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Methodology for the Design and Evaluation of Green Roofs in Egypt

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Abstract

Green roofs have been gaining popularity in recent years, as an effective way to solve many environmental problems, many countries concerned with the application of green roofs in cities. In spite of the importance of using green roofs on buildings, the use of green roofs in Egypt is still absent. Egypt has been suffering recently from increasing energy demand compared to production rates, especially in the residential sector as a result of high population growth and high temperatures. Where the main objective of the study is to reduce energy consumption, reduce carbon dioxide emissions and increase the insulation on the roofs of residential buildings, this paper is working to try applying green roofs on residential buildings in Egypt through a proposed methodology for the design and evaluation. In this context, uses and applies different sections of green roofs on residential buildings in eight climate zones of Egypt in accordance with the requirements of thermal performance of the Egyptian energy code.

Keywords: Green roofs, Egyptian climate zones, Energy code.

1. Introduction

Recently world is suffering from rapid urbanization, especially in developing countries and this caused a shortage in green spaces in urban communities [1], resulting in serious environmental problems such as the phenomenon of urban heat islands, which is evident in the increase in the temperatures of capitals and cities compared to the surrounding areas. this phenomenon increases the pressure on the cooling load because of the increased demand for internal environmental comfort, which means an increase in energy consumption [2].

Like many other countries, Egypt faces constant pressure from increasing rates of urbanization. There are almost no green spaces within the large Egyptian cities in addition to the overcrowding of buildings next to each other's well as the narrow width of streets [3]. All these issues have prompted to many environmental problems, such as air contamination problems and the heat island phenomenon, which increase the energy demand of energy production, especially in the residential sector, this sector consumes 40% of the total energy consumption in Egypt [4].

Green roofs have been gaining popularity over the last years as an effective way to resolve many environmental problems; they improved building energy efficiency by limiting thermal stress.

As a result, green roofs are becoming popular breathing roof alternative to traditional roof systems. Despite environmental concerns all over the world, the rapid increase the rate of energy consumption, and the rising importance of green roofs, till now there has been limited knowledge in Egypt about how to use, manage and apply green roofs.

From the description above, this paper aims to reduce energy consumption, reduce carbon dioxide emissions and increase the insulation on the roofs of residential buildings in Egypt. To achieve this aim, the study proposed a methodology based on using the different proposed sections of green roofs on residential buildings in the eight climate zones of Egypt in accordance with the requirements of thermal performance of the Egyptian energy code.

2. Green Roofs In Egypt

Egypt suffered recently from high pollution rates, which lead to negative effects, both in short, and long-term and through different levels and sectors at (health, environment, economy, etc.). Green roofs can overcome the lack of parks and green spaces in the cities. In Egypt, green roofs are still very limited in application and recently researchers have recommended green roofs as a solution to limited green spaces.

The shortage of guidance and technical personnel trained to explain and train people on those systems, and the lack of media's role of the direction and guidance, as well as, the lack of fertilizers or fluids feeding crops cultivated on roofs in the markets are all considered as the major constraints against the cultivation the roofs in Egypt [5].

The most important goals of planting green roofs in Egypt are; a) the compensate of shortage of green spaces, b) the increased production of our basic needs of vegetables, fruits,

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and medicinal plants, c) enhancing air-purifying of pollutants, d) increasing the efficiency of rooftops' insulation, and finally, e) reducing energy consumption [6] .

2.1. Green roofs vegetation types

Green roofs considered as hostile environmental sites due to; a) the exposure to high temperatures, b) high sun radiation, c) high sun radiation, d) the rainfall, and, e) the wind. All these previous points provide difficult conditions for plant growth. So plant choice requires a complete study of the site, climate, and maintenance factors, as well as considering the site aesthetics [7].

The reasons behind considering of a green roof project have great influence on green roof design methodology—process, construction and required level of maintenance. For instance, a green roof which designed for the aim of increasing aesthetic value may concentrate on types of ornamental significance more than drought tolerance or low maintenance and include various species with different blooming times, consider planting in patterns and consider textures, foliage colors and extending the planting area beyond the boundaries [8]. Another example, a green roof designed for the objective of food production may increase the loading weight capacity of the roof, depth and organic content of growing media, ensure good entrance to the site, and provide irrigation [9], Thus, it should be considered the requirements of other goals of green roofs such as (stormwater management, provide biodiversity outcomes, maximize thermal insulation) during the design process.

