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A study of the place of Nanotechnology in Green roof design for Reducing Energy Consumption

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Abstract

Today, our major concern is that by an everyday increase in energy consumption and with all the limitations in energy resources, we will facenot only the problems of polluting our natural environment and wasting our national resources, but also the problem of endangering the future life of human kind. In Iran, like in other countries, the annual consumptionincrease of different types of energy has made energy consumption management and raising energy efficiency national necessities. To be able to solve the energy and natural environment crisis and decrease energy wastage, we need to change our construction methods. In this respect, different components of a building each can act effectively in satisfying the structure's self-sufficiency. Regarding the wideness of the roof compared to other external components of a building, studying its thermal performance is an important step in finding proper solutions for reducing the building heat wastage and decreasing energy consumption as a result. One strategy is building green roofs. Designed and implemented properly, a green roof can largely reduce energy consumption among other various advantages. Nanotechnology can be a great help when making this type of roof and can greatly affect the energy consumption reduction. The aim of this paper is to study how effective the roof and specially the green roof can be in reducing energy consumption. It also intends to propose new strategies in designing and implementing green roofs using Nanotechnology in order to reduce energy consumption.

Keywords: Nanotechnology, green roof, green architecture, energy, heat transfer.

Introduction

The physical expansion of cities has resulted in natural environment and green space destruction. On the other hand, developing such green space can play an important role in human life and can replace the missing natural environment. Therefore, making green roofs can be a solution to environmental problems that are a result of lack city green space, green space development, and stabilizing city environment.

A roof is part of a building that protects other building parts. However, this is not its only job; it also can play an important role in efficiently using limited energy resources by affecting the heating, cooling, air conditioning and lighting of constructions, although the main approach in designing roofs is regarding their protective role and reasonable cost. Green roof is a light weighted engineered system that enables plants to grow on a building roof and protects the roof[1].

Nanotechnology enables us to create new building materials with modern characteristics. Such materials could last more and have higher functionality and efficiency. Most importantly, the majority of suppositions on environmental stability, smart materials and structures and multi-functional materials could be realized through this technology.

The application of nanotechnology in architecture encompasses a wide range of materials and equipment and its purpose is to realize the theories. The areas in which nanotechnology can improve construction conditions are: building materials enhancement, damage prevention, weight and volume reduction of building materials, reduction of production stages, efficient usage of materials, and reduction of maintenance and maintenance cost. The result would be a reduction in the usage of raw materials and energy. It would also result in a reduction in CO_2, saving natural resources, more dynamic economics and therefore more peace and comfort[2].

Material and Methods

The methodology of the research is descriptive-analytic, and the geographical domain of study is Iran. Data collection is conducted through observation and field work; some data have been gathered through documentary research method.The purpose of the present paper is to study the place of nanotechnology in building green roofs in order to reduce energy consumption using the above-mentioned methods.

Green roof: A green roof is a roof parts or all of which is covered with vegetation and soil, or vegetation medium. The term 'green roof' is sometimes used for roofs that observe 'green architecture' concepts like solar panels or photovoltaicplates. In fact, a green roof is a roof that plants can grow on it. Vegetation diversity on such a structure can range from an artificial grass covered roof to a roof garden with various plants. Here, we need plants that can resist water shortage, freezing, storms, and other harsh conditions on top of a roof. The types of plants chosen for this purpose depend on weather and climatic conditions[3].

Implementing green roofs is not much different in details from ordinary roofs and it includes applying humidity-thermal insulating material, waterproofing the roof, and using sand and seam-cover. However, in green roof projects we need special materials for humidity drainage and safekeeping of the plants according to predefined building standards. Creating green facades is another technology that has fewer structural limitations and less vegetation diversity compared to green roofs[4].

