THE ROLE OF LANDSCAPING ON BUILDINGS' ENERGY EFFICIENCY

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ABSTRACT

During the recent years, the number of buildings has been increased with the rapid growth of populations in cities, which cause proliferation in the total energy consumption. It also has negative impacts on the urban environment. Today, one of the challenges of buildings' design is to find some efficient solutions to reduce the energy consumption. For this purpose, different types of construction materials and methods have been applied.

Over the past few years, sustainable building design which is an energy and ecologically consciousness approach has gained significant importance in urban design. According to the goals of this term, structural materials are not sufficient enough uniquely. Therefore, new adaption strategies such as placing the vegetation directly on buildings (rooftop garden, green walls and etc.) have become more efficient.

In this study, the role of landscaping on energy efficiencies of the buildings has been evaluated. Various methods of integrating plants to the buildings have been analyzed in order to decrease the energy consumption. In addition, the methods have been compared with construction materials from different points of view: the energy consumption, the surface temperatures and energy fluxes out of buildings and their effects on environmental problems.

The results obtained from different studies indicate that landscaping has significant role on optimizing energy performance in buildings especially during utility peak demand period. Although, landscaping would require more time and cost initially in contrast with construction materials used in buildings. Within the scope of sustainable design in urban area, it is obvious that using the plants in buildings will have positive impacts resolving the environmental issues and energy saving comparing to non-vegetated buildings.

Key words: Energy, Green roof, Buildings' energy consumption, Sustainable architecture, Environmental problems.

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1. INTRODUCTION

Through the history of life, Human beings consume energy resources and damage the natural resources according to his needs. During the years, quest of energy and natural resources caused the development of new techniques on energy generation and change human lifestyle. Population growth, rapid urbanization, fast moving consumption of energy and natural resources caused anxiety about the future of human life. Therefore, sustainable use of energy and the earth's natural resources become vital to ensure the next generations life on the earth.
Nowadays, most of the people live in cities. Therefore, energy and natural resources consumption are high in urban areas. The relative share of buildings as a major elements of cities, in energy usage and environmental impact, as compared to other areas of human activities is undoubtedly significant. As a result, such positive and effective activities for environment and the consumption of energy in buildings are important. Sustainable architecture is a general term to achieve these two objectives. Towards the goals of sustainable architecture to obtain environmental quality, buildings must be constructed both to use less energy and have environmentally sensitive design. Existing structural materials are not sufficient enough to achieve these goals. Therefore, in recent years, using vegetable materials and new adaption strategies such as placing the vegetation directly on buildings or surround of the buildings have become more efficient than constructional applications.
In this study, the roles of landscaping and vegetative materials usage on energy efficiencies of the buildings has been evaluated by analyzing the various methods of integrating plants to or surround of the buildings. In addition, the methods have been compared with construction materials from different points of view: the energy consumption, the effects on surface temperatures and energy reflection out of buildings and their effects on environment.

2. ENERGY AND BUİLDİNGS

The concept of energy is consists of three parameters; generation, transmission and consumption. For a sustainable life style, increasing the generation of energy is not enough. The transmission and consumption parameters also have effective role on energy cycle.
Today, cities by definition are a focal point of energy consumption. Different researches indicate that most of the energy consumption of the cities belongs to the buildings. Due to the climate condition in different cities, energy consumption of buildings is varied. In addition, many other factors such as orientation, form, shape, depth, obstruction angle and etc. of buildings are effective on energy usage. Furthermore, construction materials used in buildings can be effective on the amount of the wasted energy. As a result, government policy makers and building professionals, including architects, building engineers, project managers and etc. play an important role enhancing the planning, design, construction, operation and maintenance of the building energy efficiency process in order to form a sustainable urban development.

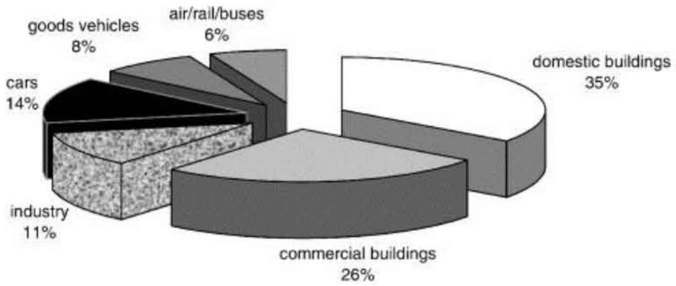

Figure 1. Energy use breakdown for London (Steemers 2003).

