Optimization of design parameters of using green roof as an alternative system in residential buildings to reduce energy consumption

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Abstract
The evolution of climate toward the gradual rise in global temperature has led to many worrying consequences and encompasses many aspects of the world's life. Among them, special attention should be paid to the resistance of the building's energy design to global warming, as economic measures and effective measures can be greatly affected by climate change over the time. In this paper, using the green roof concept and the use of two genetic optimization and harmony search algorithms, we investigated the use of green roof system to improve building energy consumption. The results showed that the harmonic search algorithm provided better results than the genetic algorithm in terms of energy saving. Compared with the solar panel system, it was also found that using green roofs with 3987 kWh or 89.5% is better than solar panel in saving annual building load. On the other hand, according to the useful infrastructure of the building, the amount of energy saved per square meter of building roof per year (350 m 2), approximately 23.54 kWh for green roof use and 12.72 kWh for use It will be solar panel. Also, the share of savings in the cooling section is 15.94 kWh for the green roof and 8.35 kWh for the solar panel and in the heating section, 7.6 kWh for the green roof and 4.36 kWh for the solar panel.
Keywords: Residential Building - Energy – Green Roof - Genetic algorithm – Harmony Search

1- Introduction

Energy is one of the main factors in the continuation of human life. Depending on the variety, energy sources can provide all the important tools, such as water or electricity. Systems that use renewable energy sources (RES) are systems that use the energy from natural resources and are naturally replenished [1]. These systems are the main factors that reduce greenhouse effects and are unsustainable for dealing with energy resources. [2] .RES is used in two modes of connected or independent network. They can be used uniquely or in mixtures. Optimization techniques such as minimizing costs [3, 4], maximizing production [5], and optimizing storage [6] are used for RES to make the best use of them.

Green roof is a passive cooling technology to reduce power consumption in air conditioning systems [7-10]. Ordinary green roofs are formed by composite layers laid from bottom to top based on root barrier, drainage, filter, water storage, growing bed and vegetation: [11]. A wide range of vegetation growth forms, depending on the depth of the bed, can be planted [12-13]. The biomass structure, vegetation density, and density of the vegetation, which is determined by the leaf surface index, can regulate shade, rate of evaporation and transpiration, and thermal and insulation cooling

[14]. The role of the bed in supporting plant growth is complemented by the water storage layer. Rainwater or irrigation is stored in the water-absorbing material to meet the water needs between irrigation or rainwater areas. Excessive soil moisture through the drainage layer can escape the green roof system. Modern green ceilings can be classified into wide and compact types [15]. They are distinguished by the depth of the bed and the shape of the vegetation growth. Tight green roofs require a compressed bed of more than 20 cm to support shrubs and trees and provide more complex habitats for wildlife. In contrast, herbaceous plants, including drought tolerant species, are often selected for large green ceilings with a bedding of less than 20 cm. Studies have shown that both types of green roofs have good thermal insulation performance against the reduction of solar energy penetration into buildings. They also offer high-quality green space, which is rarely seen in low-density urban areas. Freshwater has increasingly become a source of shortages in many areas, including cities in different climates. Proper use and saving of water is of particular importance for maintaining economic growth and urban development. Despite the many economic and ecological benefits of green roofs, the use of scarce water for irrigation can be controversial, especially in semi-arid and arid regions. There is a common desire to apply large amounts of irrigation water to green roofs, even if rain or air sensors are installed to adjust the timing and volume of irrigation. For example, evaporation and transpiration are hot in spring and the lowest and highest in the cool dry autumn in Hong Kong [17]. An irrigation program set up by rain sensors may not provide enough water in the fall, regardless of the disappearance of evaporation and transpiration. Rainfall data alone cannot store the amount of water in soil pores [18], which may be overused and wasted. Optimizing a green roof irrigation program is still a knowledge gap that has not yet been filled by research. This calls for the creation of an intelligent irrigation model to improve water efficiency.

