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ORIGINAL ARTICLE

Study of effective factors in the design of zero energy buildings in arid climate (case of Isfahan City)

Negar Aminoroayaei, Bahram Shahedi*

Department of Architecture, Isfahan (khorasgan) Branch, Islamic Azad University, Isfahan, Iran
**E-mail: n.aminoroayaei@yahoo.com*
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In the current century, a suitable strategy is concerned for optimal consumption of energy, due to limited natural resources and fossil fuels for moving towards sustainable development and environmental protection. Given the rising cost of energy, environmental pollution and the end of fossil fuels, zero-energy buildings became a popular option in today's world. The purpose of this study is to investigate the factors affecting the design of zero-energy buildings, in order to reduce energy consumption and increase productivity, including plan form, climatic characteristics, materials, coverage etc. The present study collects the features of zero-energy building in Isfahan, which is based on the Emberger Climate View in the arid climate, by examining the books and related writings, field observations and using a descriptive method, in the form of qualitative studies. The results of the research showed that some actions are needed to save energy and, in general, less consumption of renewable energy by considering the climate and the use of natural conditions.
Keywords: energy; zero energy; zero-energy building; sustainable architecture; Isfahan

Introduction

The twenty-first century is a transitional period for humanity habitation on the earth. The pressure on our planet's resources is increasingly unbearable and the problems caused by water and resource shortages, increased energy and cost of demand, reduced fossil fuel reserves and climate change, have been alarmed for the whole world (Hootman, 2013). The alarm of Earth's resource constraints was first noticed by Italian businessman Pecchi and director of the Organization for Economic Co-operation and Development (OECD), Mr. A.Kingura, who is a custodian of the Rome club organization. In a report, they stated that energy constraint and the world's dependence on the fossil fuels, especially oil, will shake the world (Foroughi ,1996). Global energy security still heavily relies on exhaustible fossil fuels, the use of which also contributes significantly to global environmental problems. Recent unprecedented rise in oil prices and threatening global wording recalls the urgent need to find solutions to energy and environmental crises (Padmakanthi, Gunatilake, 2009). Only a few of the problems caused by degradation at the energy level are the doubling of river water loss since 1960, the loss of 40 percent of the world's coral reefs, a 19 percent increase in the concentration of carbon dioxide Since 1959 and the extinction of 100 species of plant, which is more than the usual trend over millions of years. (Third Millennium Ecosystem Organization, 2005) Evidence suggests that with increased heating of the planet, the availability of energy will increase to drive extreme weather events, which could have a shaking effect across the Earth system with local, regional and global positive feedbacks that feed each other, amplifying and accelerating the warming (Le et al., 2006). The idea and principle of net zero energy consumption has attracted a lot of attention because of the use of renewable energy as a means to remove pollutants and greenhouse gases. Nowadays, plans related to zero-energy principles have become very popular due to increased fuel Fossils costs and their destructive effects on the environment and weather conditions, and disturbing the very ecological balance (Hemati , Zargarabadi, 2015). Rapid industrialization and intensive use of energy has, on the other hand, led to an energy crisis on the one hand and environmental damage by emitting carbon dioxide (Ganesan et al., 2011). In pursuit of effort to reduce energy waste and environmental pollution in the field of architecture, concepts such as sustainable architecture, green architecture and zero energy architecture has been considered. In this type of architecture, considering the environmental conditions, the climate of the area and the use of technology of the day, it seeks to provide a building, capable of adapting to nature and creating high environmental quality space and, ultimately, user comfort, so that According to Richard Rogers, "Buildings are like birds that envelope their feathers in the winter, and adapt themselves to new environmental conditions, and they adjust their metabolism accordingly."

Methods

Zero-energy buildings

A building with zero energy consumption is a building that achieves all its energy needs, through renewable energies or with the creativity that the designer spends on it, due to climatic conditions. The design of these buildings is that, it is necessary first to reduce the energy requirement of the building to achieve a zero-energy building, and then minimize the energy consumption of the building to the choice of efficient mechanical and electrical equipment; Finally, produce local energy, equivalent to the annual energy consumption of the building, using a variety of energy systems and renewable energy to achieve a zero-energy approach. Of course, high-performance buildings are not a lot, so the combination of zero-energy building is used with a global electricity network, so that when the home system does not respond to the use of renewable energy, It is possible to purchase electricity from the national network, and it is sold to the network at a time when the electricity generation is more than the house needs, which saves costs.

Effective factors on building physics

In this section, the purpose is providing analyzes to understand the factors influencing the construction design process near zero energy, and the natural factors that influence the building are discussed, which, of course, they depend on the following:

- The energy of the site is the energy that is measured on the site, the relatively simple measurements that most people are familiar with and use, such as the measured energy by the building facility meters and the numbers listed on the bill of General services.
- Source energy: The same primary energy used to generate and deliver energy to the site
- Energy Contaminants: Specifies the key energy value of net zero energy, which means removing greenhouse gas contaminants from the energy used in the building.
- Energy costs: In a building with a zero energy cost, the amount of money that the owner pays to the electricity network for his energy services in one year is equal to the amount of money that the national network pays to the owner for the energy exported from the building to the network.

Climate

The climate of weather conditions, predominant in one place, is defined as the average of a long period of time. Climate is an important variable in the design of the zero energy projects, which affects the external thermal loads of the project, as well as a free energy source available in various forms and quantities. Simply put, the net zero energy projects must be accountable to the climate. So that it can passively reduce the thermal loads, along with the use of all energy in the climate and the site. Pure zero energy building is applicable in any climate.

