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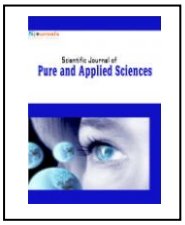

Original article

The investigation of the impacts of walls and green facades on the optimization of energy consumption in buildings and its role in a sustainable development

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ABSTRACT

In recent decades, artificial environments, compared to the natural spaces in urban areas, are expanding day by day. Following the same trend in Iran, apartment living frame without any natural space has changed. And it is while the need to nature is still alive in human beings. Moreover, all over the world due to major problems such as global warming, air and water pollution, excessive energy consumption and its high economic costs, utilizing technologies of sustainable architecture and specially creating green buildings has got great importance. In this regard, the use of green areas can be used as appropriate strategy in order to solve existing problems and creating sustainable architecture. In this paper with research method based on library studies and descriptive analytic approach, green walls, to improve the energy consumption efficiency in buildings, have been investigated. And also the role of these systems in visual aesthetics of urban area in line with the objectives of sustainable development is examined. It seems that using green walls as a way to reduce the energy consumption in buildings can be an effective option to advance the goals of sustainablearchitecture.

1. Introduction

Generally, the trend of population growth and the use of fossil resources and environmental pollutants make the life on the earth harder and harder each day, so that it forces us to find new solutions for fixing this problem. As a result of this, the human need for nature and environmental protection and establishing a sustainable relation with the environment and a design that can respond to these problems is increasingly felt every day.In this field, attempts have been made so far by different groups in the world which made this to become a movement. Architects as one of these groups are trying to find new ways to provide an optimal life for human beings like other groups. It is evident that the spaces designed by architects are effective on environmental, local and global conditions due to positive and destructive aspects, hence we can say that the work of architects in this field is particularly sensitive (Haghlessan, 2008: 101).In this regard, using methods such as facades and green walls can be very helpful in the reduction of destructive environmental impacts of buildings.Also, in regard with the impact of green walls on the reduction of energy waste in buildings, we can refer to four fundamental mechanisms:Preventing from direct confrontation of solar radiation due to the shadow formed by plants, thermal insulation, evaporative cooling by evaporation and preventing from wind direct confrontation. (Gabriel Perez et al, 2011:88).Primary researches on the role of plants in solar radiations controlling date back to 80s. Various uses of plants were selected in order to study the manner of sunlight reduction. The obtained results with the reduction of heat and improving the interior and exterior air of building were impressive (Hoyano, 1988: 11). Akbari et al showed that the two shading trees in both studied houses caused 30% savings in energy consumption for cooling in the hot season which is equal to daily saving of 3.6 and 4.8 n/a1 kW. (Akbari et al,1997:27).Another result of the studies indicates the fact that solar radiation in the space shaded by trees (W2/m2 100) is significantly lower than the space without shadow (W/m2 600) (Papadakis et al, 2001:33).Also, 5%-30% of the direct sunlight is returned by the leaves of plants, 5%-20% is absorbed for photosynthesis operation, 10%-50% is converted to heat, 20%-40% is for evaporation and 5%-30% passes through the leaves (Krusche et al, 1982).Green wall by avoiding the direct hit of sunlight, causes the formation of a system for temperature reduction in hot weather, secondly green façade reduces the surrounding temperature by evaporation (Wong et al, 2009:41).The results of Kohler experiments on traditional green walls (2007-2008) indicate that the severity of shadow impact caused by the plant depends on its leaves density. Ivy is one of the plant species that has the greatest impact on temperature reduction (Kohler, 2008:11).In an experimental approach conducted by Cheng, the effect of vegetation on thermal performance of green walls which is a Turf Based Vertical Planningindicates that a trellis reduces interior temperature and causes a delay in the passage of sunlight and thus leads to energy consumption reduction and air conditioning. Temperature drop is quite evident near the space planting (Cheng et al, 2010:45).

2. The history of using green surfaces

In cold regions with high and heavy wind blowing, the creation of walls and fences of green plants, hedges and hedgerows, shemshad walls and rows of foliage trees as a protective layer has been a conventional work for a long time.