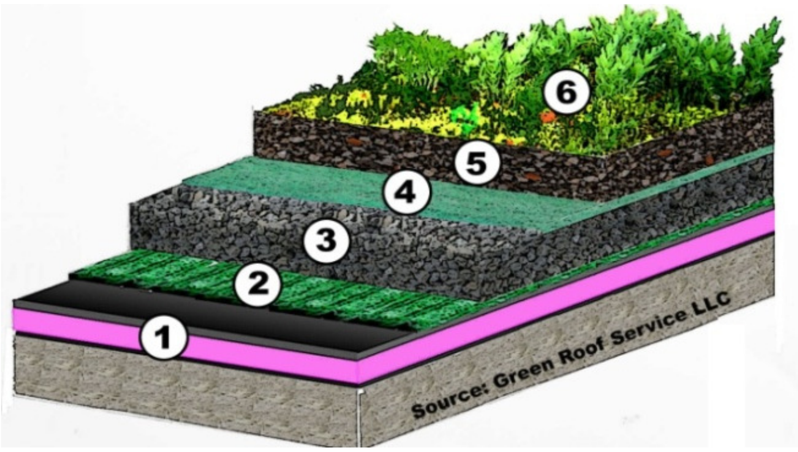
History of green roofs: The idea of creating gardens on the roof has first been suggested by Iranians 2500 years ago and applied on ziggurat roofs. The people of Babylonia also made green roofs in 600 B.C. They were green spaces on roofs and terraces. Nebuchadnezzar made these gardens for his wife who was a Median princess and missed the mountains and greenness of her homeland. He ordered making a huge extraordinary mountain. This mountain was actually a cubic building with 120 meters of height and five roofs each resting on columns. On them, they planted many grass, flowers, and fruit trees and watered them with water pumps. During renaissance in France and Italy special types of roof gardens were formed. These roof gardens were mostly made by governments and in public buildings. In 1600, a German made a small garden in his terrace. Such processes of converting terraces and roofs to gardens continued until 1875 in Germany and Russia. le Corbusier and Wright were naturalistic pioneers who created green roofs in 20^{th} century[5].

How to build green roofs: Making different roof gardens requires special planning and knowledge. Green roofs need technology beyond that of usual roof engineering systems. This technology must be able to consider the maintenance capabilities, control the weight of soil, rain, and snow, and embed sidewalks. A green roof is comprised of three parts[6]: The roof of the building, which is found on top of all buildings and is covered with a layer of insulating material like tarred gunny cloth, etc.; the insulating layer may itself be covered with mosaic, asphalt, or stone. Roof garden, which is a protective layer and separates the insulating layer and the soil and plants layer. Soil, fertilizer and watering system, each placed precisely as planned.

Different types of green roofs: Green roofs or roof gardens are divided into three main categories based on the implementation system, the average depth of cultivation (growing media), and the extent of required utilities[7]: The extensive system (figure 4), The intensive system (figure 5), The modular or planter box system (figure 6)

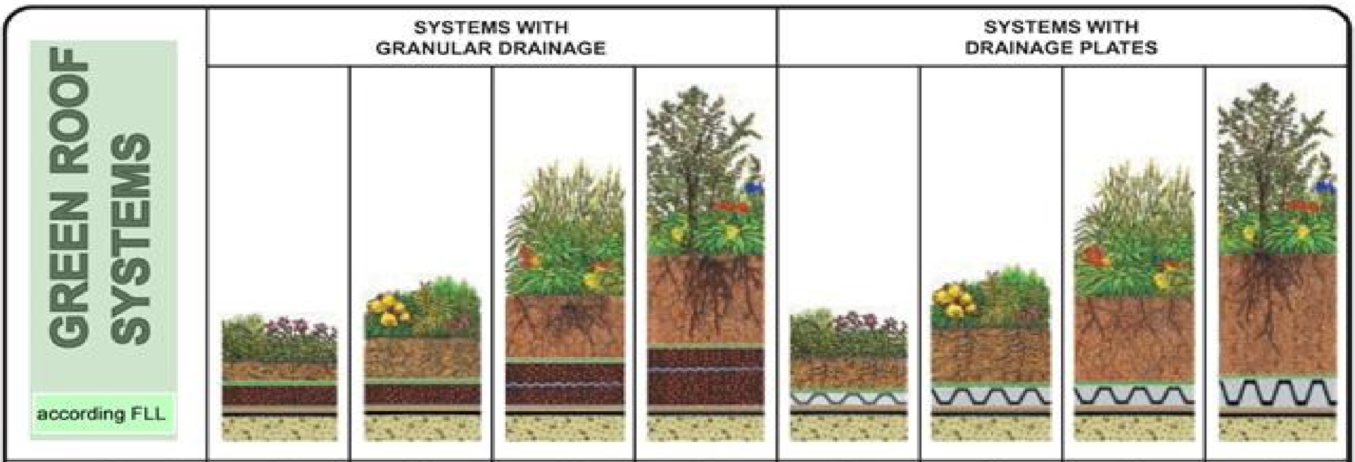
Energy consumption reduction in green roofs: Green roofs can balance the temperature and act as thermal insulating layers. Results show that an increase in temperature is observable during the cold months of the year. This means that a reduction in the heating load of the building during this period is more visible. The result is a reduction in energy consumption. However, these roofs do not affect the cooling load[8].