Green roofs support various types of plant species for instance, herbaceous perennials, sedum, turfs, annual & biennial plants, and shrubs [10-12].

According to Egyptian environment requirements, it can be cultivated different kinds of plants such as, a)fruiting vegetables such as pepper, eggplant, cantaloupe, zucchini, b)leafy greens such as lettuce, cabbage, spinach , c)medicinal and aromatic plants as mint, basil, marjoram, rosemary, thyme), d)ornamental plants and flowers such as carnations, Jerbera, bots, alsnjunamalcholls, gardenia, garwenya, filanjame) and, e) fruit trees which used or dwarf varieties that are controlled growth by pruning process, including the lemon, grapes, peaches, huskberries [13].

2.2. Green roofs growing media

One of the key components that characterize the green roof system is the growing media; the media supports the plants, giving water and supplement capacity, and adds to the roof insulation protection [14]. Growing media is lightweight, engineered layer may or may not include soil as the primary organic matter [15].

Proper selection of the soil is critical to the long-term success of a green roof [16].

The growing media should be designed in coordination with all design elements of a green roof project. The load-bearing capacity of the roof will force the design weight, depth of the growing media and, in turn, it will effect on choosing the plantings selection as well as the green roof system whether it is extensive green roof or intensive green roof.

2.2.1. Extensive green roofs

Extensive green roofs are lightweight with a shallow layer of growing substrate of less than 250 mm deep and they generally have lower water requirements (little or no irrigation), and use small, low-growing plant species [17].

2.2.2. Intensive green roofs

Intensive green roofs are generally heavier mainly because the deeper layer of growing substrate. Also, they support a variety of types of plants because it can support heavier weight; they are readily accessed by people [18]. Intensive green roof system needs usually more irrigation and maintenance requirements than extensive roof system, and is highly engineered landscapes; usually they built directly on structures with a large weight load capacity, such as car parks. Roof gardens are terms also used to describe these types of green roofs and are often very aesthetically because of the variety of trees, shrubs, used for vegetation [19].

In Egypt, the green roof system typically does not include an irrigation system, so the plantings must be drought tolerant, able to withstand heat, cold and high winds, as well as possess various other special qualities based on design intent. Low maintenance landscapes often use sedum, grass, small perennials, and other succulents. Sedum and grass are often used. All these plant types typically grow well in 2-inch to 6-inch soils [20].

There are several growing medias that can be used for green roofs, and vary depending on natural and chemical properties of both of them such as (Peat moss- Rice husks- Vermiculite – Pumice- Perlite) [3].

3. Green roof sections design methodology

Green roof sections design methodology at residential Buildings according to Egyptian climate zones procedure, is divided into two main phases: 1) Green roofs sections design at residential Buildings in Egypt, 2) Evaluation of Green Roof Sections according to Egyptian climate zones.

3.1 Green roofs sections design at residential buildings in Egypt

In this part, green roof sections will be designed and calculated according to the requirement and variables of residential buildings in Egypt through three phases as follows:

- Phase one: sections variables selection.
- Phase two: green roof sections installation systems.
- Phase three: green roofs sections design.

3.1.1. Phase one: sections variables selection

The aim of this phase is to determine how the different variables of the green roof assembly affect the thermal performance of the same sections in different climate zones in Egypt, and to see how they perform against a standard roof.

There are several variables that may affect the performance of the green roof, such as, a) insulation and growing media thickness, b) plant type, c) roof slope, d) roof orientation, e) building height, f) shading, g) location or climate, and, h) building function. In order to narrow down the variables for parametric testing according to the case study zones, the following variables are selected:

- Vegetation type.
- Growing media type.
- Growing media depth.

- Growing media moisture.
- The thickness of reinforced concrete slab. See Figure (1).