In Mediterranean countries, green facades have been formed a part of the natural climate control system of buildings from antiquity. The use of stems, developments of climbing plants and fruit trees is also an ancient trick, because the heat stored in the back wall will help the plants grow. The buildings covered by plants are the symbol of building harmony with nature. Facades crusted with plant which have been created by garden city movement in the late 19th century, can be considered as the first environmental reactions against industrialization. (Doroodian, 2009:48)

The French botanist and artist, Patrick Blanc, is the inventor of the green wall. He is the one who brought vertical gardens to the dry environment of mechanical cities and could create such an attractive harmony between plant, brick and cement facade of city buildings. His vertical gardens can be spread in any manner and in any environment. They can be grown in an interior space, exterior façade and any type of weather. He selects plants on the basis of compatibility, their growth potential and their dependence on light and converts walls to a standing garden by the help of them. In fact, Patrick Blanc has demonstrated that we can create the most beautiful human landscapes by an inspiration from nature. His green walls tell us that we should not necessarily fight with nature and change everything in our favor in order to have a healthy, happy and growing life. This is actually the shortest and the worst path that does not lead to any beautiful spot (FarmahinFarahani, 2010:84).

What is new about modern using of vegetated walls is the issue of background texture. Today, not only the facades of private and villa houses are covered with plants, but also it is used in the construction of museums, office buildings, commercial buildings, luxury hotels, restaurants, agencies and even official and governmental buildings facades. However, the international spread of using plants on facades and also its organization and institutionalization is considered a new activity. Today, vegetated facades are particularly more prevalent in big cities of America, Asia and Australia where the issue of hot weather is more critical compared to Europe's cities (Doroodian, 2009:48).

3. The green wall, introduction and advantage

The term "green wall" or "vertical gardens" is a global term that is a living coating system with the benefits of green roofs. Suitable plants include a wide range of perennial and annual plants and trellises and various trees.(alstmaprrepr_001.cfm.)Green wall is a modern technology that today has slowly found its place in metropolitan cities of the world. Green wall is said to be a wall that is covered with vegetation as an independent structure or part of a building (RahimiMeshkin&Khosravimehr, 2011:6). A living green wall is a vertical rearing of plants and other elements that naturally removes toxic materials and unsanitary and harmful pollutants from the environment. In other words, green wall helps to purify the environment. Most of living green walls are for indoors, but also can be used outside the building. The building of green facades is of fewer structural limitations compared to green roofs, in contrast their plant diversity is low. Where the possibility of developing horizontal green surfaces is limited or impossible in urban spaces, vertical green spaces can have the same ecological efficiency for softening unsuitable environmental conditions. (Image 1) represents the role of green wall in creating a sustainable environment based on key factors such as the improvement of energy efficiency, protection of building, improvement of environmental quality, reduction of the effects of urban heat island and creation of optimal visual qualities.

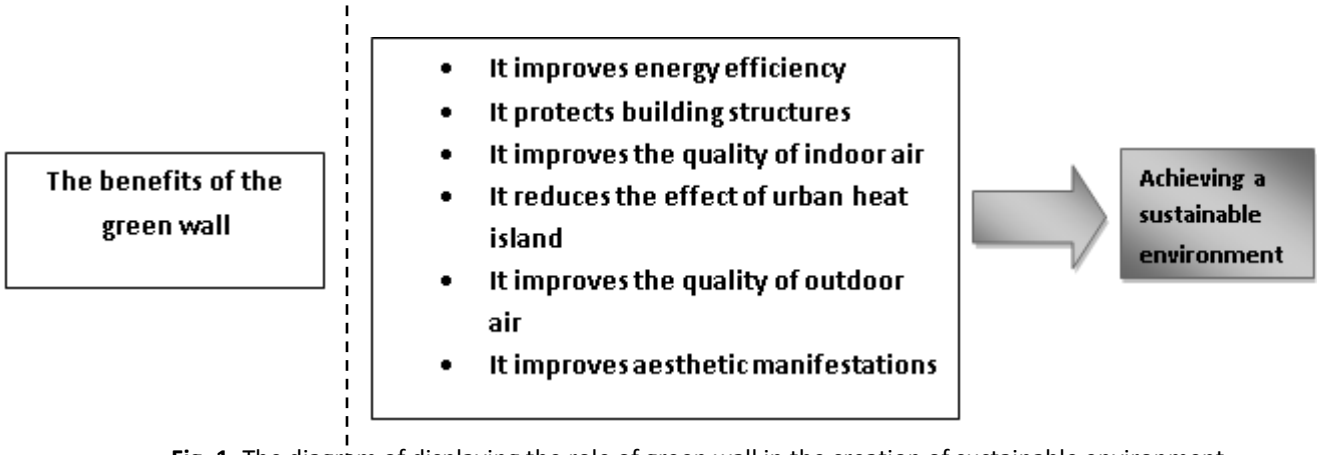


Fig. 1. The diagram of displaying the role of green wall in the creation of sustainable environment.

