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# COMPARATIVE INVESTIGATION OF ENERGY MANAGEMENT STATUS IN GREEN ARCHITECTURE AND ITS EFFECT ON SUSTAINABLE DEVELOPMENT

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## ABSTRACT

*Mechanical life and development of the industrial revolution have separated human from the nature and involved him in a situation far from natural environment. In this regard, with indiscriminate use of natural resources, human caused irreparable damages and destroyed most of natural resources and by now, several years after the Industrial Revolution, those countries that started this revolution are taking the natural sources and nature into consideration. For example, they create a harmony between architecture and nature considering appropriate use of nature and energy consumption management. In this study, it has been attempted to investigate the relationship between these two aspects and for this purpose, library research method was used.*

**Keywords:** sustainable architecture, energy management, sustainable development, industrial revolution

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## 1. INTRODUCTION

The necessities to use clean energies and environmental protection as well as the residents seem very important. In Germany, almost 10% of houses directly benefit from green space such as green roofs. In Tokyo, Tokyo 2000 Program came into effect in April 2001. In this program, the usable space of new houses with the area of more than 1000 square meters should have 20% green roof. Green roof has been effective in urban planning in North America in regions such as Chicago, Portland, Oregon, and Toronto. In Chicago where 20000 square meter of green roof is located on its municipality, the energy storage regulation was

approved in 2002 and it was stated that new buildings should have green roof or reflective roof. In Vancouver, population growth leads to increased instability in both energy consumption and wastes. In this regard, experts have recognized that green roof technology can solve this problem. According to the environmental effects and variety of species, green roof creates positive effects on the environment. Reducing pollutions resulted from sewage and increasing the required oxygen for human are other positive effects on green roofs. Since previous generations have used the characteristics of this potential over time, its utilization in urban space, in addition to absorbing noises and cooling the environment, leads to decreased energy consumption. The residents of buildings with green roof create a sustainable system by producing food products and soil stabilization. An investment in green roof technology is the most important method that allows our cities to grow and develop. It seems that it is necessary for Iranian cities to take important steps in this regard.

## 2. STATEMENT OF THE PROBLEM

Development of urban green spaces and its logical distribution in the cities, consistent with urban constructions, is one of the major challenges of contemporary cities. Since open and green urban spaces almost lack direct economic values, it seems that the development of constructions in short-term periods will create more profits in local governments and public sector, increases land use in short-term economic services, and develops urban green spaces compared with other investments but receive less financial support. This challenge exists in developed and developing countries, but in developing countries, due to the importance of economic resources in short-term period, it is more significant. The commitments of the developed countries to the environmental agreements and charters as well as the pressure of public thoughts that have more informed view toward environmental issues, have led to a motivation to identify new solutions to develop urban green space. The developers of private sector in construction to decrease costs and achieve more profits, increase the percentage of green energies and green spaces in different ways and in this regard, the establishment of parks and residential buildings with green views at large scale seems impossible with this progressive trend of big cities (Mahmoudi and Pakari, 2012).