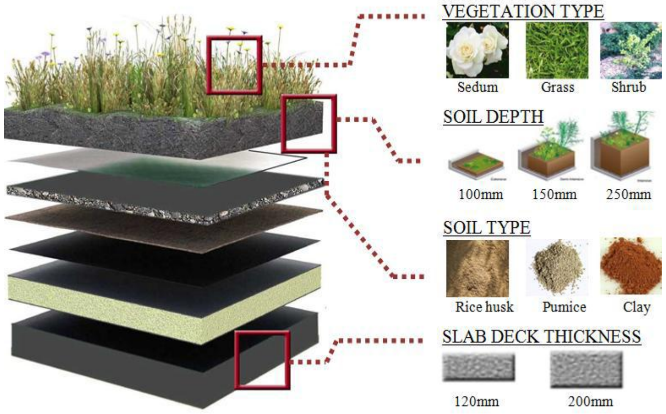


Figure 1: Test variables and their subset variables.

Variable (1): the vegetation type

Plants types were selected depending on the study which based on the most effective objectives for the presence of green roofs in Egypt, as follows:

- Produce food.
- Aesthetics and a design statement on the building.
- Maximize thermal insulation.

Depending on the green roof system in Egypt (extensive green roof) and the required crops that are grown on as well as achieving of the main targets of cultivation roofs in Egypt the choosing vegetation types are sedum, grass and shrubs.

Variable (2): growing media or soil depth

The growing media or soil depth of a green roof assembly is generally connected with the vegetation types. A green roof assembly with low vegetation will normally have a growing media depth of two inches to max ten inches. Such an assembly is located under the "Extensive green roof" type category. Green roof assembly that consists of a diversity of plants, including trees, needs a soil depth greater than twelve inches such an assembly is considered under the "Intensive green roof" type category. They generally need a greater cost and require more maintenance.

The most suitable green roof in residential buildings in Egypt is "Extensive green roof", to avoid the weight of green roof section. For the purpose of study (according to vegetation type variable "1"), the soil depth variables are selected as follows:

- 100 mm thick soil.
- 150 mm thick soil.
- 250 mm thick soil.

Variable (3): growing media type selection

As it mentioned before, growing media should support the plants, providing water and nutrient storage, and contributes to the roof insulation. In addition, this media should have the ability to retain water, provide the necessary ventilation for root growth, as well as does not contain harmful or toxic materials.
For the purpose of study, the following growing media variables were selected as follows:

- Rice husk
- Pumice 75% and sand 25%
- Clay soil

Type 1: rice husk

Recently, Egypt has been suffering from dark clouds resulting from burning rice husk. During the harvesting months of October and November, the smog can become unbearable at times, even for residents who have become accustomed to the polluted air.
The burning of rice husk is responsible for around six percent of the total air pollution on a yearly basis, but the figure skyrockets to 45 percent during those two months [21].
Egypt already has Law 4/1999, which was amended in 2009, against the burning of rice husk, "But these laws have never been implemented and that's the problem," farmers can't afford to pay any fines and they don't know what to do with the rice husk except to burn it [22].
Studies have been undergoing to study the possibility of using rice husk instead of burning it and soiling the environment.
The use of compacted rice husks bales as an organic growing media in green houses and open field production is a new approach in Egypt. This method has been developed in order to control soil borne pests and diseases as well as weed without pesticides use. Field trials were successfully carried out with cucumber, pepper and cantaloupe [23-25].
In addition to the previous advantages, the grains of rice husks are characterized by having lightweight growing media as well as providing ventilation for the growth of various plants roots [3].

Type 2: pumice 75% and sand 25%

Pumice is a rock of volcanic origin celikaty containing aluminum, potassium and sodium elements and is found naturally with no need of artificial processes, but the only operation done on it is crushing and grinding to the appropriate size.

Pumice as a growing media has been selected because of its properties. Where it provides good ventilation conditions in the growth environment easily cleaned and disinfected.
Sand provides good drainage, but it lacks the ability to retain water, so it is added to pumice in order to get both advantages[3].

Type 3: clay soil

Clayey and sandy soils are the main types of cultivated soil in Egypt, clay soil is usually highly fertile and many plants thrive in it, and it also retains water well.

Variable (4): growing media moisture

Three things affect the rate at which solid conducts heat:
1) The soil depth, 2) the thermal conductivity, and, 3)temperature difference.
Soil thermal conductivity, in turn, is affected by four factors: moisture content, density, composition and temperature. However, moisture content has the greatest impact on the soil thermal conductivity [26].