4. Different kinds of living surfaces

4.1. Separate and individual planting (Green facade)

Green façade is a kind of green wall in which a simple structure is simply attached to the building wall like a trellis and acts as an staddle for creeping and climbing plants like Vine, Ivy etc. Green facades can lean on building façade, railing and pillars or to be built as an independent structure. The structure of green façade trellis can be made of different materials such as wood, metal, mesh network, cable wires etc. In this kind of green wall all types of climbers are planted at the foot of the wall and in the ground, but if this is not possible they will be planted in pots and are directed upwards by a trellis mounted on the wall. In its more complex form, plants can also be repeated at the flower boxes in distances between balconies and roofs and on building facades. (Image 2)

Fig. 2. Examples of traditional climbing plants on the building façade.

So, as a result the following classification can be provided for it:

- Sticky and climbing plants that on the creeping wall or wrap around a size and twist and almost do not need any support structure.
- Intrusive plants which penetrate into anywhere in the wall or hook up to it and for their protection all types of wires and thin pliable tube, trellis and similar items is used.
- The plants on balconies that in this method plants and flowers are grown simply in containers and mounted on balconies, shelf and the like.

4.2. Environment-interested wall, living wall

Living walls are the combination of panels with pre-planted vegetation which are mounted vertically with a distance to building facade by a light structure system or are independently self-standing. These walls consist of modular frames with a special irrigation system which are often made of polypropylene plastic containers and have a modest growth. These frames are often self-sustaining and can be set up independently and without joining the main wall. Then they will be filled with soil or feeding materials and later with plants. Its components require minimal repair in their sites only once. Living alls can also be used in interior spaces of buildings. Living walls have different operational details depending on their manufacturer, the kind of plates and their inner or outer types. Living wall is considered a more complex and costly system compared to green façade and requires more protection in terms of irrigation and supply of additive nutrients for plants. Among the advantages of living walls we can refer to the diversity of its plants. The other advantage of living walls due to their vegetation and pre-planted plants is that they will achieve the desired results concerning the final growth of plants faster in terms of time. Living walls are themselves divided into the following (Fig. 3):

Fig. 3. Living wall.

4.3. Passive living walls

Passive living walls are made of modular square or rectangle panels which provide the planting medium vertically and protect plant components. These modular panels are attached with a distance to building façade or its structure by a light structure system. The operational details of panels are different depending on their manufacturer and are made of different materials such as plastic, polystyrene, polypropylene, clay, metal (steel, aluminum), industrial textile (a kind of felt) or light concrete. In order to make the system of living walls much lighter, hydroponic and semi-hydroponic planting systems are commonly used and in most cases, the planting bed has only the role of plant preservative and nutrients will be available to plants by irrigation system. The planting bed is selected according to the type of plant and system operational details associated with the depth intended for planting bed and generally a combination of (organic substrates: peat moss, cocopeat, rice bran etc.) and (mineral substrates of perlite, stone wool, industrial catridge, volcanic rocks etc.) The irrigation system of living walls is usually a drip one. The living walls plants will be specially maintained for at least three months in the greenhouse after being planted in panels and before being mounted on facades. After the installation of panels between twelve to eighteen months is needed for the pre-grown space of the panels to be firm and strong. (Images 4 & 5) (Instructions for green walls implementation, 2011: 15-22)