Figure-1
An instance of using plants of the roof



i. Roof deck, Insulation, Waterproofing
ii. Protection and Storage Layer
iii. Drainage and Capillarity Layer
iv. Root permeable Filter
v. Extensive Growing Met
vi. Plants, Vegetation

Figure -2
Functional layers of a typical extensive green roof



System Designation	**G1**	**G2**	**G3**	**G4**	**P1**	**P2**	**P3**	**P4**
Typical Plants	Sedum herbs	Sedum herbs perennials	Perennials grasses shrubs	Grasses shrubs trees	Sedum herbs	Sedum herbs perennials	Perennials grasses shrubs	Grasses shrubs trees
Extensive soil mix	2*	4*	-	-	3*	5-	-	-
Intensive soil mix	-	-	6*	9*	-	-	8*	12*
Separation fabric	1/8*	1/8*	1/8*	1/8*	1/8*	1/8*	1/8*	1/8*
Granular drainage	2*	2*	4*	6*	-	-	-	-
Drainage Plate	-	-	-	-	1*	1-1/2*	1-1/2*	2-1/2*
Protection mat	1/4*	1/4*	1/4*	1/4*	1/4*	1/4*	1/4*	1/4*
Nominal thickness	4*	6*	10*	15*	4*	7*	10*	15*
Dry Weight	19 lbs/ft^2	28 lbs/ft^2	45 lbs/ft^2	69 lbs/ft^2	14 lbs/ft^2	23 lbs/ft^2	34 lbs/ft^2	52 lbs/ft^2
Saturated Weight	26 lbs/ft^2	41 lbs/ft^2	70 lbs/ft^2	105 lbs/ft^2	23 lbs/ft^2	37 lbs/ft^2	57 lbs/ft^2	85 lbs/ft^2
Minimum slope	0:12	0:12	0:12	0:12	0:12	0:12	0:12	0:12
Maximum Slope	1:12	1:12	1:12	1:12	1:12	1:12	1:12	1:12
Water retention/Year	50%	60%	70%	80%	50%	60%	70%	80%
Irrigation System	-	-	Subsurface	Subsurface	-	-	Surface	Surface