During the recent years, according to urban sustainable development objectives; reduction of energy consumption and environmental condition improvement in the cities, landscaping has gained importance. For this purpose, various methods and materials have been emerged. These methods and their materials for buildings' energy efficiency could be considered as two headings:

- Landscaping surround the buildings
- Landscaping directly on buildings

2.1. Landscaping surround the buildings

Landscaping surround the buildings could have positive effects on energy consumption as well as environmental problems. Different planting design next to the buildings can be effective on energy consumption over the year. Some examples are written as followings:

- Planting tree for the purpose of providing shade in summer. This can block the sun's warming rays and reduce energy consumption of buildings for cooling. Planting deciduous tree also can redirect sunlight into the house and decrease energy consumption of heating in winter (figure 2).

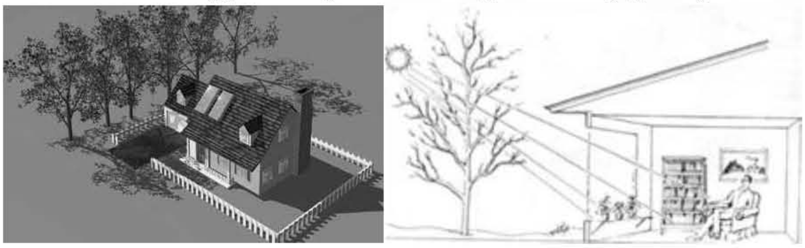

Figure 2. Planting tree for the purpose of reducing energy consumption in summer and winter

- Trees also can be used as wind break (figure 3). This method can prevent heat loss during the cold season. Trees and wall sheltering, where climbing plants are used as buildings wind break, can slow winds speed.

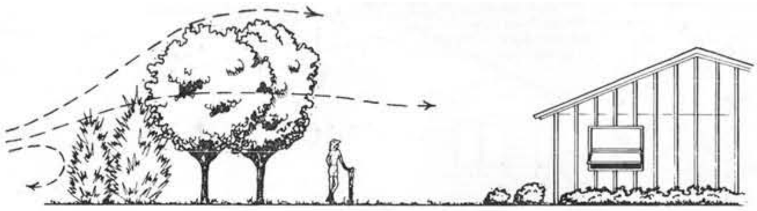

Figure 3. Planting trees as wind break

- Using pervious paving, high albedo paving, shade, and minimizing paved areas surround the buildings have a positive impact on microclimate as well as reducing the heat island in cities that reduce energy consumption indirectly.

Today, the lack of the open space in most of the cities is a problem for using plants surrounds the buildings. So this type of landscaping is only possible in places where land has suitable conditions for this usage.

2.2. Landscaping Directly on Buildings

Since 1980s a growing interest in environmental issues resulted in the vision to bring nature into the cities. For this purpose, various technologies and methods have been developed and different materials have been produced. Green roofs and green walls are some of these methods. Beside the environmental benefits, their positive effect on energy consumption and storm water management, urban heat island, noise pollution and etc. have been proved by several researches.

2.2.1 Green roof

Use of the concrete by the middle of the 17th century allowed for the construction of green roof. Research of Dunnett and Kingsbury (2008) indicates that the 1868 World Exhibition in Paris was the emergence of modern green roofs. Today, the term "green roof" is generally used to represent an innovative established approach to urban design that uses living materials to make the urban environment more livable, efficient, and sustainable. Other common terms used to describe this approach are eco roofs, and vegetated roofs (Banting et al. 2005).
According to Frost (2008), green roof is a roof surface that contains a growing medium that can sustain a layer of plants. Green roofs typically include filter layer, drainage layer, and waterproofing layer.
The progress of green roof technology makes different kind of green roof system applicable. The most common systems can be categorized as below:

- Complete system
- Modular systems
- Precultivated vegetation blankets

2.2.2 Green walls

Building facades and exterior walls are usually under permanent environmental influences, such as sun and acid rain. These environmental influences cause damages and shorten the life of these elements. Green walls system can protect facades and offer many benefits like the green roof.

Vegetated facades are not new technology and can offer multiple benefits as a component of current urban design. According to Kohler (2008) research, in many European and some North American cities woody climbers were frequently used as a cover for simple facades in the 19^{th} century. Incentive programs were developed in many cities of Germany, including supported tenant initiatives for planting and maintaining climbers in facades. However, Green walls and facades have not been developed widespread outside of Germany because they are not as well-known as green roofs.

Many researches have conducted on issues such as evaporative cooling effects of plants on green wall, improving urban life and biodiversity, positive effects on urban microclimate and buildings' ecological footprint. However, there is still a lack of implementation and evaluation of the effects of Green walls on energy consumption. Therefore, in this research for evaluation the positive effects of landscaping on energy consumption, green roof were focused and investigated.