The use of optimization techniques for irrigated agriculture using reproductive resources is widely covered in the literature. Kampana et al. [19] examined the terrestrial distribution of grasslands for the implementation of photovoltaic water pumping systems. They used an explicit and explicit spatial optimization model of resources using auxiliary resources to assess the optimal location for the implementation of photovoltaic water pumping system (PVWP). In this paper, using a genetic algorithm, a drip irrigation system consisting of renewable energy and diesel energy is proposed, in which the energy cost is optimized based on the current net cost. The authors in [21] used GA to find the optimal size of PVWP systems for irrigation. Their goal was to maximize annual profits. Tsang and Jim [22] noted that green roof irrigation lacks reliable and cost-effective measures for water and neural network maintenance and fuzzy logic, which are taught by real-time weather variables to create a suitable irrigation strategy. . The authors [23] integrated a technique for order performance similar to the ideal solution (TOPSIS) method with the analytical hierarchical method (AHP) to optimally measure PVWP according to economic respect.

Artificial intelligence calculations, such as the genetic algorithm (GA), the artificial neural network (ANN) and fuzzy logic (FL), can provide flexibility for irrigation researchers to deal with the complex problems of the real world. GA can be used to optimize irrigation restrictions on agricultural land, such as economic gain, water demand, crop yield, and area under cultivation using minimum or maximum target yields (eg, 24-26). Computational flexibility, exemplified by the use of linear and nonlinear methods, allows researchers to solve complex problems significantly. Compared to the biological mechanisms of genes, GA laws are governed by four basic actions: parental selection, crossover, switching, and mutation [28]. Possible solutions are defined as chromosomes. Target functions have become fitness functions that measure the function of chromosomes according to the objectives of the study. New chromosomes are formed at the intersection and mutation. The chromosomes that have the highest levels of fitness in successive populations can survive. The best set of chromosomes is obtained by repeating the possible solutions until convergence is achieved.

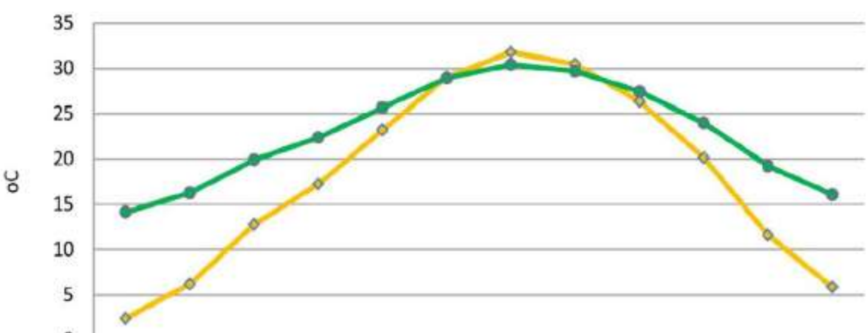
Chantrelle et al. [29] Minimizes energy consumption, CO2 emissions and emissions, and proposes a multi-criteria approach to building retrofitting. Fan and Xia [30] examined the initial energy consumption, net present value, and payback time to optimize the resilience of the building envelope and the installation of the photovoltaic system. Also Yang et al. [31] Focused on optimizing envelope design using a non-dominant genetic alignment algorithm and considering objective functions, construction costs, energy performance, and window opening rate.