According to the growing medias types which are selected in this study, the moisture degree of each type are identified depends on the type of growing media as well as the largest and lowest moisture percentage that make the soil suitable for agriculture. These moisture degrees are:

- Rice husk (10- 22 % moisture degree).
- Pumice 25 % & sand75% (11- 55 % moisture degree).
- Clay (5- 25 % degree).

Variable (5): concrete slab thickness

In this study, the use of less common and the maximum thickness of reinforced concrete are used as the following:

- (120 mm Reinforced Concrete)
- (200 mm Reinforced Concrete)

The following table (1) summarizes the sections selection variables.

Table 1: Green roof sections variables according to the study

Variables	Variable 1	Variable 2	Variable3
Vegetation type	Grass	Sedum	shrubs
Thickness of growing media/ soil depth	100 mm	150 mm	250 mm
Growing media type	Rice husk	pumice	clay
Growing media moisture	Rice husk (10- 22%)	Pumice 25%&sand75 % (11- 55%)	Clay (5- 25%).
Reinforced concrete slab thickness	120 mm	200 mm	------

3.1.2. Phase two: green roof sections installation systems

There are two main systems for green roofs at general:
1) built-in-place green roof system and, 2) green roof module system [27].

- Built-in-place green roofs: this system is used in most conventional green roofs, which consists of series of components that must be installed in layers on a roof surface. See Figure (2).

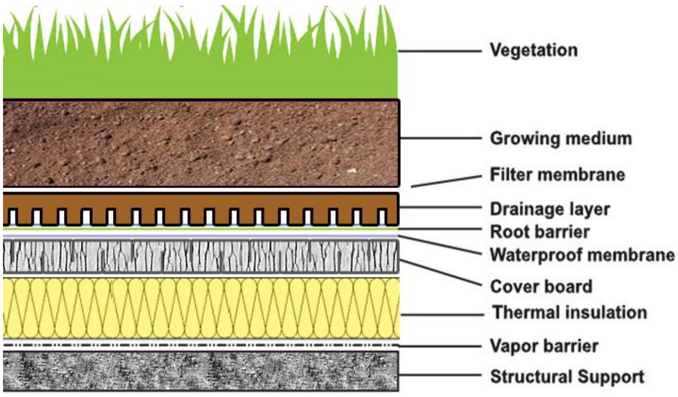


Figure 2: Typical layers for a green roof.

- Green roof module system: basically, modular design tries to subdivide a system into small standard parts that are easily interchangeable. For green roof systems, modular designs are often self-contained, pre-planted blocks giving an instant greening effect and greater design flexibility. Module system is essentially green roof plants grown in movable trays or crate [28].

Nowadays, tray systems are the most commonly found modular green roofs in practice. Often, plastic interlocking containers are filled with a drainage system, growing media, and vegetation layer. The tray system can easily be removed or replaced without affecting the original structure or other plants [29].

In Egypt, wooden tables system is used for the production of crops that do not require a large space for the growth of plant roots such as leafy crops used (arugula, radishes, parsley).

3.1.3. Phase three: green roof section design

Green roof sections at residential buildings in Egypt are designed and calculated as follows:

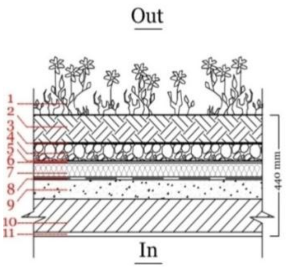
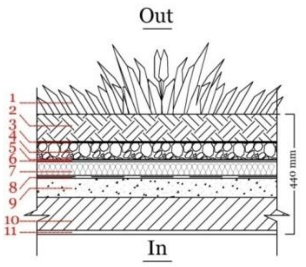
- Green roof sections shape.
- Green roof sections layers' calculations.
- Green roof whole sections' calculations.