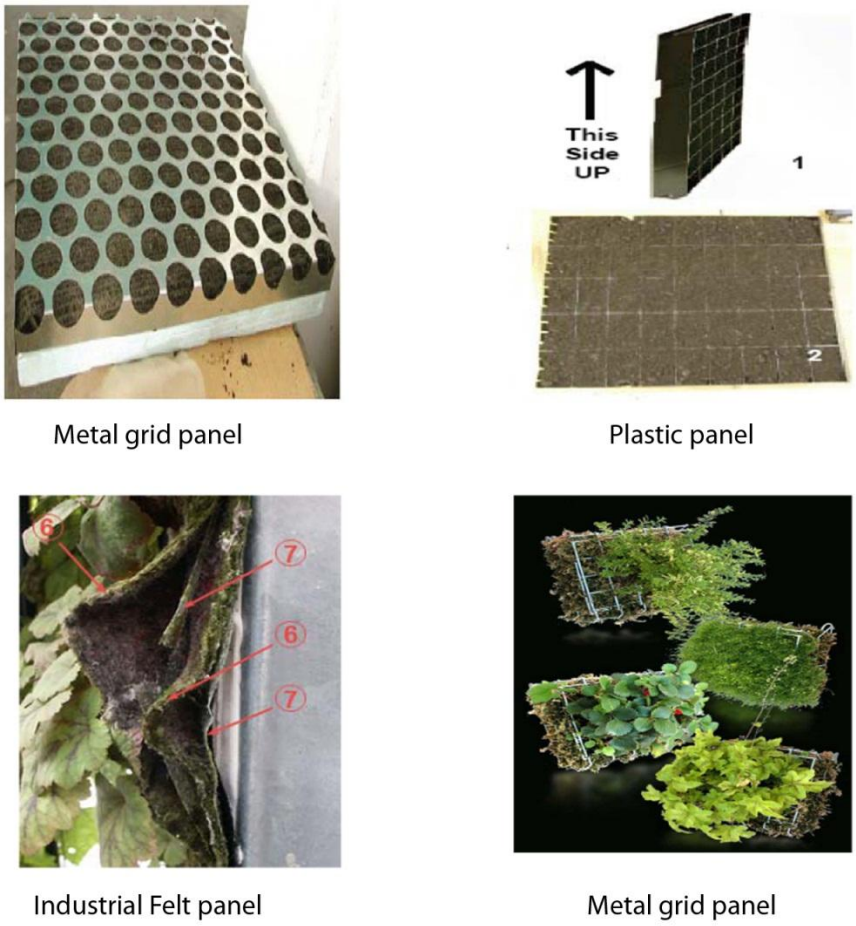


Fig. 4. The panels used in living wall.

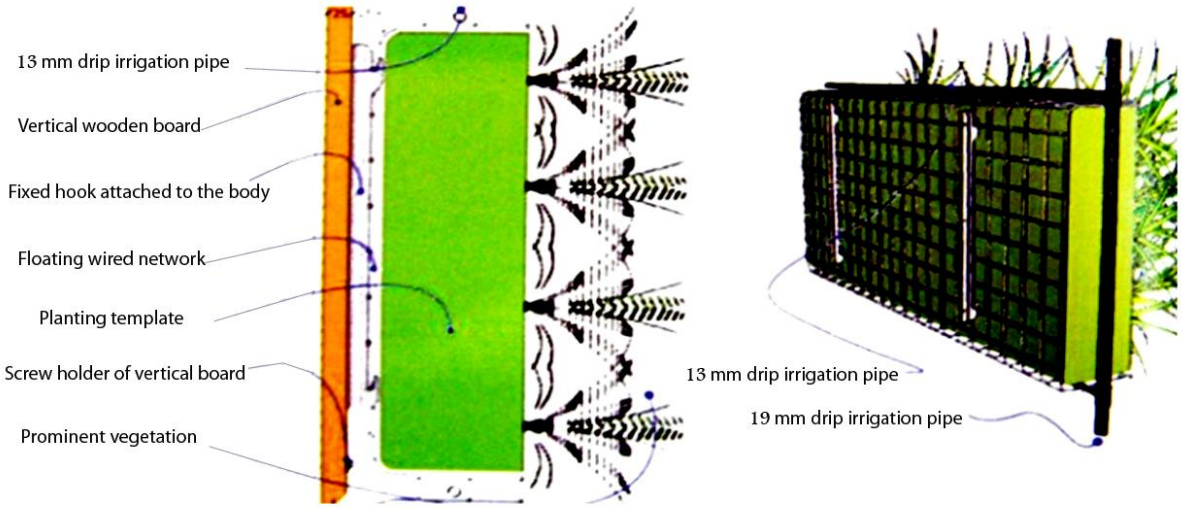


Fig. 5. The planting template and irrigation method of living wall.

4.4. Active living wall

The active living wall is one of the newest kinds of green walls designed by the integration of the building heating, cooling and ventilation plants in such a way to purify the indoor air and act ac heat regulator. Active living walls get their natural cleansing power through the air received from the lower part of the wall. Passive living walls do not have any air movements through the lower part of the wall.Some of the active walls are placed behind the glass in order to have a more regulated airflow compared to passive walls. Walls can be covered with moss or formed like a green wall by small plants.

This system gets help from the features of different suitable plants for air purification and removal of all types of suspended particles, pollutions and impurities in the air in order to create a healthy and sanitary climate in the interior spaces of building. A suction fan draws the air from the interior vegetated space to the inside and allows it to pass its bed after moving and mixing with these plants and pass the interior parts of system in order to create a clean, sanitary and pleasant air inside the building without using chemical purifiers. Car stands with their specific impurities such as oil and petrol, harmful gases, smoke and steam of oil and chemical products are certainly more likely to produce greater emissions compared to residential and office environments.

The dimensions of this purifier wall and its suction power along with other qualitative and quantitative features of this device with existed features and functions in the space, its various types of facilities and equipments, the amount of produced pollution, the number of people using the space depend on the required degree of cleanliness and purity in the desired atmosphere and the like. In a normal and average condition of residential and office spaces, the level ratio of “biofilter” to the area of available space should be about one percent in order to create an optimal condition. In other words, in a standard working condition one square meter of the biofilter wall surface is enough for an area of 100 square meters. Thus the required improvement is obtained in the internal environmental conditions.