In this regard, Mustafa et al. [32] Developed a new method to minimize building life cycle costs, life cycle pollutants, and maximize occupant thermal satisfaction. Minimizing energy demand for heating, cooling and lighting was one of the goals of Schnagussia et al. [33] which examined the different climates of Palermo, Turin, Frankfurt and Oslo. Diakaki et al. [34], which proposed a new decision-making model to be used for a case study in Athens, and Dollargam et al. [35] which has used particle optimization for a case study in Iran. Zhang et al. [36] set a similar goal by implementing a genetic algorithm to optimize the heat output and amount of daylight in a school building based on energy demand for heating and lighting. Subsequent studies have proposed multi-objective frameworks for improving building energy performance by examining more than three objective functions for optimizing retrofitting [37, 38] or for the sustainable design of new structures [39, 40]. Couscla et al. [41] proposed a method of using electrical energy storage in residential buildings to optimize electricity costs. In this study, the tools and size of a photovoltaic system with energy-related energy storage are examined from an economic perspective. A new theory for profitability measurement has been proposed using case studies of an apartment and a detached house in Finland. To maximize benefits, several alternative models for measuring electricity and pricing are used and compared. Studies show that the right size of photovoltaic system can be increased by using electrical energy storage and reasonable electricity prices. This has led to an increase in demand for photovoltaic energy in residential buildings. In addition, it is possible that, with all incentives in mind, energy storage along with photovoltaic power generation will be more cost-effective than photovoltaic power generation. Photovoltaic power generation has also increased the profitability of electricity storage, which means that the use of electricity storage in the residential sector can also be increased. Dodo et al. [42] evaluated the building envelope measures by optimizing the cost for a multi-storey residential building in cold weather. In this paper, cost-effective building envelopes are analyzed, including insulation of attic roofs, ground floor and exterior walls, and windows and doors of new buildings. The analysis is based on a multi-story building in southern Sweden that is at least 100 years old. They consider the integration of dynamic energy simulation, total economic analysis and marginalization, and consider different scenarios of real discount rates and annual increase in energy prices. Their study showed that the amount of affordable insulation thickness used in building envelope elements is significantly higher than the amount of thickness required to meet the minimum energy requirements in the current Swedish building. For Windows, the value of U at a reasonable price is almost equal to the minimum required to provide the Swedish building code. In general, energy savings and high costs are achieved when optimal economic and economic measures are implemented collectively. Compared to the reference, the annual heat reduction of 28-43% of the building is done with optimal cost measures over a period of 50 years. Cost savings range between € 21 and € 188k. Almeida and Ferreira [43], who ran the IEA EBC program, used the An556 program to find solutions and generate guidance for European residential buildings, not only in terms of energy reduction benefits and Greenhouse gas emissions, as well as the added value of modernization, are also being considered. Process. Given the goal of reducing greenhouse gas emissions, measures that increase the use of renewable energy can be as effective as measures of energy efficiency, so determining the optimal balance between minimizing energy demand and using renewable energy is very important. This paper discusses the use of a green roof system to optimize energy consumption in a residential building. Therefore, using the Genetic Algorithm (GA) and Harmony Search (HS), we try to optimize energy consumption in the building to use green roof technology. The structure of this article is as follows: The case study of this research is presented in Section 2, Section 3 examines the technology and method of green roofing that is followed in this work, the results and discussions are presented in Section 4, and Section 5 concludes the article.

2- Case Study

For this study, a south building with north construction position (north to alley and south to yard) was selected. This building which is in Tehran has 4 floors and each floor has 4 units with an average area of 80 m^2 (there are two units with a total area of 70 m^2 and two units with a total area of 90 m^2). In total, this building has 240 m^2 of ambient, 360 m^2 of the roof surface and 1340 m^2 of the ambient wall. 350 m^2 of the ambient wall is to the north side, 350 m^2 to the south side, 320 m^2 to the east side and 320 m^2 to the west side of the building. Ambient walls of a building with 3cm plaster, 20cm optional ambient wall replacement, 2cm mortar and 3cm Coated granite stone and 3 cm plaster, 20 cm optional roof replacement, 2 cm mortar were used to construct the roof.

Tehran is generally warm and dry, except for the slightly humid and temperate northern highlands. There are three geographical factors affecting the overall climate of Tehran province. These factors include: Alborz Mountains in the north, Western rainfed sports and Desert Plains in the south of the province. Elevation factor plays a major role in Tehran's climate. Therefore, as the altitude decreases from north to south the temperature increases, but the rainfall is lower.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean temp	2.44	6.2	12.8	17.24	23.2	29.04	31.78	30.46	26.34	20.16	11.62	5.88
Heidari	14.15	16.24	19.90	22.37	25.68	28.92	30.44	29.71	27.42	23.99	19.25	16.06

Fig1. Comfort temperature of Tehran residents in different months

2-1 Air temperature

According to the average annual air temperature, the warmest city in Iran is Minab and the coldest in Ardebil. The chart below shows the average annual temperature, precipitation and humidity of Tehran. Accordingly, Tehran has cold winters and hot summers.

