Principles of Climate Responsive Design in North Cyprus

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Abstract
Buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of heating, cooling and lighting. With an increase in economic and industrial activities the demand for energy is also rising. The increased production and consumption of energy entail higher levels of pollution and eventually climate change, with possible disastrous consequences. Increasing awareness of the environmental impact of dioxide carbon emissions caused the renewed interest in environmentally friendly technologies. The use of renewable energy sources and the rational use of energy are the fundamental imputes for any responsible energy policies. The use of renewable non-commercial energy resources became widespread in housing sector of many countries with limited resources of commercial energy. Cyprus is one of the countries experiencing shortage of fossil fuels and abundance of natural renewable energy sources. The understanding and identification of climatic influence at the buildings is one of the most important part of the design process. A new approach is needed to integrate renewable energies in building design in a way to meet high building performance.

Key words: Energy, renewable sources of energy, climate responsive design

Introduction
With increasing urbanization in the World, cities are growing in number and population. At present 2% of world’s land surface is covered by cities, yet the people living in them consume 75% of the resources consumed by mankind. Indeed, the ecological footprint of cities is many times larger than the areas they physically occupy (Rees 1999). With an increase in economic and industrial activities the demand for energy is also rising. The increased production and consumption of energy entail higher levels of pollution and eventually climate change, with possible disastrous consequences. It is a well accepted fact that commercial energy use has to
be minimized. This is because of the environmental effects and the availability problems. Gas, oil and coal are non-renewable natural resources which will be of great value to future generations. When gas, oil and coal are burnt, they release harmful gases, which trap heat in the atmosphere and cause global warming. The climate system contains many processes that will change if warming occurs. Critical processes include heat transfer by winds, the hydrological cycle involving evaporation, precipitation, rain off and ground water and the formation of clouds and ice. Climate change is real. It is happening now, and green house gases produced by human activities are significantly contributing to it. Increasing awareness of the environmental impact of dioxide carbon emissions caused the renewed interest in environmentally friendly technologies (Overbay 1999).

**Energy Resources and Buildings**

The use of renewable energy sources and the rational use of energy are the fundamental imputes for any responsible energy policies. The World Summit on Sustainable Development [WSSD] in Johannesburg committed governments and societies to “encourage and promote the development of renewable energy sources to accelerate the shift towards sustainable consumption and production” (WSSD 2002). The focus has now shifted to non-commercial energy resources, which are renewable in nature (Soeburto 2000). This is found to have less environmental effects and also availability is guaranteed. It is accepted, that renewable energy is sustainable form of energy. Sustainable energy is that, which has minimal negative impacts on human health and the healthy functioning of ecological systems. A great potential of renewable energy is one of the sources of sustainable development for the future (Szokolay 2004).

Buildings are responsible for approximately 40% of the total world annual energy consumption (Rees 1999). Most of this energy is for the provision of heating, cooling and lighting. The use of renewable and non-commercial energy resources became widespread in housing sector of many countries with limited resources of commercial energy (Soeburto 2000). Cyprus is one of the countries experiencing shortage of fossil fuels and abundance of renewable natural energy sources, such solar energy and wind energy. The average annual increase in electricity consumption in North Cyprus building sector during the past 20 years has been about 10%. In recent years the demand for electricity has been stretched to its limits in winter (Ilkan 2005). This raised the question of whether renewable energy resources could be utilized to reduce the level of peak demand. Cyprus, being a Mediterranean island, enjoys abundant solar energy. Studies show that a considerable potential of solar energy could be utilized for passive space heating and active water heating and also for electrical power generation (Ilkan 2005). Use of renewable non-commercial energy resources would increase electrical reserve and reduce the need for capacity expansion.
Climate Considerations
Climate is one of the most important factors that define the formation of building types with sensitivity to environmental conditions. Different climatic conditions pertaining to the different regions of the world force them to consider some special precautions to establish comfortable living spaces (Givoni 1992). The Mediterranean climate prevails in all countries bordering the Mediterranean Sea between 30 to 45 latitude degrees north of the Equator. These climates are in the polar front region in winter, and thus have moderate temperatures and changeable, rainy weather. Summers are hot and dry, due to the domination of the subtropical high pressure systems, except in the immediate coastal areas, where summers are milder due to the nearby presence of cold ocean currents that may bring fog but prevent rain (Kottek et al. 2006). The Mediterranean climate type is characterized through location and weather patterns. For example, in Cyprus rainfall occurs almost in winter from north-western frontal storms. During the summer, the subtropical high pressure zone dominates weather patterns, preventing rainfall. The wet winter with moderate weather and dry summer with hot weather seasonality is defining characteristic of Cyprus climate (Kottek et al. 2006).