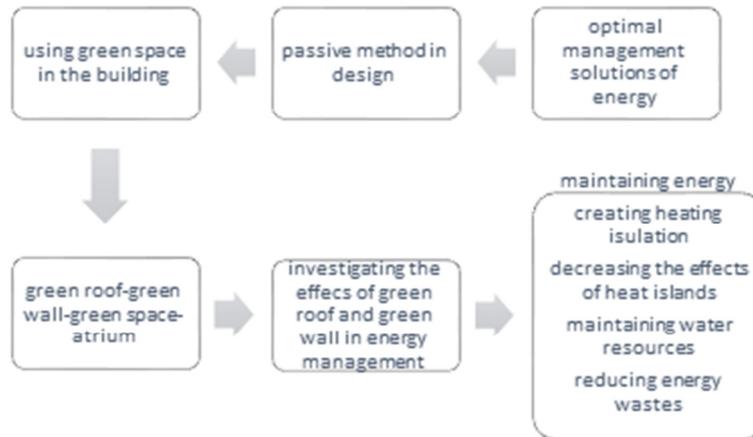
Areas of green space, due to improvement and sustainability of the quality, have made green roof a suitable option in big cities of Iran. Environmental problems are one of the main issues of cities and are resulted from their interaction with the natural environment, because urban development is accompanied by the domination of constructions, industries, and economic activities and this has influenced the nature and provided the context for vast pollutions. The result of this trend is imbalance and incompatibility between human and nature and disturbs the ecosystem relationships. With the development of cities, the values of natural environment will be destroyed and people have been deprived of natural attractions and psychological and social problems are increased. The concentration of populations within cities and suburbs and mismatch between the growth of urban services and urban infrastructures, especially in developing countries, have changed urban areas to polluted environments with problems for waste disposal and provision of drinking water (Salehi, 2001). Decreased energy consumption of buildings is not only done using materials and facilities, but by suitable urban planning consistent with the climate, energy consumption can be reduced. Nasrollahi (2012) in his studies on the architecture regulations and models to reduce energy consumption, proposed the major factors that influence energy consumption of the building as follow:

Heat shell of the building

Heating, cooling, and ventilation

Architecture and form of the building

In this study, according to the available information and previous information, the following process will be provided:



**Figure 1** The path to reach the research goal

### 3. RESEARCH QUESTIONS

What is the effect of using plants in buildings?

How green space can promote the environmental quality?

What is the effect of using plants on the promotion of environmental quality and outdoor air quality?

What is the role of plants in sustainable urban development?

### 4. OPTIMIZED ENERGY MANAGEMENT WITH SUSTAINABLE DEVELOPMENT APPROACH (GREEN ARCHITECTURE)

According to the ecological limitations and environmental effects, each stage of city development and each dimension of urban design considers economic and industrial sectors (Shafiei et al. 2013). A sustainable society considers major ecological limitations, looks for social sustainability and high quality of life, uses comprehensive solutions, relies on equality and justice, and emphasizes the importance of societies (collective life) and requires estimation of all social and environmental costs resulted from private and governmental decisions (Vafadar, 2007).

In order to achieve environmental goals of sustainable development, the following strategies should be taken into consideration:

1. Using renewable resources or those that are renewable;
2. Optimization of renewable resources utilization and minimizing natural resources consumption according to their natural growth;
3. Minimum production of wastes and pollutions that have absorption potential;
4. Creating a healthy environment for the next generations and provision of basic needs of human and the society (Panahi, 2007).

The dimensions of environmental dimensions of sustainable development are enumerated as follow:

Maintaining natural ecosystem balance

Integration of development with the environment

Natural management and planning

Optimal use of water, soil, and energy resources

Substitution of renewable resources (Panahi, 2007)

According to the conducted studies and investigations, environmental dimensions of sustainable development are divided into 5 main branches (Diagram 2).

## 5. ENERGY CONSUMPTION MANAGEMENT SOLUTIONS

In this approach, it is possible to classify the general measures of energy consumption optimization as active and passive methods and using instruments and standards related to energy consumption (Noori et al. 2008).

**Table 1** Classification of energy consumption optimization measures

Row	Method	Description
1	Active	Using different renewable energies consistent with the available conditions in the environment to function as an alternative for renewable and fossil fuels.
2	Passive	This method expresses optimal design consistent with the climate and concentrates on the available potentials in the environment and design such as how to use sun radiation or arrangement of the inner space and achieve the design goals.

## 5. INTELLECTUAL SYSTEM IN ISLAMIC ARCHITECTURE

Islamic architecture is taken from Byzantium, Persia, and India. In this type of architecture, for intellectual systems and concepts are integrated that are presented in Table (2).

## 6. THE APPLICATION OF GREEN SPACE IN ARCHITECTURE

Gardens and trees in each area create a peaceful atmosphere. For example, in desert areas, trees provide shadows and compensate the shortage of moisture in the environment. This green surface absorbs the radiations of the sun and prevents their reoccurrence and increased temperature and decreases dusts around the buildings.