Figure -3
Green roofs systems

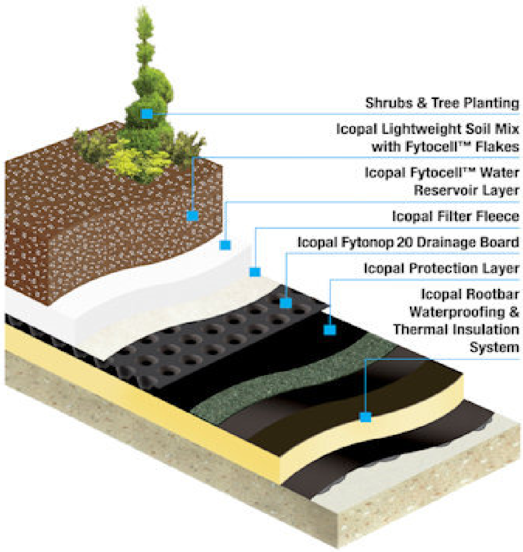


Figure-4
Details ofthe extensive system

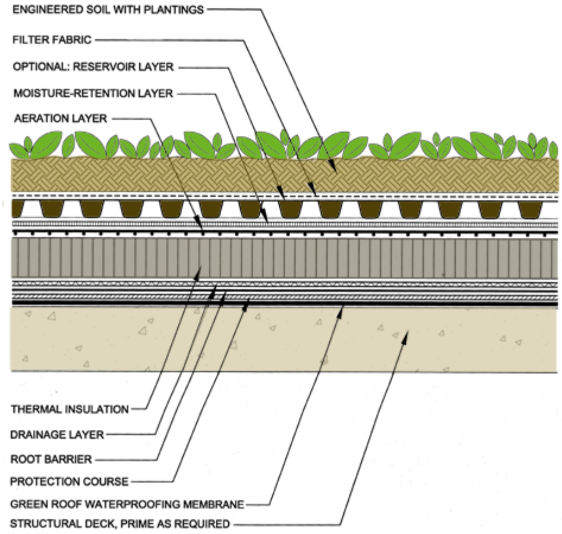


Figure-5
Details of the intensive system

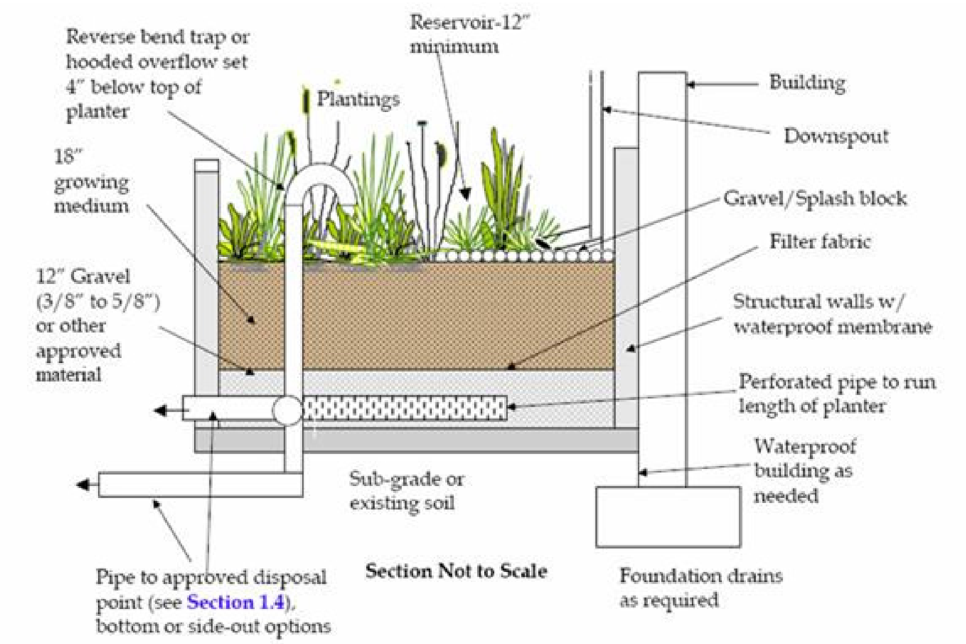


Figure-6
Details of the Planter Box system

Heat transfer reduction through saving the building's energy: Green roofs protect the building from direct sunlight. Therefore, they implicitly cool the building and reduce the amount of heat transferred. Heat always transfers from bodies and spaces of higher temperature to those of lower temperature. Thus, at buildings roofs the direction of heat transfer in winter is from inside to outside whereas in summer it is from outside to inside of the building. Green roofs help cooling a building in summer and keeping it warm in winter through reducing thermal fluctuations at the external surface of the roof and increasing the thermal tolerance of roof layers. Based on a study in University of Toronto, green roofs are adequately functional in keeping internal spaces warm in cold areas[9].

Plants could lessen the coldness of winter winds, adjust the mini climate of roof top space, and thus help keeping the heat of the building. It is worth mentioning that the impact of mitigating the action of the wind is more considerable than that of casting shadows. Vegetation prevents the planting environment from freezing in winter and this makes the roof more insulated.

Nevertheless, if in dense green roofs, the vegetation freezes, or is covered by snow, this would serve as an edge for the building to keep its internal energy in winter.