The successful types of these walls are in the form of hydroponic (keeping in the nutrient solution) in such a manner that their denuded roots are kept wet and watered with nutrient solutions. Felt keeps a significant amount of water and allows the plant to remain constantly wet. In this system, the air produced by plants is used in the air conditioning system of building. Plant foliage absorb monoxide and carbon dioxide, remove the root’s microorganisms, organic compounds and particles suspended in the air and the natural process of plants produces fresh air which is drawn into the system by a ventilator and then distributed inside the building. In this system the plant’s root is placed between the two layers of industrial textile and the planting system is hydroponic and their feeding is done by water enriched with nutrients. (Image 6)

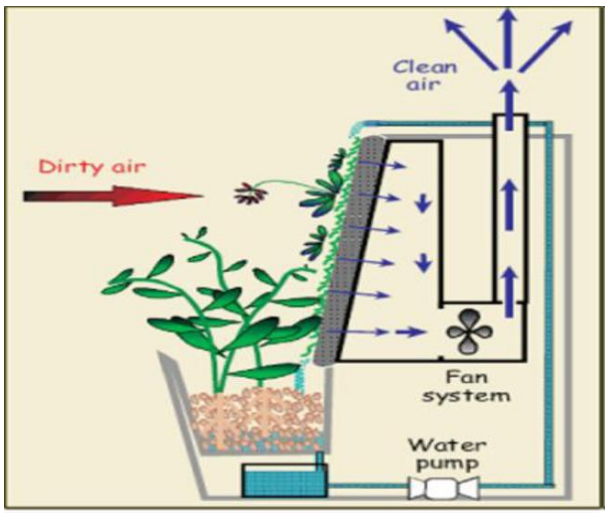


Fig. 6. The function of active living wall.

4.5. The vegetated wall of water cultivation «patrick blanc»

An individual named Patrick Blanc found for the first time that if the water reaches the plants' roots contains the necessary nutritional elements in the composition and specified ratio and certain crucial elements, it will no longer need soil for the continuation of its growth. By the study of tropical rain forests, he founded his special pattern of vertical gardening on «water cultivation» techniques among which we can mention a planting method without soil.

«Patrick Blanc» considers himself more as an artist and botanist rather than a programmer and technical designer, his designs of planting all kinds of flowers and plants and combining them together in a proper order are similar to natural patterns, environment-interested motifs and carpet designs and the distribution of form, color, texture and required conditions for optimal growth of selected species and their proper juxtaposition has been done. The implementation and cultivation of plants is given to occupational companies and programmers. (Image 7)

Fig. 7. Brownell Museum, Paris, Living wall, Patrick Blanc.

4.6. The structure of patrick blanc vegetated wall

This structure consists of the following:

- The external wall with waterproof construction sealants.
- A stainless support structure of feeding and irrigation system of cultivated plants (for example stainless steel) that can perform conditioning by creating necessary distance.
- A stainless expanded PVC board in 10 mm thickness as the bed.
- Two 3 mm layers of felt with the combination of 3 mm thick polyamide resins as the work context.
- Selected plants in felt packages.

Roots grow radially among their protective felt bags, they can grow to the size of six meters after a few years and continue to be held by the protective structure.

The irrigation and feeding of plants is done by polypropylene horizontal pipes which are mounted on the external layer and on top of the felt. In winter, this system continuously does the irrigation act 2 to 3 times per minute and in summer 5 to 6 times. When the temperature reaches below one degree Celsius the liquid production stops automatically.

This kind of wall is a combination of two industrial textile layers (a kind of felt) and plants' roots are kept between the two mentioned layers.

Due to the high volume of system's moisture a thin stainless PVC layer is placed adjacent to the wall of building. These layers are maintained by some frames and food products are distributed through irrigation system from top to bottom. The vegetated walls of Patrick Blanc are considered artworks and by putting together the colors, sizes and textures of different plants and the use of appropriate light engineering he creates a kind of living painting.

4.7. Decorative surfaces with planting inside the wall surface

The indoor vegetated walls can be found abundantly in shops and restaurants. These walls some of which are specifically for indoor spaces can lead to the improvement of indoor air condition and an air conditioning in a decorative manner or with a remarkable effect.

In conditions of decorative use, single or isolated plants are usually preferred to a combined and group use. These plants with decorative elements and forms accompanied by a variety of lights and ornamental lamps will be of more visual impact, meanwhile due to the exposure in the indoor space of building they need adequate light for the growth, food processing and photosynthesis operation and a facing lighting must be done by installing special floodlights or the necessary light should be provided through a window, wall or roof skylights either directly or indirectly. The design of this system has created some dents and pores with decorative forms in the main wall or a mounted fake wall and the plants are grown inside of these chambers. These walls which are of various and desired decorative forms are adorned with suitable plants in different sizes, ranging from herbaceous, annual and spices plants to perennial shrubs and bushes which have several short stems and emit a slight scent in space.