It is useful to refer to a climate classification system to understand the climate in the global sense. One of the most common systems is the Koppen climate classification system (Fig. 1). This system was first published in 1918, and it has been developed over time and is still used to this day. It is based on five basic climatic classifications (identified by capital letters A to E), divided into categories and subcategories (with lower case symbols). The first five classes are: A: Tropical B: Arid C: Temperate D: Cold E: Polar

Iran is in an arid climatic zone, and we will look at the factors influencing this climate.

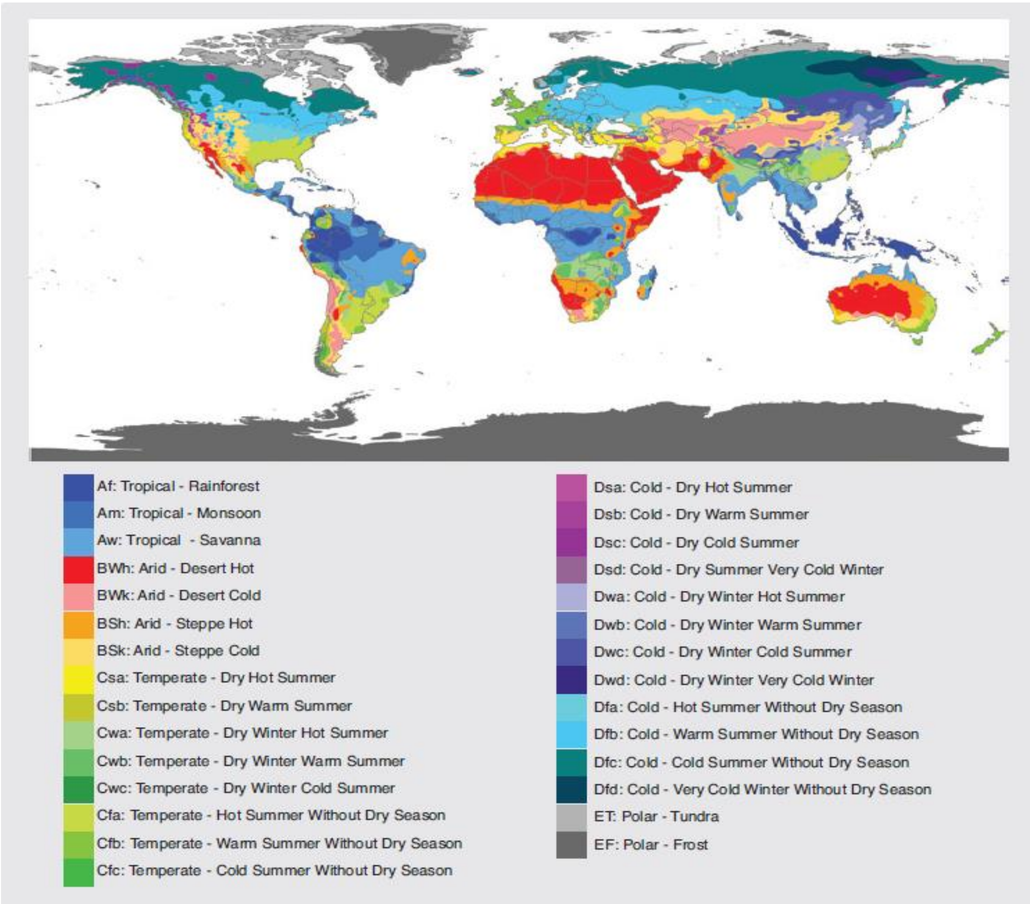
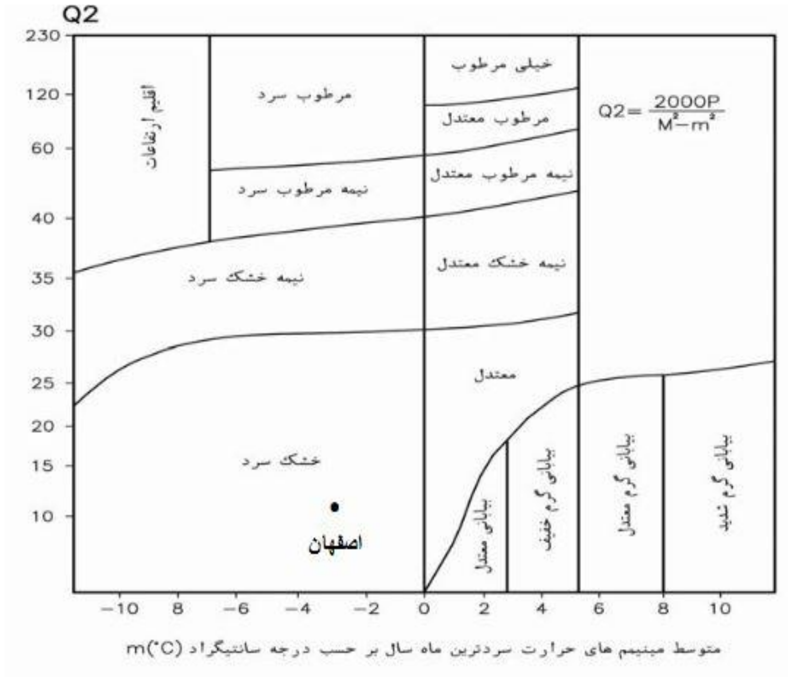


Fig. 1. Koppen climate classification Map. Map references: Pill et al., 2007.

A) Climatic Features of B Climate Classification: Arid

Arid areas are characterized by a lack of rainfall. The arid and semi-arid climate can be cold or hot. The city of Isfahan is located in a dry, cold climate based on the Emberger climate view (Fig. 2).