Studies about the temperature of the space under ordinary roofs and under green roofs in summer and in winter, carried out in Nottingham University and Trent University in Peterborough in Canada, indicate the influence of green roofs in heat transfer reduction[10] (tables-1 and 2)

Table-1
Nottingham University studies about the temperature of the space under ordinary roofs and green roofs in summer

Average temperature / daytime temperature	18.4 degrees centigrade
The temperature of the space under ordinary roofs	32 degrees centigrade
The temperature of the space under green roofs	17.1 degrees centigrade

Table-2
Nottingham University studies about the temperature of the space under ordinary roofs and green roofs in winter

Average temperature / daytime temperature	0 degrees centigrade
The temperature of the space under ordinary roofs	0/2 degrees centigrade
The temperature of the space under green roofs	4/7 degrees centigrade

Accordingly, the following reduce heat transfer and hence energy consumption in green roofs:

Increasing the thermal tolerance of the roof: There is less energy wastage from inside to outside space during winter and less heat transfer from outside to inside of the building during summer. In green roofs, this is achieved through more roof layers and thus more thermal tolerance of the roof. Green roofs have a great impact on cooling the space under the roof and during winter, they keep the heat inside the building.

Retaining humidity: Live vegetation plays an important role in balancing the building temperature by retaining humidity. Water, as a thermal substance, prevents temperature fluctuations. This can cool the building in summer and keep it relatively warm in winter.

Plant photosynthesis (reducing sunlight absorption): Reactions taken place in soil, like supplying and propagation, and photosynthesis and transpiration of plants, reduce the amount of solar energy absorbed by the roof; as a result, the temperature of the space under these roofs decreases during summer.

In thermal sense, green roofs are functional in winter as well. Plants constantly keep some air between their roots, which acts as a thermal layer. However, the functionality of this layer depends on the amount of humidity retained[11].

Table-3
How green roof reduces energy consumption

	The effective factor	Explanation
1	Humidity insulating layer	Protects against ultra violet and chemical harms and act as an insulating material against heat. This characteristic of green roofs extends the life of humidity insulating layer up to 2 times and reduces the costs.
2	Noise pollution reduction	The insulating that green roofs offer reduces noise pollution.
3	Thermal insulating layer	Prevents the heat and the cool air from going out of the building in winter and in summer respectively.
4	Electricity utilization decrease	Saves power up to 10 percent in multi-story and 20 to 30 percent in one-story buildings.
5	Roof life span increase	It increases the roof life span at least 2 times and in most cases up to 3 times the original. In fact, it protects the roof against ultra-violate radiations.
6	Reducing the negative effects of water flow	The annual balance sheet shows that it reduces the total amount of rainwater flow 50 to 90 percent. In fact, it keeps the rainwater in itself and little by little sends it to wells.
7	Roof temperature reduction	It reduces the roof temperature from 60 degrees to 25 degrees centigrade.

Nanotechnology: Nanotechnology is the ability to create, manipulate, and use matter on nanometer (atomic, molecular, and supramolecular) scale. Particle dimensions are very important in nanotechnology because at Nano scale, material dimensions are very influential in its characteristics. Physical, chemical, and biochemical characteristics of atoms and molecules are different from those of material mass. These dimensions are different in different materials; however, something is a Nano material if at least one of its dimensions is less than 100 Nanometers.

Nanotechnology reduces our need for rare materials and by reducing the polluters provides a healthier natural environment. As an example, studies show that in 10 to 15 years, nanotechnology will decrease the global energy consumption up to 10 percent, which will result in saving 100 billion dollars a year and reducing air pollution to the extent of 200 million tons of carbon. As we know, although 70 percent of earth surface is covered by water, only less than 3 percent of it is fresh water. Icebergs comprise 79 and underground water comprises 20 percent of this fresh water. Lakes and wells comprise only one percent of drinkable water on earth that is easily accessible.

Nanotechnology influences many sections of water technology like dam construction, water pipe protection, water and effluent purification and water desalination[12].

History of nanotechnology: In 400 B. C. the Greek philosopher, Democritus, first used the term 'atom' – meaning undividable in Greek –for the constructing particles (building blocks) of different materials. In this respect, we can call him father of Nano technology and sciences. Nano is the Greek root of Nanus meaning dwarf. Nanotechnology – the fourth movement in industrial revolution – is a significant phenomenon that has influenced every scientific branch to the extent that in the next decade, superiority of products will depend on it[13]. Nanotechnology in essence means working at the level of atoms and molecules from one to 100 nanometers. The aim is to form and manipulate the arrangement of atoms or molecules using materials, equipment, and systems with modern capabilities and thus reaching a higher level of material functionality and efficiency. In fact, if all materials and systems organize their underlying structure at Nano scale, then all reactions take place faster and more efficient and we will move towards constant development. One of the many advantages of this technology is high functionality production, transmission, consumption, and preservation of energy. Nanotechnology has revolutionized this area. As a result, using this technology, researchers in Nano sciences try to make inside and outside of buildings more comfortable by discovering a new class of high performance building materials and reducing the costs especially in energy consumption, to ultimately achieve constant development[14].