Green roof sections shape

This part shows the design of green roof sections above the roofs of residential buildings in Egypt, according to the layers of traditional green roofs, and the variables of each layer of the green roof layers.
Based on the previous green roof layers' variables:
There are (three vegetation type: (sedum, grass & shrubs) × three soil type: (rice husk, pumice-sand & clay soil) × three depth of soil: (100 mm & 150 mm & 250 mm) × two soil moisture degree × two thickness of concrete slab: (120 mm & 200 mm) = 96 valid green roof sections.)
The following illustration is an example of designed green roof sections; see Table (2) which presents:

1. The description of the green roof section included thickness of reinforced concrete slab, vegetation type, growing media type and moisture.
2. Green roof sections shape.
3. Green roof sections layers.

Table 2: Example of designed green roof sections

Description	Inverted roof section (120 mm reinforced concrete) with sedum as a vegetation layer & rice husk (10% moisture 100mm)	Inverted roof section (120 mm reinforced concrete) with grasses as a vegetation layer & pumice , sand soil (55% moisture 100 mm
Sections shape		
Sections layers	1. Sedum (vegetation layer) 2. Rice husk soil 3. Filter sheet 4. Drainage layer 5. Root barrier 6. Waterproof layer 7. Thermal insulation 8. Vapor barrier 9. Ordinary concrete 10.reinforced concrete 11. Internal plaster	1. Grass (vegetation layer) 2. Pumice, sand growing media 3. Filter sheet 4. Drainage layer 5. Root barrier 6. Waterproof layer 7. Thermal insulation 8. Vapor barrier 9. Ordinary concrete 10.reinforced concrete 11. Internal plaster

Green roof sections layers' calculations

(Material - Physical properties - Thermal properties – loads on the roof properties)

This part calculates the physical properties and thermal characteristics of each layer of the designed green roof sections, such as (density, specific heat, thermal conductivity, and thermal transmittance).

Green roof whole sections calculations

(Physical properties - Thermal properties - Loads on the roof properties)

This part calculates the physical properties and thermal characteristics of each designed green roof section as a whole.

3.2. Evaluation of green roof sections according to Egyptian climate zones

The application of green roofs sections that have been designed on the various climatic regions of Egypt according to Egyptian energy code to improve energy efficiency in buildings, through the evaluation of these sections in terms of:

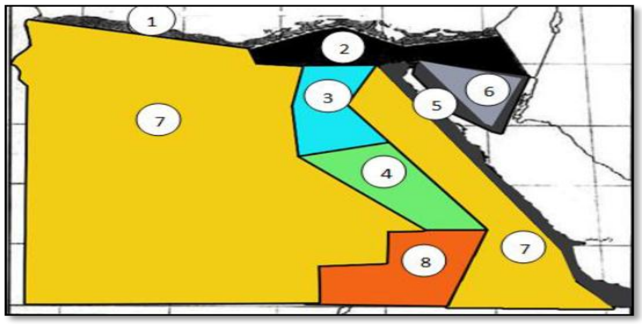
- Green roof sections function evaluation.
- Green roof sections thermal energy evaluation.
- Green roof sections electricity energy evaluation.
- Green roof sections environment evaluation.

3.2.1. Green roof sections function evaluation

In the Egyptian code, Egypt was divided into eight climate zones, see table (3), each of the climate zones was clarified and cities located in it were defined, and the allowed R-value for roofs at un-conditioned and conditioned buildings is stated, see table (4).

Where: R-value for section before and after insulation ≥ R-value allowed.

Table 3: Eight climatic regions of Egypt



	Climate zone	Egyptian cities
1.	North Coast Region.	El Arish-Port SaidDamietta-Elbehera-Alexandria-MarsaMatrouh-Salloum
2.	Delta & Cairo Region.	Cairo- Garabiyh - Dakahlia - Sharkiha
3.	Upper Egypt "north part" Region.	BeniSuef - Fayoum - Minya
4.	Upper Egypt "southern part".	Assiut - Sohag - Qena until Edfu
5.	Eastern Coast Region.	Hurghada - Suez - MarsaAlam - RasSidr - Sharm el Sheikh - Taba - Dahab
6.	Heights region.	St. Catherine - Tur
7.	Desert region.	Bahariya Oasis - Siwa - Farafra - aldakhlh - Owaynat
8.	South Egypt Region.	Aswan - Toshka - Abu Simbel