The average minimum temperature of the coldest month of the year, according ° C/ Climate of Altitudes, Cold Wet, Cold semi-wet, cold semi-arid, cold arid, very wet, moderate wet, moderate semi-wet, moderate semi-arid, moderate, moderate desert, low hot desert, moderate hot desert, severe hot desert



Average annual temperature in degrees Celsius/ Annual precipitation in millimeters/ very wet B type/ very wet A type/ wet/ semi-wet/ Mediterranean/ semi-arid/ Arid desert/ super arid

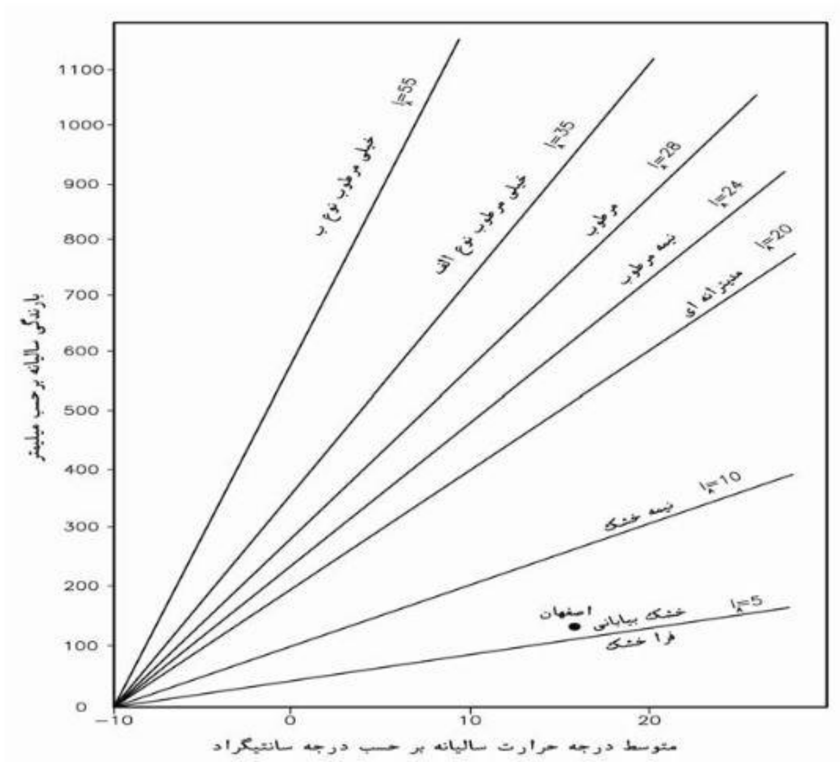


Fig. 2. Top: Location of Isfahan in the Ambergee climate view. Below: The location of Isfahan, by Domartron method (Source: Sheikhbigloo, Mohammadi)

B) Micro climate

Micro climate is the term used to describe local climate parameters, based on specific spatial characteristics. An analysis of a site illustrates many of the features that affect microclimate, including the natural and artifact features that affect solar access, wind patterns, and temperature. One of the goals of site analysis is the definition of the site's micro climate. Another goal is to identify potential design strategies based on the microclimate for the development in project and design processes.

C) Cold Microclimate

Creating cold micro climate during hot or very hot weather can be beneficial for the site and building. The provision of solar shading, solar reflections, cold breeze of water, and evapotranspiration from vegetation, all contribute to the creation of a cold micro climate. Cold microclimate can be developed in areas such as courtyards and pedestrian walkways, during the summer.

(Fig. 3) These exterior areas can reduce the thermal loads on the building and can be used to cool and blow the air directly into the building. There are several techniques for developing cold microclimates; in most cases, the options are limited to the creativity only applied to the solution.

Fig. 3. Microclimate in the open-air and indoor comfort yard increases in a hot climate like Iran. (Source: Writer)

Blocking the breeze can have a great impact on the comfort of pedestrians in exterior areas by creating a colder microclimate. The density and orientation of the building can be used to promote low-speed wind flow in the areas desired. The wind, although highly complex, is understandable through science; the general rules can be adjusted according to the approximate conditions, and more precise analysis by wind specialists can be used to improve accurate design responses and expected quantitative results for pedestrian comfort. Exterior microclimate, along with a calm breeze is also used for the natural ventilation of adjacent buildings.

Trees and other vegetation envelope have more advantages than shadow; they provide moisture through evapotranspiration, and produce a cooling effect, especially in arid climates that evaporation is an effective means of cooling (Figure 4). Landscape design is one of the most important elements of designing a successful microclimate, because the vegetation affects the reflection of the sun, shadow, and evapotranspiration. Landscape design combines the natural and human qualities of water reservoirs. Water can be used in a variety of ways to create a cold microclimate. The design of the exterior envelope can include a secondary assembly to create a specialized microclimate, right next to the building's envelope. Many of these strategies are also considered as good passive building design strategies.