Nanotechnology in building construction: By using modern technologies and making a healthier environment,future buildings should be more efficient, more secure, and less energy wasting. There are many problems in architecture and civil engineering (the increase in construction costs, the pollution in cities) which affect buildings. Nanotechnology is much promising in making significant progress in areas such as converting and saving solar energy, thermo-electrical convertors, batteries, and high performance fuel cells. Manipulating and combining Nano-structures and creating new materials in order to develop new methods in building construction brings new trusts for energy management in future buildings. Today, nanotechnology is expanding all over the world covering many interdisciplinary aspects. Without a strategic research and development plan, coordinating all these aspects would be difficult. It is now possible to provide proper building materials for managing the building's energy using this technology. National research council institution has also studied other potentials of these materials – generally or specifically – as applied to building materials: High strength and endurance, High hardness, Reinforced glass (reinforcing strength without affecting transparency), More strength in hanging bridges, Wider arcs (also in bridges).

Nanotechnology and energy: Nanotechnology will make big changes in the way we use natural resources, energy, and water and will reduce the amount of effluent and pollution. Modern technologies also make it possible to recycle and reuse materials, energy, and water. Regarding energy, nanotechnology can affect performance, storage, and production of energy greatly while reducing consumption. For example, firms producing chemicals have made reinforced polymer matter from Nano-particles that can replace metal parts in automobiles. Wide use of these materials can save up to 1.5 billion liters of petroleum each year. There are also other uses for thermal conducting property of materials made by nanotechnology. With a proper density, these materials can conduct heat from surface to thermal holes rapidly and hence the possibility of producing such modified thermal resistant materials is being considered.In future, the development of insulating materials and thermal pipes may provide us with thermal conductance difference in length and width of pipes. The use can be in heating the buildings –this system can replace the present liquid-based systems of heating.