Fig. 8. Indoor vegetated wall.

5- The function of vertical green systems regarding energy consumption reduction

In urban spaces, the evaporative and shading effect of plants can significantly reduce the ambient temperature. Furthermore, plants can reduce the damaging effects of the sun's ultraviolet on the body of buildings. From since it was proven that solar ultraviolet radiations cause damages to building facades, plastic components and their color, green facades can play a role in the reduction of related detrimental effects as an effective solution. (MaecOttele et al, 2011:43).

Green facades have the capability of making big changes (moisture and temperature) in the space between the wall and green façade. The air between this has the ability to create an effective thermal insulation. The air recirculation and ventilation in the space between, leaves density and the manner of designing are among the factors that increase the efficiency (Gabriel Perez et al, 2011:88).

The vertical green system of buildings prevents the direct confrontation of wind to the façade as a deterrent. A computer simulation conducted by McPherson in 1988 for testing the impact of radiation density and wind speed reduction with regard to vegetation on the energy performance with similar resistance in four cities of America despite the existence of four different climates, indicates that the vertical green system design for cold weather should reduce winter winds and provide the access to sunlight for southern and eastern walls. In temperate climates, it is of importance that the summer wind is not blocked by the green wall. In hot climates, the tall shading trees and also short vegetation must be used to increase wind and shading (McPherson et al, 1988:12).

One of the strategies to increase energy efficiency is the blocking of wind. In winter, the cold wind has a major role in reducing the indoor temperature. In buildings insulated against the cold, the wind reduces the efficiency of insulation. Dinsdale has showed that the building through plants (green walls and roofs) reduces the demand for heat energy to 25% against cold winds (Dinsdale, 2006).

The use of vertical green systems with a good management and design can serve as a helpful tool to regulate the heat inside the building.

Generally, in an evaluation of vertical green systems as passive systems of energy saving in buildings, the following aspects should be considered: building system, plant type, maintenance and functions which affect the behavior of green façade as a passive system. (Perez et al, 2011:25).

There are some parameters that affect the behavior of green facades as a passive system. There are essentially four basic mechanisms that vertical green systems employ for preventing energy waste as passive systems:

1- Preventing direct sunlight with the effect of generated shadow by means of green vegetation.

2- The generated thermal insulation by green vegetation and its substrate.

3- Evaporative cooling that occurs by evaporation from plants and their substrate.

4- The reduction of wind effects (Perez et al, 2011:52).

Table 1

The function of green facades in the reduction of energy consumption as a passive system.

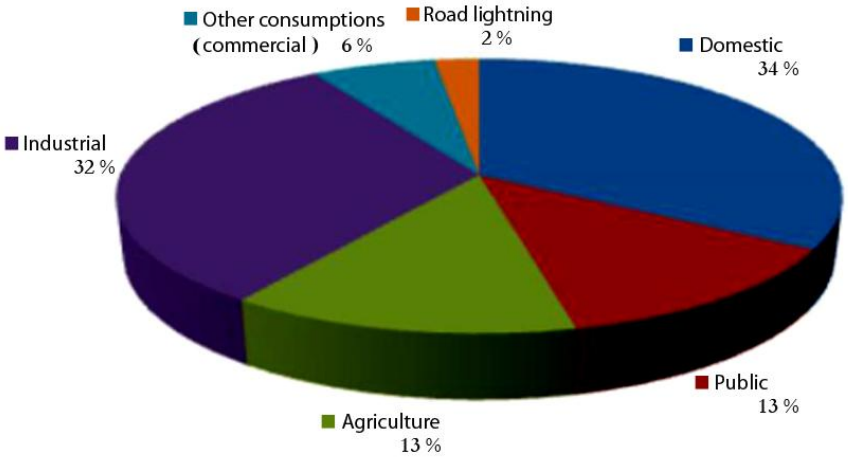
Preventing from direct sunlight	Thermal insulation	Evaporative cooling	Reduction of wind effect
Density of leaves (the number of substrates)	Density of leaves (the number of substrates)	The example of a plant used in (dry/wet) climates	Density of leaves (the number of substrates)
	Making changes in the air between wall and vegetation layer	Wind speed	Façade orientation
	The ability to avoid wind hits	moisture	Wind direction and speed
	The existence of substrates, diameter and density of bulk, moisture		

By embedding a support structure for climbing plants, a space is created between green facade and building wall and the air between them acts as insulation and reduces temperature fluctuations. As a result, the cost of heating and air conditioning of building is considerably reduced (Introduction to Green Walls technology, 2008).