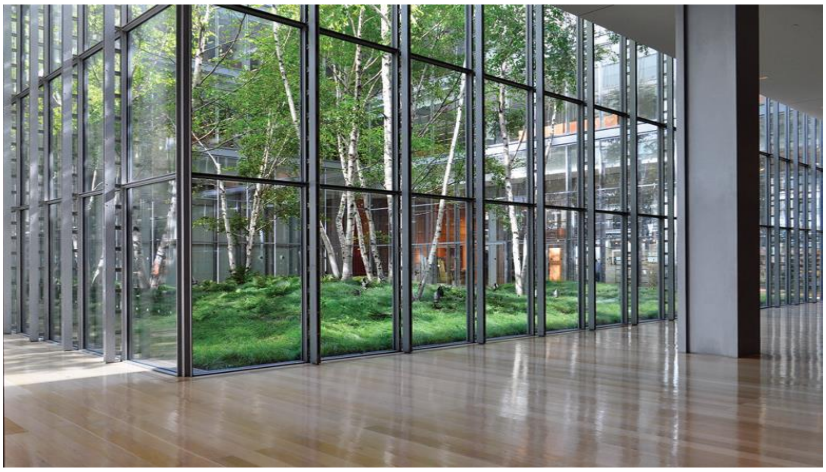


Fig. 4. Garden courtyard, like the New York Times building in New York, by Renzo Piano Workshop.

High albedo (Sepiday means the percentage of light reflection from the surface of an object, and it is from the words adopted by the Persian language and literature academy, instead of albedo in English. "Dictionary approved by the Academy: 1997 to 2006) and surfaces with high solar reflectance have a positive cooling effect and reduced cooling load. Vegetation and water are used to create a microclimate, for exterior walls and roof surfaces. Green roofs and swimming pools on the roof are common examples. The BCA Academy in Singapore has equipped the existing buildings with the walls of the vegetation and the shading of windows made with Photovoltaic with a strategy for reducing energy consumption to become a zero-net energy building, through the development of a cooling microclimate in the facade of the building (Fig. 5).

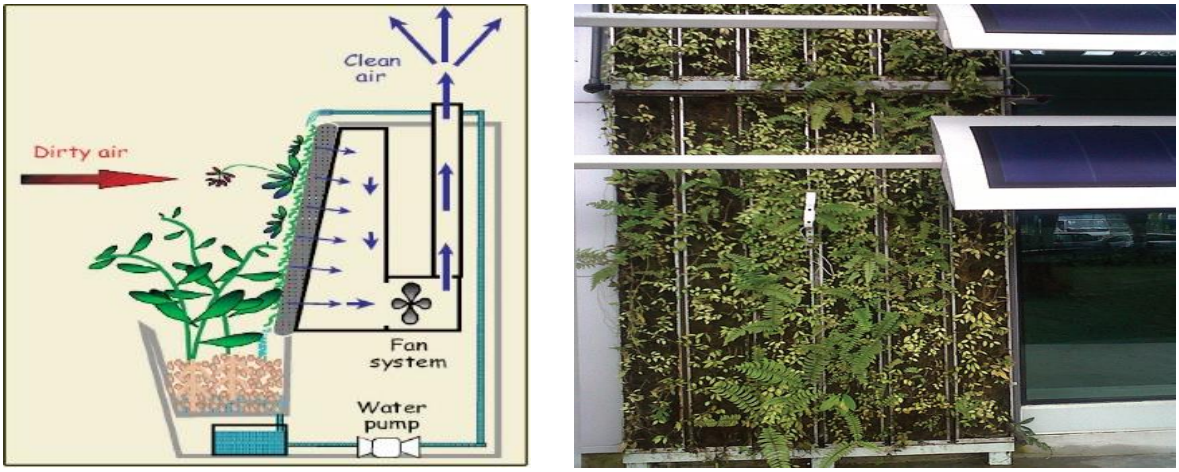


Fig. 5. The landscape proximate to the vegetation wall and the BIPV shadow hood for the Academy BCA Academy in Singapore. (Source: Patrick M. McLawie)

Sun radiation

The sun in the northern hemisphere traverses the seasonal routes from the east to the west in the southern sky (Fig. 6). Summer has the higher angle of the sun, and the winter has the smallest angle. These solar angles directly affect the amount of solar radiation received at the horizontal and vertical surfaces (Fig. 7). Lower angles tend to focus the radiation on vertical surfaces, and more solar angles tend to focus the radiation on horizontal surfaces. Stretching high-rise buildings for many building applications in the East-West axis, with a maximum of southern and northern views, is the best way to control the solar system. As a general rule, solar control is acceptable by changing the 15-degree orientation. The sun in the southern sky is more easily exposed to shadows than sunrise and sunset in the east / west, with very little solar angle. The western sun is the most problematic situation, as it adds significant solar heating at the end of the day, when it comes close to the high temperature in the exterior space. The solar radiation for the east and west directions is higher during the summer than in the southern direction. In addition, the sun is at its highest in the summer, and the shading is possible in the summer, for the southern direction in terms of architecture. The northern direction has the lowest direct sunlight (morning and night) and often does not require solar control.