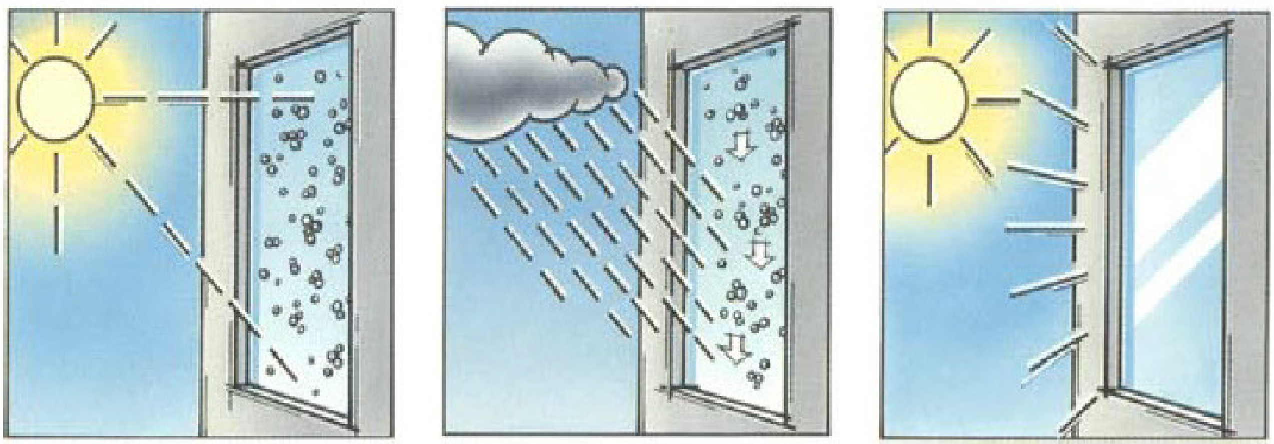


Figure-7
Glass reinforced by nano-technology

Materials consist 70 % of GDP growth in industrial societies in one or more than one areas and therefore are crucial for economics. Nanotechnology provides us with almost countless ways of producing new materials. Nano matter is new matter the basic structure of which is defined on nanometer scale. By reducing the size, Nano matter shows a different behavior on each scale. Nanotechnology lets us make new materials and objects with new performance and functionality characteristics. Electrical equipment provides another market for this technology. Industrial sketches shows that advances in optical LED-based Nano equipment can reduce energy consumption globally up to 10 % in 10 to 15 years. This will save 100 billion dollars and reduce the propagation of 200 million ton carbon gases every year. Major changes are also expected in lighting technology in the next decade. Nano-sized LED semi-conductors can be produced in large quantities. In America, approximately 20 % of the total amount of power produced is used for lighting (whether in ordinary light bulbs or fluorescent).Nanotechnology is much promising in making significant progress in areas such as converting and saving solar energy, thermo-electrical convertors, batteries, high performance fuel cells, and efficient electrical power transmission lines[15].

Using nanotechnology in green roofs: Building materials produced by nanotechnology that green roofs can also benefit from include:

Nano covers and Nano insulating: The most important advantages Nano-covers and Nano-insulating offer in roofs are: good insulating coverage, corrosion-resistant coverage, higher resistance against heat transfer, higher resistance against friction and corruption and, self-cleaning ability.

Instances of Nano insulating material used in roofs and green roofs: VIP-vacuum insulation panels.

These are good thermal insulating material much thinner than usual. Compared to ordinary ones like polystyrene they are 10 time less heat conducting. Their thickness is between 2 to 40 millimeters. They can be applied to walls and roofs with 30 to 50 years of longevity approximately. Without doubt using these panels increases energy consumption efficiency in buildings and consequently CO_2 propagation.

Aerogel and nanogel thermal insulation: Aerogel is a type of material in which gas bubbles are suspended in liquids or solids. Holes created in aerogel mass are usually less than 100 nanometers diagonally. Advances in aerogel development led to nanogels. nanogel's crucial characteristic is its Nano-sized micro-holes. Being 99 % porous, they are semi-transparent and supporting and they are suitable for semi-transparent constructional insulation. In addition to reducing heat transfer from buildings in cold weather and cold areas, this material has an effect called cold wall, which can be useful to prevent heat from transferring into a building in hot areas. Therefore, it reduces building heating and cooling costs (energy consumption reduction). Because of their hydrophobicity, humidity is not a threatening factor for them[16].

Figure-8
An example ofthe VIP- Vacuum insulation panels

Nano waterproofing: Absorbing water is much harmful to a non-protected building. Instances are nitration, bulging of walls, paint flaking off, mold, dirt absorption, cracking and early wear-out, degrading concrete strength and ironware corrosion. An appropriate solution to this problem is using waterproofing materials. Made from nano particles, water-proofing materials in filtrate into other surface materials, providing long-term protection. Waterproofing materials can be used in the following constructions: new buildings, old buildings, concrete and cement blocks, tiles, and stones. Many parts of a building can become waterproof with this method: foundation and pillars, interior walls, exterior walls and coverings, bathrooms, internal wiring places and ducts, roof or ground water supplies, and rooftops.

Heat-blocker materials: We can also improve the insulation quality of building materials by using Nano-coatings on external surface of materials in a variety of ways. Coverings and coatings that act as heat-blockers are usually sprayed on the surface; this thin layer will play the role of heat insulating materials.

Heat-guarding materials (phase changing materials or PCM): These materials fulfill two goals: they prevent energy wastage and, at the same time, help storing energy the most efficiently. The major application of these materials in construction industry is for energy storage[17].

The outcome of using nanotechnology in green roofs: According to the studies, we can satisfy the following expectations about reducing energy consumption (directly or indirectly) by using nanotechnology in green roofs: Limiting heat transfer to allowed amounts; Preventing water and moisture infiltration as required; Providing more endurance against weather and climatic conditions; Providing adequate fire resistance (thermal and heat insulating of different parts of the external; surface in addition to strengthening against tensions); Providing and keeping the thermal comfort of controlled spaces using Nano thermal insulation; Reducing the width of layers that provide the thermal strength of a cover; Increasing the longevity of the external surface of the roof; Reducing the maintenance costs.