The relative humidity of the Cyprus could be determined by local factors. During the spring - summer minimum value can be observed in Nicosia, which is lower than 50% of relative humidity, and the maximum is in coastal area. For example, Girne has the characteristics of hot-humid climate. Rainfall trends to be heavier on windward site of mountains. According to Koppen climate classification (Kottek et al. 2006), the Cyprus climate is Mediterranean, but there are some climatic variations. Rainfall tends to be higher in northern coastal areas, while summer droughts are common for island. See breezes have a warming effect on coastal area in winter time. The understanding and identification of climatic influence at the buildings is one of the most important part of design process. An approach is needed to integrate renewable energies in building design in a way to meet high building performance (Givoni1992).

Climate Sensitivity of Traditional Cyprus Architecture
Traditional Cypriot cities and buildings are mostly organized according to local climate. The main focus on open spaces - streets and courtyards - came out from the characteristics of urban density and morphology. Sun controlling and ventilation along the selection of construction materials represent issues of climate sensitivity (Saymanlier 1998). Morphology of urban design in Cyprus is characterized by a framework of streets and squares, which cut through dense and low buildings. From the point of climate sensitivity, direction and density of the street networks also one of the important factors. Densities of building structures and networks of streets have an significant effect on the microclimate of open spaces. According to Rapoport (1969), greater density contributes to lower solar irradiation with more temperature stability. In traditional Cyprus architecture main streets orientation often depend on direction of
the fresh breezes from sea or mountain (Saymanlier 1998). With this solution inhabitants of houses take advantage of natural ventilation. From the point of irradiation, the main alignment is east-west, which enables better use of solar radiation in winter time and better sun protection in summer (Olgay 1963). Historical observation show that this principles derived from classical Greek-Roman cities with their east-west axes, and from Islamic cities with their narrow streets and systems of ventilation (Hawkes 1998). Application of these principles in Cyprus urban design resulted in building fabric of cellular structure carved into public and private spaces.

Empirical investigations of the climatic behavior of outdoor spaces show that the performance of the buildings depends upon the relationship with surrounding elements (Hamphreys 1978). If the ratio between the size of buildings and width of open spaces is lower, temperature of outdoor spaces and surrounding buildings will be lower. This is reason why dimensions of open spaces are narrow in hot climates (Correa 1982). This principle gives the opportunity for extensive use of courtyards. Open spaces of courtyards are experiencing minimal solar radiation during daytime in summer, which limits the heating of courtyard’s surrounding walls. As a result of this design solution, the temperatures of the courtyard are significantly lower than the temperature of external spaces. During the night, the courtyard retains cool air, which benefits the surrounding buildings. Thus, courtyard houses are one of the fundamental climate responsive principles in traditional architecture (Rajapaksha 2002).

The climate of Cyprus with its hot and dry summers and wet moderate winters causes some problems for energy efficiency of buildings, because of the requirement for a combination of summer cooling and winter heating. Buildings can benefits of winter sun penetration, while they should be protected from excessive solar radiation in summer (Heshlong 1978). At the same time buildings need good ventilation in summer and protection from winter winds (Hamphreys 1978). Energy efficient building design solutions should balance these factors. The climate sensitivity features of the traditional architecture in Cyprus is based on south-north oriented blocks of 1-2 storey houses, built of solid mud brick or stone walls. Intensive use of open spaces is one of the main planning elements. Houses usually contain open courtyards, which are surrounded by living and service spaces. Usually south facing walls with big openings are contrasting to north faced walls with smaller openings. Thick mud brick or stone walls of the house are providing an efficient thermal mass storage (Lawson 1996). We can say that traditional architecture “have more lessons for us, such as formal characteristics, sensory qualities, relation to site and landscape, response to climate” (Rapoport 1982).

Observations on Modern Practice
Observation of modern housing practice in North Cyprus indicated some negative developments (Keles 1998). Urbanization processes in the country sides started in the 1980’ies resulting in an increase of population in cities and consequently a
shortage in the housing market. With the establishment of the Social Housing Unit in 1984 apartment houses and row houses became widespread. These types of houses were built also in rural areas. Later the majority of private companies also built apartment houses and row houses (Ozderen 2001). In many cases these types of houses were designed and built with no consideration to solar orientation and direction of prevailing winds. Reinforced concrete and composite artificial finishing materials replaced traditional construction structures and materials. Wide use of big window openings with no respect to climatic sensitivity of internal spaces created uncomfortable living units (hot in summer and cold in winter). Narrow and not well oriented terraces and balconies are not helpful in replacing of climate effective open spaces (Keles 1998). A wrong approach in the organization of open spaces changed the morphology of urban structures and disturbed natural landscapes. The wide and not shaded urban open spaces created the effect of “heat islands” with domination of hard and reflective surfaces becoming the source of excessive heat in the cities (Givoni 1998). Increased economic considerations excluded semi open spaces from design and construction practice, which are effective climatic transition element from outside spaces to indoor spaces (Nicole & Roaf 1996). Shading of the sun at the site is necessary to enhance the effects of cross-ventilation. Inhabitants of newly built houses were forced to use mechanical ventilation systems and air-conditioning devices. Wide use of electrically operating cooling and heating devices led to ignorance of climate responsive technologies by designers (Keles 1998).