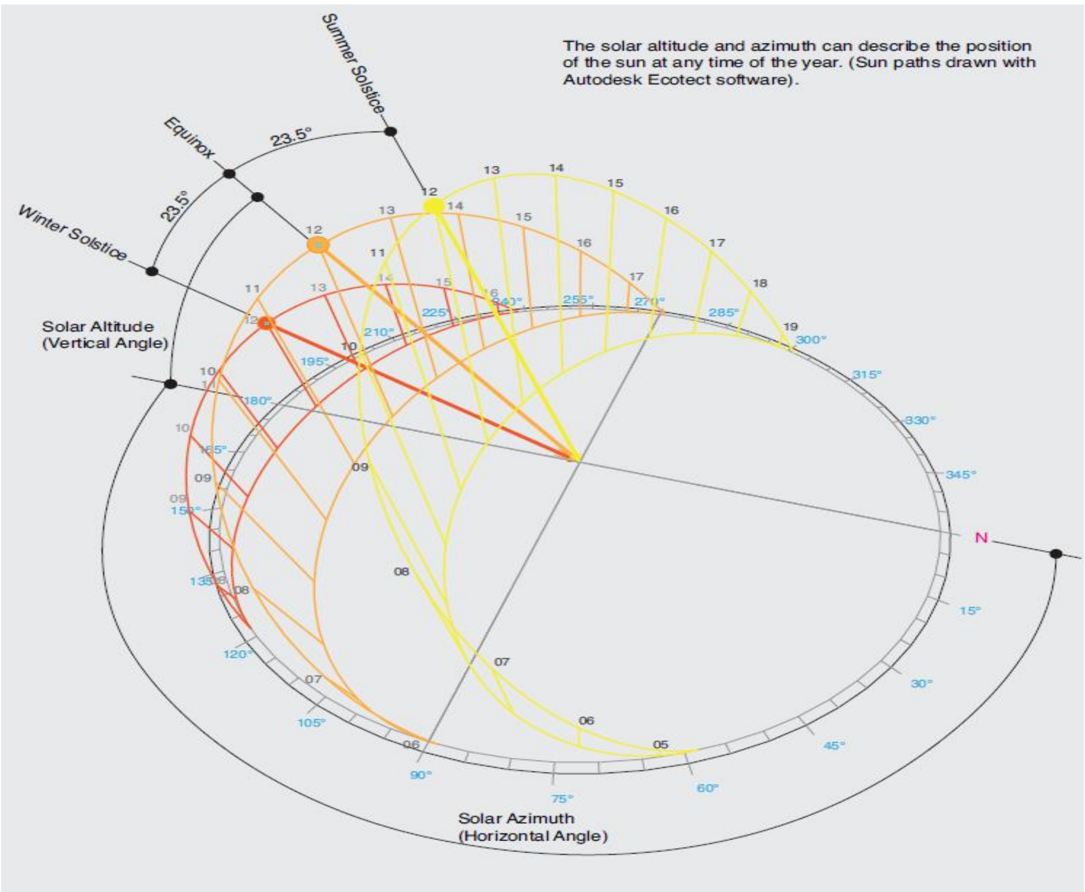


Fig. 6. Basic solar geometry.

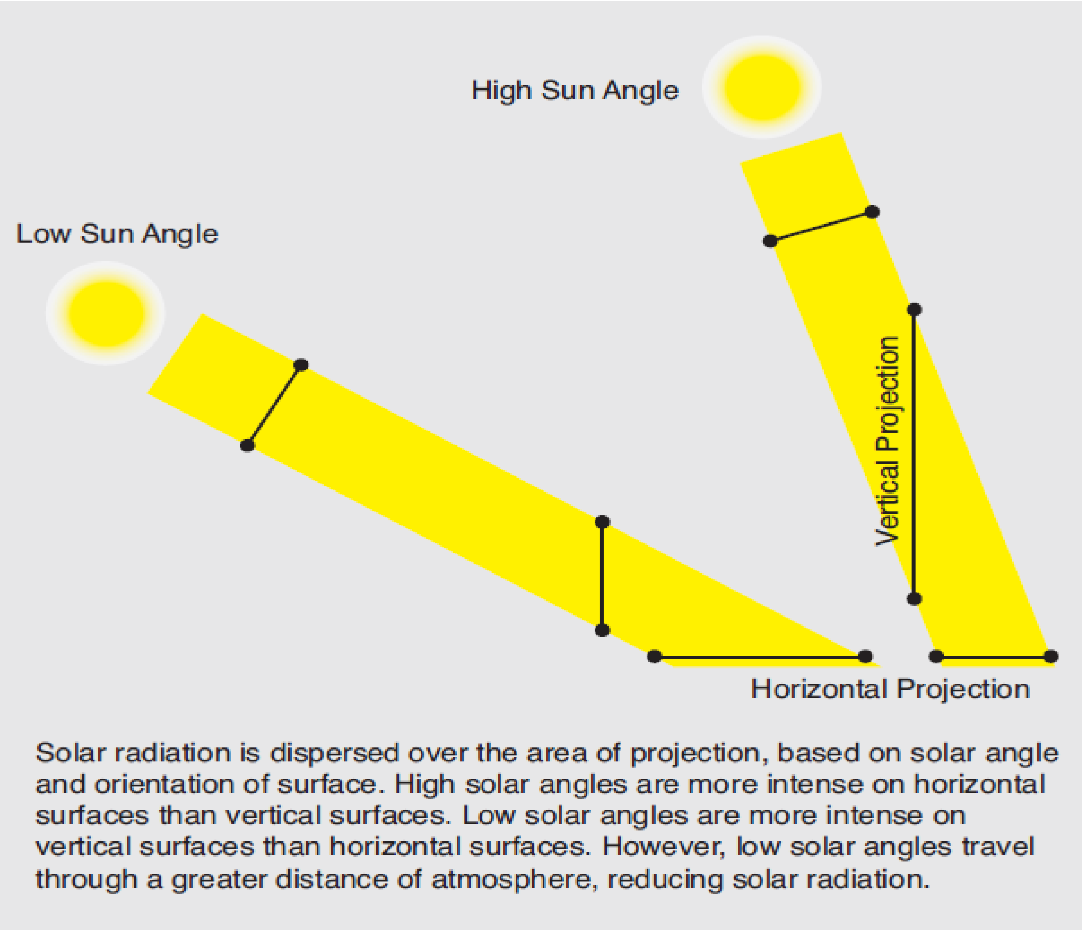


Fig. 7. Solar radiation and the angle of the sun

Wind

It is not necessary that the orientation of the building is completely perpendicular to the wind; as a general rule, it can be changed about 30 degrees. In addition, vertical fins in the facade can be used to enter a direct breeze to the windows. It is also important to consider the sources of air turbulence, such as adjacent buildings, or other site features.