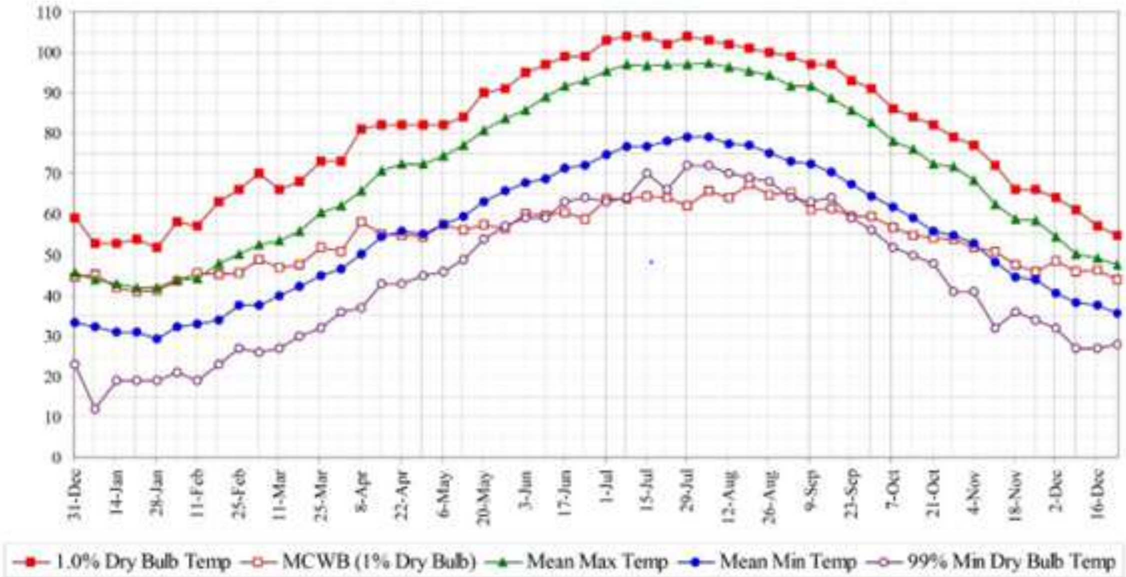


Fig2. Temperature range of Tehran city

2.2 Sun radiation

The amount of sunlight received in Iran varies by factors such as climate, latitude, altitude, and so on. Iran is one of the countries with high potential in solar energy despite 280 sunny days in more than two-thirds of it and average radiation between 2.6 and 5.5 kWh. Has been. In the studied climate (hot and dry climate zone) this number varies from 3.9 to 5.4 W / m 2. In Tehran, daily solar radiation is between 3.8 and 4.7 W / m 2. The average annual solar radiation intensity in Tehran is 4.58 kWh, so using solar energy as an alternative energy reduces fossil fuel consumption in addition to expanding the culture of using clean and non-hazardous energy and bio-pollutants. An environment among citizens also helps greatly.

2.3 Rain

Most cities in Iran, especially in hot and dry climates, have little precipitation. Tehran has an average annual rainfall of 238.8 mm. The table below shows the average monthly rainfall in Tehran. Due to climatic conditions and high evaporation rate in Tehran, evaporative cooling can be used as a passive cooling method.

3- Green roof and methodology

Numerous empirical and theoretical studies have been carried out to identify the potential of green roofs for energy saving. The benefits of energy depend on the local climate, the design of the green roof and, most importantly, the specific building features. Given that in green roofs, the benefits associated with heat transfer are mainly due to latent heat processes, the system performs better in arid climates. At the same time, the thickness and thermal properties of the green roof determine the heat exchange coefficient and the corresponding heat transfer to the building, while the type and properties of the plants determine the shading levels (LAI and radiation transmission through the layers. It is equally important because it determines the latent heat released and regulates the roof's thermal equilibrium [44], but it should be noted that the characteristics of the building also influence the amount of green roof assistance. , The impact of green roofs is much greater than on well-insulated buildings, and it is clear that better roof insulation results At the same time, the energy load characteristics of the building also affect the amount of impact the roofing system has on the buildings where much of their energy load is provided by ventilation (either on or off) or the sun. The impact of green roofs is more limited.

Conversely, in buildings where the energy load is due to heat transfer through the opaque sections, green roofs can help reduce the cooling and heating loads of the building. Existing studies conducted for different types of buildings, green roof features and weather areas show that the expected annual reduction in energy load can vary between 7% and 20%. In fact, in modern insulated buildings, the impact of green roofs is relatively low [45].

Green roofs help to reduce temperatures by preventing the roof from warming by creating a barrier between the roof and the sun and its shading on the roof [46]. Increased evapotranspiration due to the green roof also helps to cool the building as well as the surrounding environment [47]. Hein (2002) stated that green roofs in Singapore reduced the ambient temperature to 2 degrees Celsius, thereby reducing the heat transferred to the space below it.