In recent years increasing energy demand for air-conditioning in summer and space heating in winter arise interest in passive design technologies, using natural resources. The courtyard typology in design is usually attributed to cities of the Middle East, but this technology can provide solutions for energy efficient building design in modern practice of North Cyprus. Use of climate responsive solutions in modern practice should be supported with critical consideration of traditional design solutions. For example, courtyard typology is most effective for height/width ratio of 1/3 (building height to width of courtyard) and use of more width courtyard should be supported with dense deciduous plants (Rapoport 1969). Application of climate responsive technologies can be verified by using computer modeling.

**Consideration of Climate Responsive Design**

Consideration of climate responsive design in North Cyprus could be sought in following aspects:

- a) Reducing energy consumption of buildings.
- b) Utilizing natural renewable resources.
The energy consumption is based on the assumption that the buildings incorporate energy, e.g., efficient passive cooling, solar control and day lighting, and integrated energy systems (Olgyay 1963). For example, the admission of daylight into buildings alone does not guarantee that the design will be energy efficient in terms of lighting. In fact, the design for increased daylight can often raise concern relating to visual comfort (glare) and thermal comfort (increased solar gain in summer and heat losses in winter from larger apertures). Such issues will clearly need to be addressed in the design of window opening, blinds, shading devices, heating system, etc.

Day lighting strategies need to be integrated with artificial lighting systems in order to become beneficial in terms of energy use. Reduction in overall energy consumption levels by employment of a sustained program of energy consumption strategies and measures would have benefits within buildings sector. The perception should be given however is that rigorous energy conservation as an end in itself imposes a style on building design (Olgyay 1963). It would perhaps be better to support climate responsive design approach, which encompassed some elements of the pure conservation strategy together with strategies, which work with the local ambient conditions making use of energy technology systems, such as solar energy, where feasible.

It is well known that thermal mass with night ventilation can reduce indoor temperature in buildings in summer (Lawson 1996). Hence, comfort temperatures can be achieved by proper application of passive cooling systems (Rahman 1994). The reason for this is that in summer, heavy external walls delay the heat transfer from the outside spaces. Moreover, if the building has a lot of internal mass the increase in the air temperature is slow; this is because the penetrating heat rises the air temperature as well as the temperature of the heavy thermal wall (Lim 1998). The result is a slow heating of the building in summer as the maximal inside temperature is already low. The heat flowing from the inside heavy walls can be removed with good ventilation in the evening and night (Rahman 1994). The capacity to store energy also helps in winter, since energy can be stored in walls from one sunny winter day to the next cloudy one.

Investigations about climate responsive design in Cyprus are based on the synthesis of theoretical hypothesis backed by empirical evidence. The hypotheses used have been developed from basic meteorology processes and physics theory. Empirical evidence is available from the use of weather forces by designers and users of houses. Convention weather conditions typify forces available in the climate and are applicable in building design. This is one of the substantial empirical data bases available for the formulation of climate responsive design principles (Givoni 1998).

Our climate responsive design recommendations for North Cyprus suggest that living rooms should be located on south faced side of the building and glazed openings of the south wall should be protected from summer sun radiation. Horizontal shading devices of south faced walls should be designed with respect to altitude of summer sun. The
use of winter sun penetration for passive heating of spaces can be provided with properly sized openings and selection of thermally massive materials and structures for accumulating of solar energy. Pitched south oriented roof should be designed with ventilating attic. The tilt of south oriented roof with solar collectors should follow the local latitude and altitude of sun. Ventilation of spaces can be designed with use of cross-ventilation and stack effect of wind flow, as well as buoyancies ventilation effect during the time, when there is no wind flow (Hyde 2001).

The fundamentals of passive design could be seen as a creative use of site planning and building design with more connections to natural environment. Now the main problem is how the types of modern houses can be more adapted to local climate and how they can be more climate responsive. A solution can be seen in use of passive design technologies (Watson & Hyde, 2000). Passive design technologies allow us to cool and heat our homes without using commercial energy. We can use energy of sun or wind in passive design. Energy for passive cooling or heating comes from natural processes, such as direct solar gain or use of pressure differences of natural air flow. Throughout the world, in many countries thousands of homes have been designed and built to use features that take advantages of sunshine and airflow (Hyde 2000).