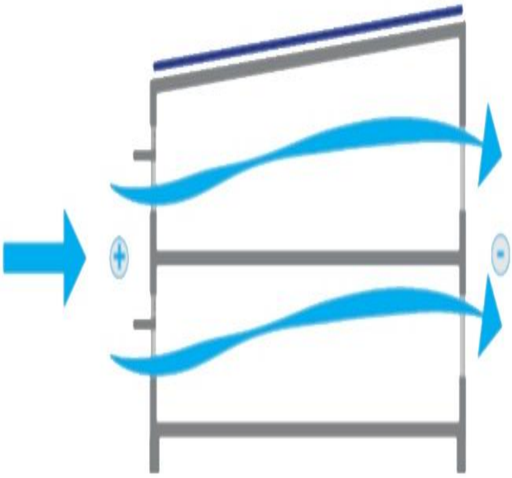


Fig. 8. The general principle of passing ventilation.

Results

Building envelope

The building envelope is the first building interface with the outer environment and the climate; therefore, it plays an important role in implementing a passive strategy, and it must be integrated with decision-making about orientation and density, as well as the design of mechanical and electrical systems. The building envelope is a vital element in the energy performance of each building.

Neutralize the envelope

The concept of Neutralize the envelope is neutralizing thermal loads from the envelope, which begins with optimizing the density and orientation of the building. The solar and wind conditions of the site affect the thermal loads in the building, depending on the orientation, envelope size and site barriers, in order to solar radiation shadow or wind penetration barriers. The ability to shade on the glass envelope is also directly affected by orientation. In addition, the effect of outdoor air temperature is noticeably on different levels in hot climates with a high level of solar radiation. In fact, in places where the height of the sun is high, the outside air temperature is also high on the roof, and so the roof is the main source of heat increase in buildings with long roofs. Cold roofs, green roofs and shady roofs can be used to reduce outdoor air temperatures. The orientation, density and proper planning of the site, will reduce the thermal loads, and when it combines with well-designed and accurate building envelope, it will be the key to the success of neutralizing the envelope. The envelope structure can be designed for heat transfer (U-factor), with super-insulated walls, using insulating materials with high thermal resistance and also eliminating thermal joints. The roof must have the highest thermal resistance in the building's envelope, because the main place of heat loss is in hot climates, as well as a high heat increase in cold climates and is related to the effect of solar radiation.

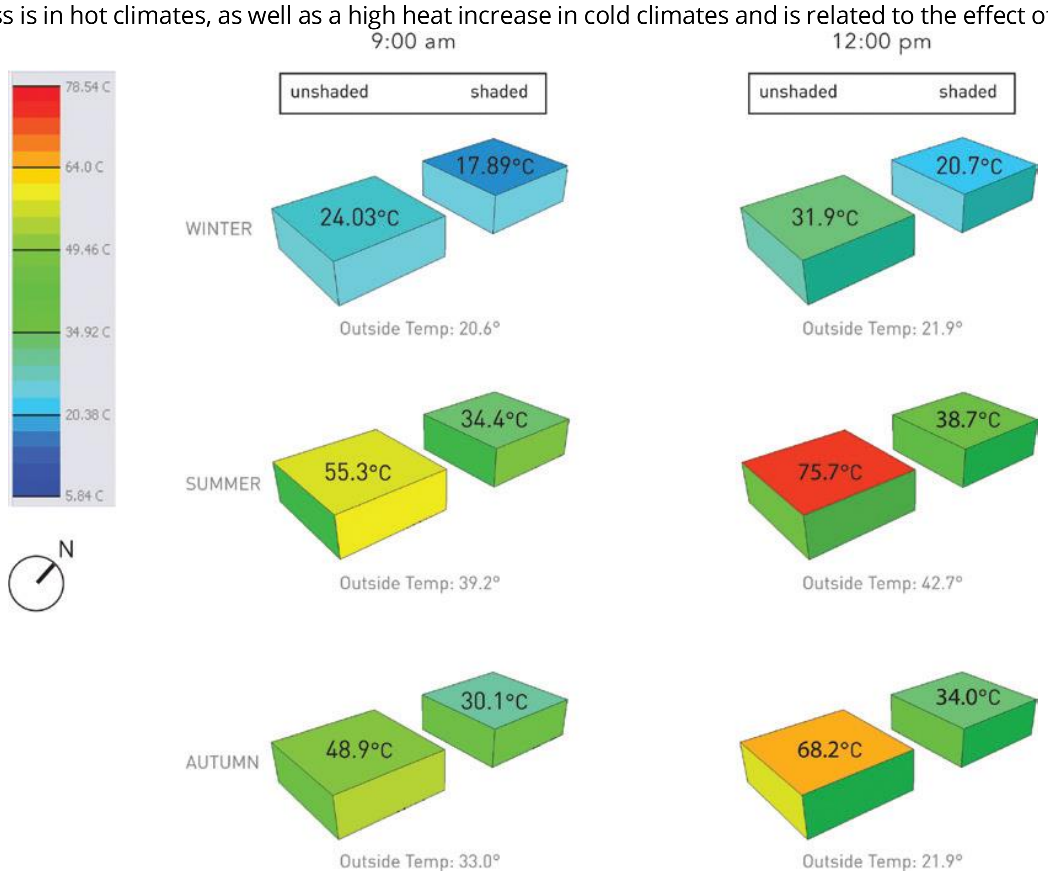


Fig. 9. The surface temperature plotted at levels, using the Open Studio, to determine the shadow effect on the roof temperature for a project in Abu Dhabi. (Source: RNL)

Convection (heat transfer, by the movement of liquids and gases) also leads to an increase or decrease in heat, through the building envelope. The air penetration through the slots in the building envelope leads to thermal leakage, between the building and the outer environment, which causes heat to rise, during the cold season and its loss, during the heating season. The wind and the pressure difference between the inside and outside of the building are penetration loss motive. The construction of an impervious building envelope is a major approach to controlling heat transfer loads.