3. THE EFFECTS OF LANDSCAPING ON BUILDINGS ENERGY CONSUMPTION

According to the research by USA National Energy Education Development project (2012), the residential and commercial sector- homes and buildings- consumes 41.2 percent of the energy used in the United States. The energy is used to heat, cool and light houses and buildings and to operate appliances and office machines. In addition, the research indicate that 54 percent of the average home's energy consumption is for heating and cooling rooms to keep living and working spaces in convenient temperature (USA National Energy Education Development project 2012).

Roofs are important determinants of building's energy flux and can represent up to 32 percent of the horizontal surface of built-up areas (Oberndorfer et al 2007). Buildings have changed the flow of energy matter through urban ecosystems that cause many environmental problems. Therefore, altering the surface properties of buildings can partially mitigate these problems. Green roof applications can reduce buildings' energy consumption and lessen several negative effects of buildings on local ecosystems.

During the summer, green roofs reduce heat flux through the roof by promoting evapotranspiration, shading the roof physically, utilizing the sun's energy in photosynthesis, and increasing the insulation and thermal mass beside lowering the energy demands of the building's cooling system (Figure 4) (Oberndorfer et al. 2007). The amount of saved energy is dependent on several factors. Among them are: the amount of roof insulation used; the height of the building; the climate and microclimate of the building; and the type and coverage of the green roof.

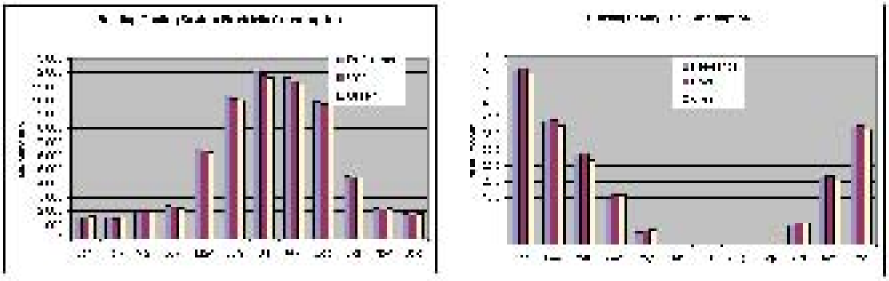

Figure 4 and 5. Energy Consumption of Model DDC Building ,Note: Coolroof is Energy Star® rated membrane or coating (Gruzen Samton Architects LLP et al., 2007).

The research of Wong and colleagues (2003) in Singapore indicates that the heat transfer through a green roof during a typical day was less than 10 percent of that of a reference roof. Green roofs prevent heat from moving through the roof in summer and heat flow out of the buildings in winter (figure 6,7).
A study in Madrid shows that a green roof reduces the cooling load on an eight-story residential building by 6 percent during the summer (Saiz et al. 2006). In a peak demand simulation, the cooling load was reduced by 10 percent for the entire building and by 25, 9, 2, and 1 percent for the four floors immediately below the green roof. For a typical residential house in Toronto, the cooling load during July was reduced by 25 percent for the building and by 60 percent for the floor below the green roof (Saiz et al. 2006).

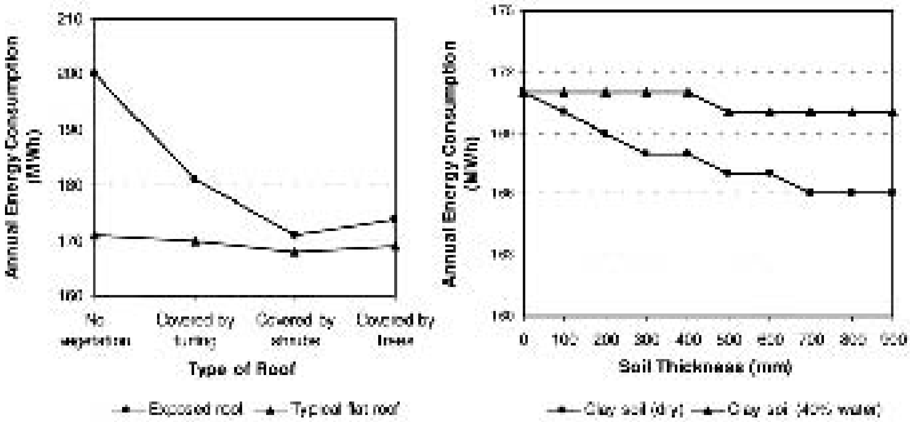

Figure 6 and 7. Comparison of annual energy consumption for different types of roofs for a five-story commercial building. Comparison of annual energy consumption for different soil thickness on a roof of five-story commercial building (Wong et al. 2002).

Landscaping would require more time and cost initially in contrast with construction materials used in buildings. But, they can payoff their costs thourgh the years by saving energy. Possman Cider Cooling and Storage Facility in Frankfurt, Germany yielded a 2-3 year payoff of their green roof system through the savings in heating, cooling costs and equipment costs. Consequently additional cooling towers had become unnecessary (http://www.greenroofguide.co.uk/downloads/dev_guide_v3.pdf).