By investigating the statistics related to the annual energy consumption in different parts of Iran, it can be seen that nearly 34% of the total annual energy consumption is spent in buildings (image 9) and since this part of energy consumption does not have a productive role like industry and agriculture, any strategy and approach, even a long-term one which can reduce energy consumption in this part will effectively help to achieve sustainable development. The energy consumption in buildings is spent on the establishment of a proper heating condition in cold seasons and sufficient cryogenic load for creating comfort conditions in hot seasons.

Fig. 9. A comparative diagram of annual energy consumption percentage in different parts of Iran.

Scientific studies conducted by McPherson et al indicate that the use of green facades with proper design will



increase thermal energy maintenance in seasons to 20%. Therefore, the same amount of energy consumption reduction used in heating is achieved (McPherson et al, 1989:129-138).

Regarding its impact on the improvement of cooling comfort conditions in hot seasons of the year, calculations and surveys conducted by Cantuaria have shown 50% of electrical energy cost reduction related to equipments and installations of building ventilation (Image 10) and the most important reason for this reduction of energy consumption is that the temperature of materials used in buildings with green facades as mentioned before is much lower than ordinary buildings without any protective vegetation. (Cantuaria, G, 1995).

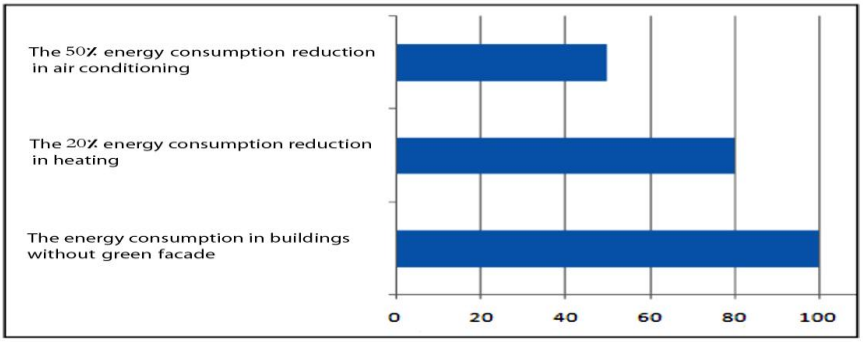


Fig. 10. The rate of energy consumption reduction of buildings in heating plants and air conditioning section base on energy consumption unit

6. The relation between sustainable development elements and green surfaces

The sustainable development is of three pillars of environmental, economic and social sustainability.

Economic sustainability: economic sustainability means to maintain and improve the current economic situation without any damages to natural resources which in this regard economic activities should lead to the growth of community accompanied with justice and efficiency.

6.1. Energy consumption reduction

green facades and walls reduce energy exchange of buildings, for instance in a hot weather when the temperature reaches 95 degrees Fahrenheit, the roof temperature will reach 175 degrees Fahrenheit. Due to this high temperature in indoor and outdoor space of building, more ventilation is used for cooling it that leads to higher energy consumption. Plants convert the temperature and moisture of soil into moisture through evaporation and this process will lead to building cooling. The cooling of indoors reduces heat reflection. In cold climates, the speed of heat loss depends on moisture content of substrates. Regarding the fact that major parts of our country are hot and dry regions, the energy efficiency of these surfaces are of particular importance. (KeshtkarGhalati et al, 2010:21)

Also, in regard with green facades in the field of energy and economy we will see the following positive effects:

6.2. Insulating and reducing wind chill of winter

the energy consumption of indoors is one of the most important achievements of green systems. The office building of Consorcio in Santiago is one of the most important environmentally friendly office complexes in the world which consumes over 48% lower energy as a result of using plants in its outer wall (Yadegari, 2010:55)

6-3. Floods reduction

green roofs and facades can also reduce or eliminate flood-related plumbing, especially in regions with combined flood plumbing and sanitary sewage pipe they will help to reduce the system overload and overflow of raw sewage into nearby waters.

6.4. Ecology, biodiversity and environment

the most important instrumental effect of green roofs and walls is that they are used in metropolitan centers. The green surfaces are predictable solutions for handling emergency ecological problems in city centers.