One of the most important features of the design of the building's envelope is the glass openings. Thermally, glass is the weakest ring in the building's envelope. The glass envelope and window frames have the lowest thermal resistance, almost among all the constituent materials of the building. Also, the glass, due to its transparency, leads to increased heat from sunlight. In addition, windows and window openings are the initial point of air leakage in the building envelope. At the same time, glass is one of the most important elements of building design, which offers many architectural, planning and functional advantages. Therefore, the maximum use of glass is an essential part of the envelope neutralization, by minimizing the associated thermal capacity. The key point is to optimize the performance of the glass system's energy, such as low heat transfer and low coefficient of solar thermal boost. The window to wall ratio (WWR) is an important criterion, which helps to balance the thermal capacity with functional benefits, such as daylight and vision. Various shadow strategies, daylight glittering devices and window attachments are available to provide advanced insulations, shading, and glare control. In general, the window design is managed by the orientation, the climate, and the building plan, and responsive buildings often combine a wide range of glass and shadow solutions to address the specific needs of each window location (Figure 10).

Fig. 10. Luis & Clark's office building, for the Missouri Ministry of Natural Resources, has been well integrated into solar control for glass envelope. (Source: BNIM)

Neutralizing the envelope will reduce the heating and cooling loads of the environment, which has many benefits, relating to system, and thermal comfort. Neutralization eliminates the need for heating and cooling of the environment in ordinary buildings. In addition, by minimizing environmental loads, it is possible to use low-energy mechanical solutions, such as radiant heating and cooling. Neutralizing the facade also leads to increased thermal comfort, as high-performance glass systems reduce indoor temperature of the glass, which can lead to discomfort in the winter, and boost solar heat, which can lead to discomfort in the summer. The installation of air or gas holes in the glass envelope, using two or more panels, significantly reduces the U factor.

Discussion

The wall facade to the story area ratio

Reducing the exterior can lead to energy savings, while maximizing energy can maximize the free energy. In most cases, maximizing free energy has many benefits, so this approach is the starting point for net zero energy projects. The important point is to minimize the large surface by neutralizing the envelope or minimizing penetration, transmission, and thermal radiation loads.

The surface-to-volume ratio is a metric tool to express the relative density of the building. The low surface to volume ratio requires a denser design. A higher ratio indicates a higher external level to take advantage of a passive strategy. However, this ratio can be a misleading criterion in the process of determining the shape of a building for the use of passive strategies. While squared buildings are dense, and, consequently, they have a lower surface to volume ratio than narrow buildings, the number of stories significantly affects this matter and the less number of stories leads to lower ratio. This result suggests that one-story and low-rise buildings are somehow optimal for passive strategies; of course, exterior walls are generally more useful than the roof for implementing passive strategies. In addition, minimizing the roof area will prevent the waste and improve the heat. In this case, multi-story buildings have a clear advantage. Considering that the roof area is an important parameter for solar energy, perhaps the most appropriate option for measuring the geometry of a building, for passive strategy, is using the exterior wall ratio (instead of the wall surface) to the gross ground area, Or the exterior wall to the floor area ratio (EW/F). The matrix (Fig. 11) provides a comparative metric of density for a range of density options for a 25,000-square-foot building. In this example, a four-story narrow building has the highest exterior wall to the floor area ratio and is optimal for passive strategies; at the same time, the densest option is in the matrix (the lowest ratio of surface to the volume (F/R)). The main disadvantage is the high ratio of floor to roof (F/R), which could limit the potential volume for photovoltaic systems in the roof.