Studies on the impact of green roofs on reducing energy consumption of buildings are considered different buildings in cities around the world. In order to calculate the amount of energy saved, according to the studies mentioned above that have obtained this number depending on the input variables between 62.2 to 3.1 kWh / year. The app is used. Considering the effect of green roofs on a particular building, they have considered different conditions and considered various parameters as variables, including leaf area index, soil thickness, soil moisture and Etc. However, considering the impact of green roof on Tehran area in the present study, not all parameters can be considered as variables and therefore a minimum and an average of them are considered in the studies. It is possible to obtain a good estimate of the amount of energy saved in the building concerned. Using the assumptions of the program for the building, and remembering that the energy consumption changes in the building if the green roof is used, the green roof features used in the model will be as follows [48-50].

For soil thickness, different numbers have been used. In the study of Singapore, from 2 to 2 mm thick, in studies in the three cities of Athens, Larouchel and Stockholm from 1 to 2 mm thick, and in research in Thailand, from 1 to 2 mm thick. Used. Leaf area index (LAI) is another parameter considered as a variable in these studies. For this parameter, values of 0.5 to 5 mm are used. Also for soil moisture, both dry and wet conditions are often assumed to be variable in moisture content in various studies.

Based on the above information and the values used in the above studies, it is assumed that dry soil, with a thickness of 1 mm and a sod with a leaf area index equal to 1, is assumed to be used, and a total roofing area of 1% by green roof. To be covered.

The most important green roof default parameters in a building include:

-**Plant height**: This parameter displays the average plant height used on the green roof, which is based on the experience of engineers and the default Sodium plant equals 1 cm. Leaf area index: The ratio of the plant surface to the land occupied by it, which usually ranges between 0.5 and 0.5. In this study, this index is considered 3.

- **Leaf Reflection Factor**: This parameter is the fraction of the amount of sunlight reflected by the plant to the total radiation received, ranging from 0.1 to 0.4. In this study, based on the Sodium plant, this number is 0.22.

-**Leaf emission coefficient**: The ratio of the thermal radiation of the leaf surface to the thermal radiation of the ideal black body is called a number ranging from -0.8. In this study, this number is considered 0.95.

- **Minimum Aperture Resistance**: This parameter indicates the resistance of the plant to moisture transfer. In other words, the higher the plant's stomatal resistance, the less evapotranspiration. This parameter is a numerical parameter between 0 and 2, which is considered in this study.

- **Minimum Soil Volume Moisture**: This parameter indicates soil moisture that is directly related to the soil type, especially porosity. In this study, this number is assumed to be 0.6, considering the climate of Tehran city and the type of green roof and plant type.

4- Results and Discussion

In order to calculate the amount of energy saved, according to the studies [51-53] that this number depends on input variables between 62.2 They have gained 3.1 kWh (m 2 / year), using the calculation algorithm (HS and GA) of this program. Hence, after applying the above coefficients in the model, the distribution of cooling and heating loads of the building in the basic building modes and the use of green roofing is presented which is presented in Table (3) (Using GA algorithm) and Table (4) (Using HS algorithm). Considering the impact of green roofs on a particular building, they have considered different conditions and considered various parameters as variables, including leaf area index, soil thickness, soil moisture, etc. However, since the impact of green roofs on a wide area of Tehran is examined in the present study, not all parameters can be considered as variables and therefore a minimum and an average for them is considered in the present study. It is taken to obtain a good estimate of the amount of energy saved for Tehran.
Table (1) shows the settings of the Genetic Algorithm and Table (2) shows the settings of the Harmony Search Algorithm.

Table (1): Genetic Algorithm Settings for the Problem

Parameter	Setting
Population Size	60
Generation	100
Selection Method	Tournoment
Non-Dominated selection	TournamentDCD
Crossover Method	Laplace
Crossover Possibility	95%
Mutation Method	Power
Mutation Possibility	0.5%

Table (2): Harmony Search Algorithm Settings for the Problem

Parameter	Setting
Harmony Memory Size	10
New Harmony Memory Size	100
Harmony Memory Consideration Rate	0.75
Pitch Alignment Rate	0.05
FW	0.1
FW_damp	0.95

Based on the parameters of both algorithms, it is possible to determine the appropriate values for the parameters of the green roof to determine the optimum energy saving using both algorithms. This is presented in Table (3).