A house designed according to passive solar design technologies naturally collects the energy of sunshine through large, equator facing openings, which is one of the main elements of passive solar design (NLCC Architects 2002). Once the heat is inside, we need to accept and absorb it. This work can be done by another element of passive solar design, which we call thermal mass absorber. Thick walls and hard floors are very good thermal absorbers, because they are collecting energy of sunshine during the winter days. At night, when the air became cool, thermally massive walls and floors releases heat to the air and this mechanism of passive solar design we call distribution element. Another aspect of sunshine is that the building will absorb heat also during summer day, when the last thing house in hot climate usually needed in this time of year is heat of solar energy. So, passive solar houses should be designed to let the sunshine inside of house during cold winter months and block the sunshine during the hot months (NLCC Architects 2002). Equator facing walls with big window openings should be designed with shading devices or in site planning consideration should be given to planting of deciduous trees in front of those walls for sun controlling. The shading devices designed with respect to high sun altitude in summer will block excessive sunshine inside of house, while low sun altitude in winter will allow penetration of internal spaces by sunshine. The same kind of work can be done also with use of deciduous plants. This kind of trees lose their leaves in winter and allow solar heating of internal spaces, while in summer the leaves protect south facing walls and spaces from sunshine. Shading of the sun at the site also can enhance effects of ventilation (Lim 1998).

The passive cooling technologies are another source, which can offer a solution for reducing energy demand of buildings (Rahman 1994). The passive cooling
technologies include cross-ventilation, stack effect and temperature or humidity driven buoyancy. In a summer time in south side of the building as air temperature increases locally, that air expands and reduces in density. Such a low density air has a higher temperature than ambient, and is forced upward by the surrounding ambient temperature and pressure. This takes the form of thermal convention, a common meteorological phenomenon (Rahman 1994). Buildings cost shadows to their north side and air in this side of the building is cooler than ambient air. So, density differences will create a pressure differences in south and north sides of the building. If we are opening windows on north and south sides, this will allow cool external air from northern side of building infiltrate the building, while the building air volume is drawn out to the south by thermal convention. The empirically calculated effect of this cross ventilation is up to 10 air changes per hour (Rahman 1994). The effect is to create air changes within the building with cooler than ambient external air suitable for comfort in summer conditions. The pre-cooled low volume cross ventilation is created with little on-going operating costs. Microclimate generated cross ventilation is based on simple and well understood meteorological phenomena (Rassel 2000).

The clerestory (high level glazed opening) can be used to introduce natural daylight into the building. The clerestory also can contribute to ventilation and cooling of the building in summer. Ventilation through clerestory is generated by the variations in air pressure from airflow around the building or from differences of relative humidity (Rajapaksha 2002). As air flows around the building, upwind surfaces dam air to higher than atmospheric pressure. Downwind and sheltered areas contain air at atmospheric or lesser pressure. North facing clerestory in North Cyprus conditions is situated in a sheltered area and relatively to prominent northern breezes from sea. In summer time it is results in air flow from the building, when clerestory windows are opened.

Existing features of the land also contribute to modifying the climate on the site from general area weather (Jones 1998). Existing vegetation and structures on the land create shade and moisture variations, land slopes and soils change the heating load on areas of the land. On land with a north facing slope, compared with a south facing slope, quite different house designs will be required for comfort. Sun penetration, wind flow and moisture mixed to varying degree are the components of microclimate. Microclimate can be used to advantage cool outside spaces, which is comfortable in summer. The changes to the home site’s microclimate also affect the interior comfort of the building. By creating a heat load, wind pressure and moisture on different sides of the house, the interior can be kept comfortable warm in winter and ventilated and cool in summer (Lim 1998). Microclimate can be created on every site of house with the combination of land’s existing features, and by placing the building appropriately on the site. The main considerations in a placing house in existing site are the definition of existing features of the land, which affect the microclimate and determine where the building is to be
situated on land for comfort and in which way its walls and openings to be oriented to maximize comfort and energy performance of the building. Buildings designed to use microclimate are achieving substantially lower energy consumption to gain the same energy performance and comfort level as conventional building (Jones 1998).

**Conclusion**

Passive design technologies can help architects create low energy environments in North Cyprus according to its suitable climate and natural conditions. These technologies can form a appropriate approach to the environmental aspects and essential life values that has been lost in recent years. In conclusion we can say that in modern practice energy efficiency of buildings and low energy environments in North Cyprus architecture can be achieved by implementing of complex strategies which include combination of following measures:

- The application of environmental regulations and policy in order to promote efficient energy usage and use of renewable energy as an alternative energy source
- The critical evaluation and application of historically elaborated practice to make a modern response to traditional materials and energy usage standards
- Mathematical modeling and computer simulation in order to place minimal demand on non-renewable energy sources
- Environmentally friendly design and engineering with consideration that building should be shaped according to the site structure and form of building should follow organic settlement patterns
- Creating microclimate through site planning and landscaping and developing use of energy efficient solutions in design, this helps to conserve energy
- These measures can help to create climate responsive design in modern architecture of North Cyprus.

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