4. COMPARİSON OF CONSTRUCTİON MATERİALS AND PLANT MATERIALS IN BUILDING

In concept of sustainable architecture and urban design, buildings must be constructed both to use less energy and have environmentally conscious design. Using plant materials in building and green roof has significant role in reducing energy consumption of buildings as described in previous section. In addition their positive impact on environmental problems is indisputable. Because of the importance of these effects, few examples are given as follows:

- Storm water management

Since plants absorb rainwater, green roofs can help reducing storm water runoff. Impervious ground cover pavement, significantly impacts the flow of storm water over land which often resulting in flooding and erosion of stream banks. A study conducted for the city of Portland, Oregon found that if half of the buildings in the downtown area had green roofs (219 acres), approximately 66 million gallons of water would be retained annually. The study also represented that 17 million gallons of combined sewage overflows would be eliminated and storm water discharges would be reduced between 11 to 15 percent (Peck and Kuhn 2003).

- Reduce urban heat island effect

According to Dunnett and Kingsbury (2008), the construction materials of buildings and paved surfaces absorb and store solar energy during the day and radiated it back as heat energy during the night. The density of buildings and other hard surfaces in urban areas can dramatically increase the air temperature compared to surrounding rural areas. Plant materials that are used in green roof and green wall, apply this energy for the process of evapotranspiration decreasing the negative effect of heat island in cities. The Organization for Landscape and Urban Greenery Technology Development estimates that if half of the roofs located in Tokyo were planted with gardens, the hottest summer temperatures would fall by 1.5 ° F (Gruzen Samton Architects LLP et al., 2007).

- Decrease noise pollution

The hard surface of buildings and pavement tend to reflect rather than absorb sound. Research of Peck and Kuhn (2003), shows that the plants and substrates of green roofs absorb sound energy. Thus, reducing sound transmission into the building's interior. Kevin Burke of William McDonough and Partners note that the green roof of Gap Inc.'s Cherry office (located near a highway and flight path of San Francisco International Airport) reduces sound transmission nearly 50 decibels (Dunnett and Kingsbury 2008).

- Increased roof life

Green roofs protect roofing materials from extreme temperature fluctuations and damaging ultraviolet solar radiation. According to Peck and Kuhn (2003), evidence suggests that the life span of green roofs is at least twice that of conventional roofs. Less frequent roof maintenance and replacement, reduces waste and associated life cycle impacts. Green roof also improve the membrane longevity. According to Oberndorfer et al. (2007). Waterproofing membranes on conventional dark roofs deteriorate rapidly in ultraviolet (UV) light, which causes the membranes to become brittle. Such membranes are consequently more easily damaged by the expansion and contraction caused by widely fluctuating roof temperatures. By physically protecting against UV light and reducing temperature fluctuations, green roofs extend the life span of the roof's waterproofing membrane and improve building energy conservation. Research of Porsche and Köhler (2003), demonstrates that some green roofs in Berlin have lasted 90 years without any need for major repairs. İn an other resarch by Liu (2004) In Ottawa, Canada, an unvegetated reference roof reached temperatures higher than 70 degrees Celsius (°C) in summer, while the surface temperature of the green roof only reached 30°C.

- Increased performance of Photovoltaics

Comparing the typical concrete roof, vegetation reduces the temperature of the roof. According to research conducted in Berlin by Kohler, the reduction of temperature provieded by vegetable at the roof surface improves the performance of photovoltaic cells, which operate more efficiently at lower temperatures (Dunnett and Kingsbury 2008).

- Others

In addition to the advantages of using vegetable materials compared with structural materials mentioned above, vegetaded surface of buildings are especially important in urban areas in which much of the land area is consumed by buildings, pavement and other artificial surface cover. They are inherently more aesthetically appealing and can improve biodiversity in cities.

5. CONCLUSION

In line with the objectives of sustainable architecture in urban area, the advantages of landscaping over conventional flat and shallow pitched roofs and walls of buildings are considerable. As stated, many researches indicate that green roofs have

a significant impact on the buildings energy consumption and improving the environmental problems. In addition, a green roof is inherently more pleasing than a typical membrane or bitumen roof offering substantial aesthetic benefits. The potential of green facades to improve urban microclimate and buildings' ecological footprint should be noted. It is true that the installation and maintenance cost of green roofs and walls are considirable. But, if vegetating roof and walls of buildings gain popularity and the technology of these methods also improves, the installation cost will decrease consequently.
As a result, with so many advantages, different methods of integrating plants to the buildings such as green roofs and green walls should be part of a comprehensive strategy toward achieving a sustainable and livable built environment .

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