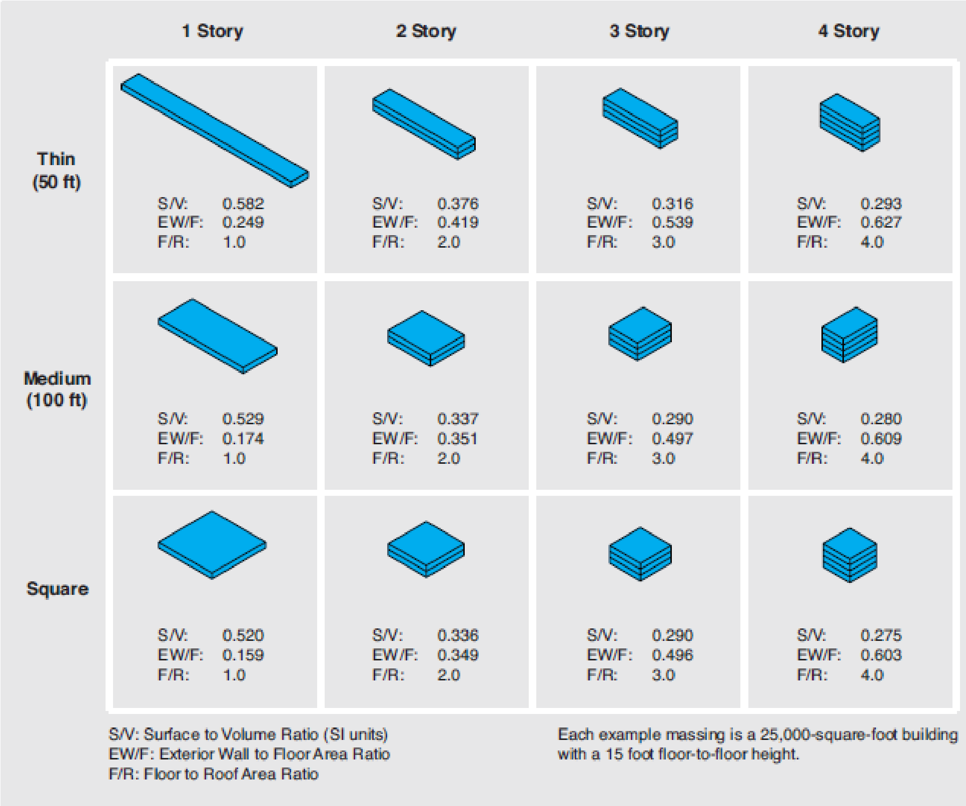


Fig. 11. Metric density matrix.

Density and Geometry for Renewable Energy

Various types of renewable energy systems can be installed or integrated into a zero-energy building, such as photovoltaic panels, solar thermal panels and wind turbines that are installed on the roof of a building with wings drawn in the west-east.

Depth of Illumination

The daylight of the day has the ability to penetrate only to a certain depth of space. Story depth is another important issue for pure zero energy building. Narrow buildings have an advantage of a passive strategy. Narrow access can be achieved in a variety of ways, and the final solution depends on other variables, such as the site and the program. The most fundamental passive form is responsive, simple, long, narrow, rectangular, which has the correct orientation. In fact, the passive design stimulus and many other forms are derived from it. Larger buildings can have long, narrow wings along the east-west axis, connected to the central spine. There are many variations in these shapes, as diverse as the sites and construction plans. The courtyard is a great way to develop the desired microclimates. (Figure 12)

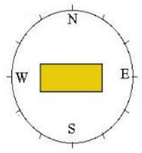
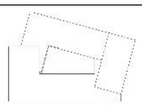
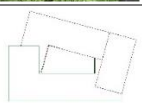
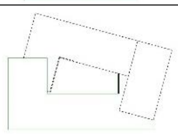
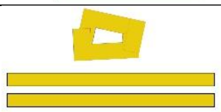
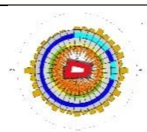
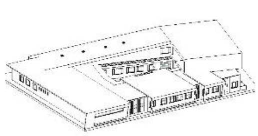
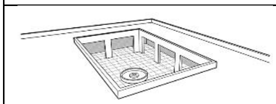
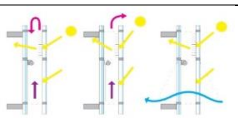
Fig. 12. Left: The yard of the DOE / NREL Research Support Building. (Source: RNL Photographer Frank Oses). Right: The corridor and Reichstag Glass Dome in Berlin, Foster & Partners work, use of mirror sets to provide daylight for the lower house space (Tania Salgado). The idea of a small microclimate yard leads to the formation of another passive axis. The enclosed yard in the corridor building is used for daylight or the natural ventilation of space.

Shadow

Shading is a basic strategy of cooling microclimate, which can be done in the form of building or adding shading elements to outer spaces; of course, it must be ensured that the shadow does not disrupt the use of daylight-saving strategy, and there should be a solar access for all solar panels. Reducing the amount of absorbed solar radiation, by exterior surfaces of the building and rigid facades also reduce the temperature of the environment. The use of surfaces with high solar reflections, or high albedo, is the usual way to minimize solar radiation absorption. The Leed scoring system has useful guidelines for solar reflection, for roofs and rugged areas.

Exterior shades not only shadow the solar radiation in window places, but also large-scale exterior canopies can shadow all of the exterior surfaces of the building and reduce surface temperatures and radiation and transfer of solar loads to the building's envelope. This type of shadow strategy is more suitable for hot climates, with cooling requirements all year round. It can be named from the trees as the most accessible and easiest canopy.

Table 1. Factors affecting the building design.

Description	Impact on the building	Factors affecting design
	Narrow-long, with a direction along the east-west axis (The stretching of buildings in the east-west axis, with the maximum southern and northern facade, is the best way to control the solar system)	Form and direction of the building
	A great way to develop favorable microclimates	Yard
	Reducing surface temperature and reducing radiation and transferring solar loads to building coverage	Vegetation
	Narrow building	Density and geometry
	Break the depth of the building / extend eastward to the west, in order to maximize the use of southern light	Solar radiation
	Minimizing the roof area will help wasting and improving the heat	Façade to roof ratio
	The direction of the building, perpendicular to the direction of the wind or with a change of 30 degrees	wind
	Potter and blades and trees reduce the absorption of solar radiation by exterior surfaces and reduce the temperature of the environment.	Solar shadow
	Use surfaces with high solar reflections	light reflection
	Use of canvas materials and bright colors	Color and materials
	Central courtyard, Waterfront, Greenery, Green roof, Green wall	Creating microclimate
	Double-walled facade, the use of moisture and heat insulation materials in walls and roofs	Insulation
	The placement of photovoltaic panels and wind turbines on roofs and walls	Energy production systems

According to the research findings, the significant results can be found in reducing the energy consumption of buildings, with the help of materials and equipment available in the country, using the potential and observing engineering points and effective parameters in the building, regarding the climate (Table 1).

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