Table (3): Determination of Optimum Parameters of Green Roof Design Using Both Optimization Methods

Parameter	Base Value	Optimum Value	
		GA	HS
Plant height	30 (cm)	28 (cm)	30 (cm)
Leaf area index	3	2.25	1.26
Leaf Reflection Factor	0.22	0.25	0.31
Leaf emission coefficient	0.95	0.95	0.97
Minimum Aperture Resistance	180	192	192
Minimum Soil Volume Moisture	0.6	0.62	0.6

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Using the optimal values obtained for green roof design variables based on both methods, we compare the optimal values of cooling and optimal heating of the green roof system relative to the base building. This is presented in Tables (4) and (5), using the Genetic Algorithm and the Harmony Search (HS) algorithm, respectively.

Table (4): Optimal Distribution of Building Cooling and Heating in Two Stands and Green Roofing (Genetic Algorithm)

Improving energy consumption with optimal green roof (kWh)	Optimal thermal load in green roof (kWh)	Base thermal load (kWh)	Optimal cooling load in green roof (kWh)	Base cooling load (kWh)	Month
1201	5124	6325	0	0	Jan
1444	3425	4869	0	0	Feb
1180	2245	3425	0	0	Mar
0	0	0	0	0	Apr
230	0	0	59	289	May
838	0	0	521	1359	Jun
736	0	0	1278	2214	Jul
632	0	0	896	1528	Aug
264	0	0	225	489	Sep
121	188	309	0	0	Oct
512	1426	1938	0	0	Nov
1083	3369	4452	0	0	Dec

Table (5): Optimal Distribution of Building Cooling and Heating in Two Stands and Green Roofing (Harmony Search Algorithm)

Improving energy consumption with optimal green roof (kWh)	Optimal thermal load in green roof (kWh)	Base thermal load (kWh)	Optimal cooling load in green roof (kWh)	Base cooling load (kWh)	Month
1590	4735	6325	0	0	Jan
2127	2742	4869	0	0	Feb
1584	1841	3425	0	0	Mar
0	0	0	0	0	Apr
257	0	0	32	289	May
942	0	0	417	1359	Jun
1185	0	0	1029	2214	Jul
814	0	0	714	1528	Aug
1292	0	0	197	489	Sep
131	138	309	0	0	Oct
726	1212	1938	0	0	Nov
1349	3103	4452	0	0	Dec

Based on the results from Tables (4) and (5), it can be seen that the harmony search (HS) algorithm performs better than the genetic algorithm (GA). This can be seen in Fig. 3, which is done on a monthly basis.

