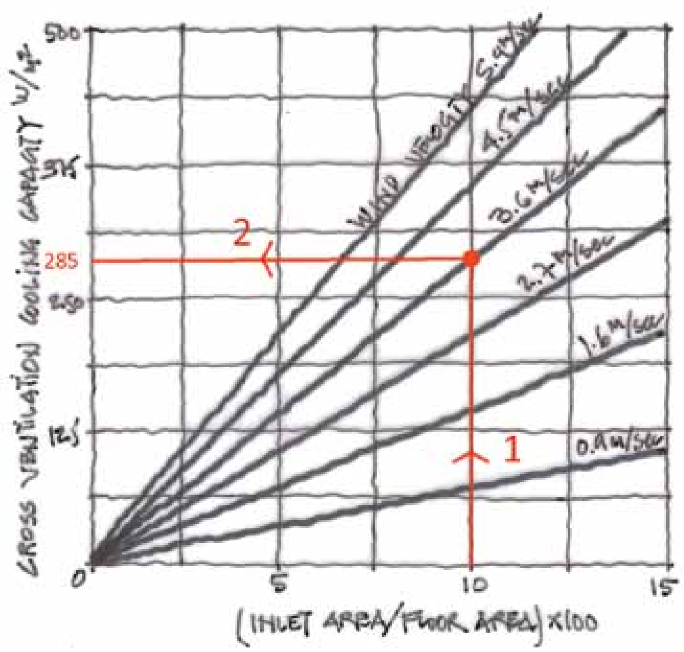


Figure 39: Cross ventilation cooling capacity, related to window size and wind speed

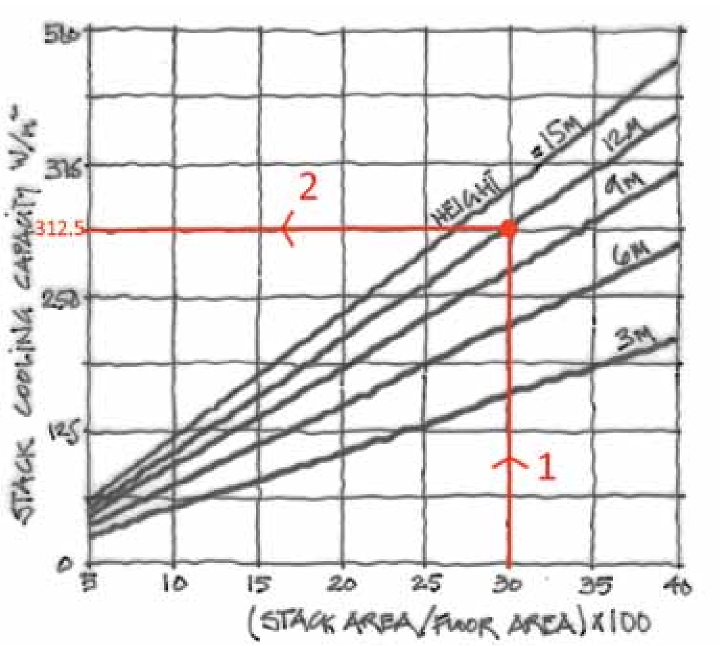


Figure 40: Stack ventilation cooling capacity, related to window size and wind speed

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Photo credits

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List of Abbreviations

AUB	*American University of Beirut*
CO2	*Coal dioxide*
EE	*Energy Efficient*
EU	*European Union*
g-value	*Solar energy transmittance (%)*
HVAC	*Heating Ventilation Air Conditioning*
Low-e	*Low emissivity*
MENA	*Middle East North Africa*
RC	*Reflection Coefficient*
RH	*Relative Humidity (%)*
R-Value	*Thermal resistance (m^2K/W)*
SC	*Shading Coefficient*
SHGC	*Solar Heat Gain Coefficient*
SGR	*Shade Glass Ratio*
SRI	*Solar Reflectance Index*
S/V ratio	*Surface to volume Ratio*
T	*Temperature (°C)*
U-Value	*Thermal conductivity (W/m.K)*
WWR	*Window Wall Ratio*
XPS	*Extruded Polystyrene*

Thanks to

New Urban Communities Authority
Dr. Hend al Farouh

Imprint

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Layout & Printing: *Integrity, Cairo - Rabab Kandil*

Copy Editor: *Tudor Lomas - Jemstone Network*

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