6.5. Using recycled materials

6.6. Aestheticism

6.7. Providing welfare (Doroodian, 2009)

Social sustainability: human and human communities are the main center of sustainable development. As it was said, the objective of sustainable development is the comprehensive development and a comprehensive development is not possible without social development. In social development the emphasis is on goals such as cultural identity, social solidarity, organizational development, citizen participation, empowerment of individuals and the possibility of social mobility. So in general we can say that the goal of sustainable development is the achievement of a dynamic and steady community and it will not be possible except with environmental protection. The establishment of green facades and roofs creates job opportunities. The creation of green facades in squares and public spaces creates a suitable visual beauty as well as affecting the growth and vitality of urban spaces by creating public spaces and making proper urban spaces pleasant. Also concerning the public green roofs, there will be a possibility of culture and information exchange between the residents of building. Children can play on green roofs, adults can exercise and the elderly can rest in its green corners and flowerbeds and if we think more, we'll find that roofs can be additionally used in addition to entertainments like excursion, reading and pastimes.

Environmental sustainability: environmental sustainability focuses on reducing the use of natural resources and nonrenewable energies, prevention from waste of energy resources, reducing waste production and emphasis on their reuse and recycle, the use of returnable materials to nature and reducing contaminations in industry and agriculture. In reaching the objectives of sustainable development, environmental sustainability is of great

importance in relation to architecture and environmental issues which have been threatening human future forced architects to seek for a solution (KeshtkarGhalati et al, 2010:22)

In short, we can say that the principles of sustainable development include the following: attention to the use of renewable resources like the energy of sun and wind, less use of nonrenewable resources and pollutants like fossil fuels, attention to future generation, attention to environment and reducing pollution according to these principles. Architects and urban planners have attempted to define sustainable architecture and urbanism and in this regard many definitions of sustainable architecture and urbanism were made in most of which attention to urban environment, creation of healthy and ecologic cities and less pollution in cities were of particular importance. A city will be healthy when its considerable space is devoted to parks and green spaces and environment, air cleanliness, ecosystems and biological cycles of other creatures are of importance there.

Creating parks and vast green spaces in cities maintains cleanliness as well as adding beauty and freshness to them and also provides the background for living all kinds of environmental creatures in city.

Urban ecology: cities are often a barrier to greenery and nature; green facades improve the air quality and provide a place for the return of animal life to city. The weather inside big cities is usually hot and dry and limited trees of the city cannot provide enough water for the city in order to keep it cool and fresh. The air quality is important in both internal and external environment. The air quality of outdoor is provided by the suitable temperature of vegetations (roof, facade).

Reduction of dust particles and smoke: vegetations refine dust particles and dangerous materials. These roofs improve microclimate by cooling and moisturizing the ambient air.

Reduction of noise pollution: green surfaces absorb sounds instead of reflecting it and insulate buildings against noise pollution. For instance, green roofs insulate buildings against sounds to 8 dB. For greater use of this advantage the selected site should be a place near a highway.

Natural habitats for animals and birds: green surfaces can provide to some extent the natural habitats that have been destroyed by hard coatings of buildings. Selecting the types of animals should be done on the basis of our culture, this was performed in an Iranian garden where according to the selection of plants type vermin got away and favorite insects and birds were attracted to garden. (KeshtkarGhalati et al, 2010:23).

The use of recyclable materials with high quality: in vegetations (roof and façade) brick, clay, plant and soil are suitable for roof's bed and rubber, polyethylene and polyester are suitable for drainage.

The costs of roof and green façades design and implementations should not be compared with the costs of an ordinary roof or façade; rather this comparison should be made based on skyrocketing costs resulted from the pollution of water, weather and environment, illnesses and deaths caused by these pollutions, individual and social harm caused by the lack of green space in the built environment. Heavy costs of using fossil fuels that are nearly over, deep psychological effects caused by the lack of beauty and aridity of cities, problems caused by floods, control costs of surface waters, insulating costs and multiple implementation of traditional black roofs should also be added to above costs. (KeshtkarGhalati et al, 2010:24).

7- Conclusion: in this article, different kinds of vertical green systems and their efficiency have been examined and any of them has a unique system and structure. The study and investigation of each system as an active or passive one is necessary for the increase of building efficiency.

Green walls are generally divided into three categories: traditional green walls such as Ivy which is a climber and uses the wall as a support structure, double-skin green facades or green curtain which are implemented apart from the wall and with a structural support with the aim of forming a green buffer and finally environment-interested or oxygen maker walls that act as a biological air purifier.

Taking advantage of green walls as a passive system leads to the beauty and adornment of environment and also can have a major role in the reduction of building energy consumption. This system increases the energy efficiency of building interior spaces by preventing direct sunlight in summers and reducing wind effects in winters. Furthermore, the thermal insulation produced in the space between the green buffer and building wall and also evaporative cooling by evaporation reduce energy waste. Taking advantage of green walls as a technique for energy consumption reduction of buildings can be an effective option to promote sustainable development objectives in large metropolises.

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