The House of Borojerdiha: the green space in this building is located at the central yard. These green surfaces, in addition to creating visual beauty, increase moisture and absorption of solar radiations and decrease the heat of desert winds by evaporation and are effective in cooling the air (Gorgi et al. 2011).

We know green architecture as sustainable architecture, a macro term that describes techniques in designing architecture that is consistent with environmental attitudes and is formed with the idea to respect the nature. Nowadays, following negative consequences of industrial world such as pollution, and decreased natural resources and energy crisis, preserving natural resources has become one of the most important concerns of people. But green architecture by looking for a way to minimize the negative effects of buildings on environment, is trying to make coordination with the nature through increasing efficiency and optimization in materials and energy consumption and expanding the environment by controlling solar radiation and using sustainable components against heat. In the lands around the city with the distance of 20 miles from Abu Dhabi, photovoltaic and wind power plants, research centers, and farms are located that provide the fuels for the factories. These farms decrease the wastes, because through absorption, the gases resulted from the factories will be balanced and would be irrigated by the waste waters of the water treatment plants (Hatmi, 2011).

## 7. DIFFERENT SOLUTIONS TO USE GREEN SPACE IN BUILDING

The constructions that are built to function as shelter for people should have the best match with the environment. The key to continue sustainable life is to decrease the disturbances that are created by human and this cannot be achieved unless the presence of natural components increases in his life. Cities, as the center of human activities and living, in order to regulate their sustainability, have to accept the structure influenced by natural systems (Baro and Badri, 1997). In new scenarios, there exists a twofold relationship between human and the environment where both the nature of the region and human influence each other by designing and building the spaces that lives in (Kish et al. 2013).

## 8. GREEN ROOF

The instrumental role of garden is to decrease the temperature around cities. Low temperature in summer decreases demand for electricity. During summer, garden can be an important factors and provides decreased demand for energy. Green roof is a roof on which plants grow. Plant diversity of such structure can include artificial grass or gardens that are covered by plants. Green roof requires those plants that are selected carefully to resist against environmental crises such as shortage of water, freezing, and sea breeze. The types of selected plants are different depending on climatic conditions. Green roof is the integration of performance and the environment. Executive details of this roof do not show a significant difference between common roofs include thermal insulation and sand water. Also, materials are included to provide facilities to keep plants in the building. Green roofs are an admitted component in modern building where some cities or governments have made them necessary. Green roof existed in Europe from forty years ago and due to the direct intervention of temperature and prevention of heat. Limited underground resources, costly energy resources, old waste disposal systems, and need for a new resource for energy renewal are effective in the success of green roofs in Europe. In Germany, as the leading country in this industry, more than 800 samples of standard green roof can be found. Global standards of green roof are exported from this country to other countries in the world. Municipalities of this country perform construction regulations and green roof from the very beginning. From 1982, green roof industry in Germany is indicating 15 to 20% annual growth. In the United States, green roofs show uniform increase compared with the past. Numerous companies and associations in North America have started green roof methods, because they know that even the ground has the potential for the development of green roof, it cannot satisfy its needs. Finally, the new World Trade Center in New York considered a green roof in its final design. Le Corbusier and Wright were the pioneers of green roofs in 20th century. In the following table, different green roofs are presented.

Table 2 Different green roofs

Row	Title	Description
1	Concentrated green roofs	This system is also known as rooftop garden that includes various types of plants and is designed like a park. Some of green roofs have big trees and fountains and this requires fundamental strengthening (Razavian et al. 2008).
2	Semi-concentrated green roofs (combined)	In this type of roof, the surface is not accessible and its façade can be observed from around the building. This type of roof has shallow planting bed and includes coverage plants. This system includes one or two plants and is usually used when the minimum weight is considered.

## 9. GREEN ROOF AND ENERGY AND OPTIMIZED ENERGY MANAGEMENT

Green roof is known with different titles and has provided a desired environment for urban environment. Black surfaces and pavements absorb solar energy and reflect them during the night. In this regard, green roofs can decrease negative effects of buildings in local ecosystems and energy consumption in buildings and show a determining role in the changing the energy in the buildings.