Conclusion

According to what mentioned above, green roof is a cheap and effective solution to reduce environmental pollutions and energy consumption. Based on previous studies, each square meter of green space can filter 500 grams of air pollution each year. Green roofs have many advantages for city environment and ecology and the spiritual, mental, social, and economic lives of its citizens.

Nanotechnology is a modern technology that has important valuable applications in various industries including construction industry. We could summarize the application of nanotechnology to architecture as the following: this technology tries to affect the construction industry in two ways. First, by optimizing and improving the functionality of the existing technologies and second, by providing new materials and products never existed before. Nanotechnology has initiated a great scientific movement towards solving many environmental problems, improving the quality of things and conditions, and specially reducing energy consumption all over the human world. Nanotechnology can help us produce building and insulating materials that when used in green roofs will satisfy expectations like limiting heat transfer, providing fire resistance materials, and redirecting environmental and non-environmental factors towards reducing energy consumption.

References

1. Ahirwar J.R., Socio-Religious Importance of Plants in Bundelkhand Region of India, *Res. J. Recent Sci.,* **2(1),** 1-4 **(2013)**
2. Bass B., Green Roofs and Green Walls: Potential Energy Savings in the winter, *Toronto :Adaptation amd Impacts Research Division Environment Canada at the University of Toronto Centre for Environment*, 58-65 **(2007)**
3. Hagh Panah M., Saghaei F. and Dehghani M., New structures in smart buildings: a sustainable architecture approach, National Conference on Sustainable Architecture and Urban Development, **(2013)**
4. Akhwanzada A.S., Tahar M. and bin Razman, An Analysis of Malaysian Renewable energy target using Simulation Modelling Approach, *Res. J. Recent Sci.,* **3(1),** 38-44 **(2014)**
5. Razavian M.T., Ghafouri Pour A. and Razavian M., Green roofs, *Geographical quarterly of Environment Planning,* **10 (2011)**
6. Saadat N., From traditional roofs to the application of nanotechnology to building roofs, National Conference on Construction, Architecture, *Urbanization and Energy Management,* **(2012)**
7. Sharghi A., Cohabitation of human and plant in tall buildings, Bagh Nazar quarterly, **5 (2010)**
8. Barret J., Bertholon P. and Marie X., conception et amenagement des jardinsurtoitures, dalles et terrasses, *publication, Syros alternatives,* 11-19 **(1988)**
9. Abedini F., Asadpour F. and Aghel Pasand A., A study and analysis on how to apply nanotechnology in sustainable architecture development, National Conference on Sustainable Architecture and Urban Development, Bookan, **(2013)**
10. Keramat Azar Z., Feizollah Beigi A. and Hajeb S., A study on the place of smart and self-repairing materials in sustainable architecture, The First National Conference on Architecture, Restoration, Urbanization and Sustainable Environment, Hamedan, Hamedan's Technical School of Shahid Mofateh, **(2013)**
11. Golabchi M., Nanotechnology in architecture and construction engineering, University of Tehran Publication **(2012)**
12. MacDonald Idu, Science and Technology in the 21st Century: Phytomedicine in Focus, *Res. J. Recent Sci.,* **2(1)**, 1-7 **(2013)**
13. Tiwari S., Air Pollution Induced changes in Foliar Morphology of two shrub species at Indore city, India, *Res. J. Recent Sci.,* **2(1),** 195-199 **(2013)**
14. Maheswaran S., Bhuvaneshwari B., Palani G.S., Nagesh R Iyer and Kalaiselvam S., An Overview on the Influence of Nano Silica in Concrete and a Research Initiative, *Res. J. Recent Sci.,* **2(1),** 17-24 **(2013)**
15. Mahmoodi Zarandi M., Pakari N. and Bahrami H., An evaluation of how green roofs affect the reduction of environment temperature, Bagh Nazar quarterly, **20 (2012)**
16. Mosnadi M. and Heidari S., Roof simulation: an approach to a precise examination of temperature influences in a virtual environment, *The Journal of Fine Arts*, **42 (2011)**
17. Yazdandad H., Emami S. and Hashemi N., Environmental values and functions of green roofs in sustainable urban development, The First National Conference of Sustainable Urban Development **(2011)**