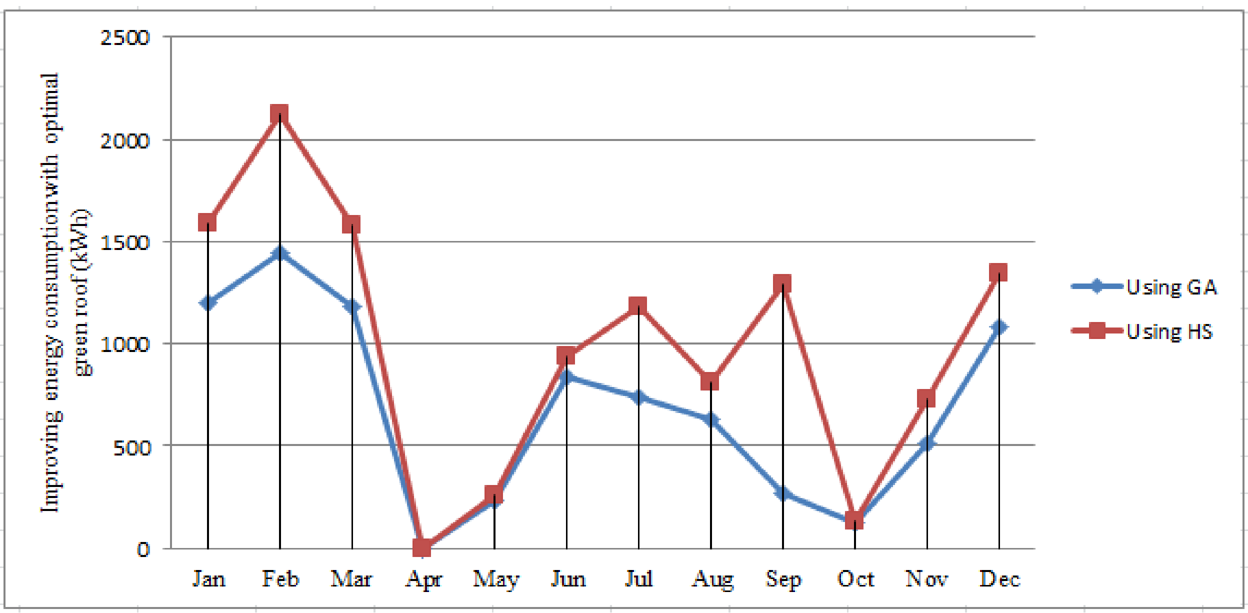

Fig3. Comparison of the improvement of energy consumption in kWh on a monthly basis compared to both methods

Finally, in order to evaluate the impact of using green roofs on buildings, we compare our work with the use of solar panels (photovoltaic system) instead of green roofs. It should be explained that this comparison is made using a Harmony Search (HS) method that yields better results than the Genetic Algorithm (GA). This comparison is explained in Table (6).

Table (6): Comparison of the Distribution of Building Cooling and Heating Loads in Base Modes, Solar Panel and Green Roof Optimization

Thermal load in solar pannel (kWh)	Optimal thermal load in green roof (kWh)	Base thermal load (kWh)	Cooling load in solar pannel (kWh)	Optimal cooling load in green roof (kWh)	Base cooling load (kWh)	Month
5869	4735	6325	0	0	0	Jan
3964	2742	4869	0	0	0	Feb
2749	1841	3425	0	0	0	Mar
0	0	0	0	0	0	Apr
0	0	0	148	32	289	May
0	0	0	968	417	1359	Jun
0	0	0	1678	1029	2214	Jul
0	0	0	1245	714	1528	Aug
0	0	0	311	197	489	Sep
241	138	309	0	0	0	Oct
1696	1212	1938	0	0	0	Nov
3874	3103	4452	0	0	0	Dec
18393	13771	21318	4350	2389	5879	Annually

Based on the results in Table (6), it can be stated that:

-All numbers are positive graphs indicating good green roof performance in all seasons and months of the year.

-The highest amount of energy saved for heating by the use of green roofs in February is 1444 kWh. This amount for cooling occurred in June and is 936 kWh. But using the solar panel, the energy recovery in the cooling sector in the same month is 905 kW and in the heating sector is 536 kW.

- The higher the indoor and outdoor temperature difference, the more energy-saving the green roof will be. So in the very cold or very hot months, the amount of energy saved by the green roof will be greater.

4- **Discussion and Conclusion**

Proper design of building energy retrofitting can't be sufficient to ensure high energy, environmental and economic performance over time over the life of the building. In this regard, the important issue of global warming risk has been presented, which can severely affect the efficiency and effectiveness of energy saving measures. Therefore, different climate scenarios should be considered for a resistant design or optimized building design, which also requires different economic perspectives. In this study, using the green roof concept and the use of two genetic optimization and harmony search algorithms, we investigated the use of green roof system to improve building energy consumption. Therefore, the important design parameters such as plant height, leaf area index, leaf reflectance coefficient, leaf emission coefficient, minimum aperture strength and minimum soil moisture content were investigated and based on these parameters, optimum values of each of these parameters were investigated. We determined from both algorithms and compared them with the ground state. The results showed that the harmonic search algorithm provided better results than the genetic algorithm in terms of energy saving. Next, we optimized the green roof results using the solar panel system. Based on the results of the analysis of alternative systems (solar panel and green roof), it can be concluded that using green roofs will save 8441 kWh of energy annually, out of which 5541 kW is related to heating and cooling. Its 2900 kW cooling system. While using the solar panel, it is 4454 kWh which has a share of heating section of 2925 kW and cooling portion of 1529 kWh. Thus, using green roofs of 3987 kWh or 89.5% is better than solar panel in saving annual building load. On the other hand, according to the useful infrastructure of the building, the amount of energy saved per square meter of building roof per year (350 m 2), approximately 23.54 kWh for green roof use and 12.72 kWh for use It will be solar panel. Also, the share of savings in the cooling section is 15.94 kWh for the green roof and 8.35 kWh for the solar panel and in the heating section, 7.6 kWh for the green roof and 4.36 kWh for the solar panel.

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