**Table 3** Advantages of using urban green roofs (Nahrli et al. 2011)

Dimensions	Advantages
Ecological	Maintaining environmental diversity and creating ecologies Improving ecological quality
Climatic	The effect of thermal islands Cooling effect Decreasing the effect of cool winds and thermal insulation (Noori et al. 2008).
Urban environmental quality	Improving air quality Exchange of oxygen and CO <sub>2</sub> Decreasing the noise (noise insulation) Decreasing the volume of runoffs resulted from rainfall (maintaining superficial wastes) Increasing water quality and prevention of pollution Decreasing the effects of electromagnetic radiations (99%) (Donnett and Kingsbury, 2004).
Economic-cultural	Decreasing the costs of artificial ventilation (cooling in summer) Increasing the life of utilization of insulation Increasing the sense of belonging to the place Energy saving (insulation in winter) Creating additional green space (Taghavi, 2014).

According to the official statistics presented by the Ministry of Power, energy consumption in household sector has allocated a large portion of country's energy consumption that reaches to 3 to 30% of total annual energy consumption of the country (Majedi and Siadati, 2015). Provision of comfort conditions in residential buildings and changes in consumption pattern toward increasing welfare have concentrated on energy consumption.

**Table 5** Classification of green roof's benefits

Row	Environmental benefits of green roof	Social benefits of green roof	Economic benefits
1	Decreasing thermal island	Aesthetic and recreational areas	Savings in energy consumption and decreasing heating and cooling costs for the building
2	Controlling the runoffs	Improving physical and spiritual health	Increasing the life of materials used in roof
3	Creating wildlife habitants	Urban agriculture, preparing food staff in the city (Sadeghi, 2014).	
4	Reducing noise pollution	Reducing the volume of wastes	
5	Reducing air pollution		

## 10. SHORTCOMINGS OF GREEN ROOF

In this section, it is attempted to enumerate the shortcomings of the green roof.

**Table 6** Shortcomings of green roof

Row	Title
1	Improving the roof structure
2	Comparative difficulty to design these roofs consistent with the climatic conditions
3	Requiring acceptable structural measures
4	Shortcomings that are created over time (Hancock, 2006)

## 11. GREEN WALL

Green wall or living wall is a type of wall that a part of it or whole parts have plant coverage. Condition-based green walls may be installed inside or outside the building. Also, there are different techniques and methods that can create green walls in different dimensions in order to creating space or façade. Also, green walls are known as living walls or biological walls. Green wall is a free wall that is relatively covered by plant coverage (Boroumand, 1991).

Green walls are magnificent. Their application in green buildings creates a wonderful perspective that despite environmental advantages, everybody can take advantage of them. Irrigation system of most of green walls is consisted of a frame, cells, and irrigation channels. Soil functions as a conductive material in the flower pots.

In this system, the plant moves on the surface of the façade. The climbing plant while has its roots in the grounds, moves upward. Recently, supportive structures are considered for green walls. In this condition, a simple structure is attached to the wall and functions as an anchor for climbing plants. Green surfaces can rely on façades, fences, and columns. Scaffolding structure of the green façade can be made by wood, metal, mesh, wire, and cable. Therefore, green facades are divided into two groups:

**Table 7** Different green walls

Row	Title	Description
1	Traditional green Façades	With direct green façades include climbing plants that grow directly without buffer. Such phenomenon is accompanied by damage to the materials, attracting animals, and maintenance costs.
2	Green shell of the living wall	They are attached to the wall using anchor to create a green coverage independent of the wall.
3	modular scaffolding	Metal scaffoldings are lighter than steel that are located on the building or have independent structures. Grid panels are together in modular form and can cover a large surface. These panels can be formed to create forms of interest.
4	Network structure	It is a very light structure that has created a buffer from steel networks for climbing plants that can be attached to the structure. Wire networks support the plants that show slow growth.
5	Cable systems	Cable system is used to maintain climbing plants with rapid growth. Cable systems are made by metal that can pass through cables and form the network of interest. Spigots are installed on the wall.
6	Felt green wall system	The design includes planting system in a way in which living plants are cultured on a vertical surface. This system includes a polymer felt that is located on the frame of the infrastructure, so that several plots will be created in upward fashion. The plant is located in the first pod and is cultured. This method is the latest method in this regard

		and has advantages compared to previous methods. The advantages of this system include light weight, easy substitution of plants, suitable ventilation, stronger drainage system, and freedom in selecting different plants (Ansari, 2006).
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## 12. CHARACTERISTICS OF THE GREEN WALL

Green walls are used in buildings as a buffer and their responsibilities are a follow:

- Separating internal and external spaces
- Prevention of heat transmission between spaces
- Prevention of sound transmission between spaces
- Resistance against strike
- Resistance against pressure
- Resistance against tensile
- Ability to bond to a variety of surfaces
- Ability to install different coverings such as tiles, stone, and wall-mount
- Ability to install windows and doors

## 13. USING GREEN SPACE IN DIFFERENT FLOORS

By studying the history of Iranian architecture, we will find that natural components have always been an important and respectable part in constructions. This tendency can be understood in the stated ideologies by famous architects such as Le Corbusier and Wright that all of these points are the effects of people’s needs on design pattern at macro level.

In designing open and semi-open private spaces and the environmental control as a dynamic component in façade, an additional space is created beside the residential spaces. This can be used as terrace or greenhouse.

## 14. THE ROLE OF VERTICAL GREEN WALLS IN URBAN LAYER

The general advantages of vertical green walls in urban layer that is related to the society and government are as follow:

- Creating beautiful urban perspectives
- Reducing heat islands in the cities
- Reducing noises in urban environments, absorbing sounds by plant coverage
- Reducing the negative effects of modern life in environment
- Increasing the air quality of urban environments (photosynthesis and oxygen production)
- Increasing the quality of water and modification of drinking water
- Increasing public health
- Creating biodiversity
- Creating environmental compatibility with changes in climate (Razavian et al. 2008)

**Table 8** Design considerations in vertical system

Row	Title	Description
1	Navigation	It is one of the most fundamental factors in selecting the type of plant coverage for living walls system
2	Selecting plant coverage	One of the most effective factors in efficiency of the system over time (Basgirzade, 2014).
3	Irrigation	Because irrigation is vertical, the design of mechanical system should be taken into consideration

4	Maintenance	Maintenance stages reduce the costs
5	Uniform design	It should be coordinated with other components of the building

## 15. CONCLUSION

The effect of sunlight in architecture, due to the formation of cities, cannot be ignored. In urban areas, temperature increases due to substituting natural plants for pavements, buildings, and other constructions that are necessary for population growth. In this phenomenon, the sunlight is changed to heat. Therefore, using plants in urban areas, buildings and their environments are cooled and reflective heat decreases and moisture increases. The advantages of plants in this regard are as follow:

- Improving natural cooling process
- Decreasing temperature in buildings
- Breaking the vertical flow of air and cools the air
- Expands shadow over the surfaces

Increase in temperature in modern urban environments is accompanied by increased number of cars, ventilations, industrial pollutions, nitrogen oxides, sulfur oxides, organic compounds, and carbon monoxide. The advantages of using plants in improving the quality of outdoor air of buildings are as follow:

- Reducing air pollutions and particles in the air by absorbing them on the leaves.
- Filtering toxic gases and particles.

The important point in development programs, especially sustainable development, is energy consumption crisis. In architecture and city, optimized consumption of energy is proposed. Therefore, using active and passive methods in energy consumption management is one of the solutions in this regard. One method is the use of green space in architecture that is effective in reducing temperature and surface evaporation of moisture. Different ways to use these living spaces in green architecture are investigated and some of operational solutions are as follow:

Green roofs, green walls, using living walls, using green space in floors and balcony or internal space.

The above factors lead to decreased pollution, decreased temperature, and increased moisture and finally provide a comfortable living space with reduced energy consumption to compensate temperature, moisture, and ventilation. Therefore, green space is highly recommended.

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