Table 4: R-Value allowed for roofs at Egyptian region and city at energy code

	Region	**City**	**Building Type**	**≥ R-Value Allowed** ($m^2.c°/watt$)
1	North Coast Region	Alexandria	Un-Conditioned	2.15
			Conditioned	2.50
2	Delta & Cairo Region	Cairo	Un-Conditioned	2.70
			Conditioned	2.70
3	Upper Egypt "north part" Region	El-Minya	Un-Conditioned	2.80
			Conditioned	2.80
4	Upper Egypt "southern part" Region	Asyut	Un-Conditioned	2.15
			Conditioned	3.00
5	Eastern Coast Region	Hurghada	Un-Conditioned	2.20
			Conditioned	2.50
6	Heights region	El-Tur	Un-Conditioned	3.00
			Conditioned	3.00
7	Desert region	El-Kharga	Un-Conditioned	3.00
			Conditioned	3.00
8	South Egypt Region	Aswan	Un-Conditioned	3.00
			Conditioned	3.00

3.2.2. Green roof sections thermal energy evaluation

The Egyptian energy code sets the thermal requirements for cities at different regions in Egypt
Where:

- Δ T (C°): The difference between the degree of internal and external design temperature.
- Cold day degree (CDD): The total daily number of hours of the temperature difference between 25 C^{O} as a bases degree and the higher degree in the dry air, in the hot days which needs cooling.
- Hot day degree (HDD): The total daily number of hours of the temperature difference between 18 C^{O} as a bases degree and the lowest degree in the dry air, in the cold days which needs heating.

Calculate rate of heat transfer in summer (Q Summer) , winter (Q Winter), and avarege in All Year (Q Year)

$$Q_{Summer} = A \times U \times \Delta T_{Summer} \quad (1)$$

$$Q_{Winter} = A \times U \times \Delta T_{Winter} \quad (2)$$

$$Q_{Year} = (Q_{(Summer)} + Q_{(Winter)}) / 2 \quad (3)$$

Where:

A = Unit area m2
U = Thermal Transmittance watt/m^2.c°
ΔT_{Summer}............C^{O}

Equation 1, 2, 3: Calculate Rate of Heat Transfer in summer, winter, average in year [31, and 32].

3.2.3. Green roof sections electricity energy evaluation

The following table shows the Δ T & DD at Egyptian regions and cities at energy code according to Egyptian energy code [30].

Table 5: Δ T & DD at Egyptian Region and City at Energy Code

	Region	City	Δ T (C°)		DD	
			Summer	Winter	CDD (25 C^{O})	HDD (18.3 C^{O})
1	North Coast Region	Alexandria	12	13.7	153	469
2	Delta & Cairo Region	Cairo	13	7.7	296	344
3	Upper Egypt "north part" Region	El-Minya	16	10.1	392	539
4	Upper Egypt "southern part" Region	Asyut	17	8.9	551	595
5	Eastern Coast Region	Hurghada	11	6	635	142
6	Heights region	El-Tur	9	8	100	830
7	Desert region	El-Kharga	13	8	1328	261
8	South Egypt Region	Aswan	15	7.9	1278	127

Calculate rate of electricity consumption in summer reduction (E- Summer)& winter (E Winter), and avarege in All Year (E Year)

$$E_{Summer} = U \times A \times CDD \times 24 \times 10^{-3} \quad (4)$$

$$E_{Winter} = U \times A \times HDD \times 24 \times 10^{-3} \quad (5)$$

$$E_{Year} = (E_{(Summer)} + E_{(Winter)}) / 2 \quad (6)$$

Where:

A = Unit area m^2
U = Thermal Transmittance watt/m^2.c°

Equation 4, 5, 6: Rate of Electricity Consumption in summer, winter, average in year [32-34].

3.2.4. Green roof sections environment evaluation

calculate CO_2 production at case of coal plant

coal plant (kg/m^2/day)

CO_2Production in Summer = $\mathbf{E_{Summer}}$ (kwh/m^2/day)× **0.9** (7)

CO_2 Production in Winter = $\mathbf{E_{Winter}}$ (kwh/m^2/day)× **0.9** (8)

CO_2 Production in All Year = $\mathbf{E_{Year}}$ (kwh/m^2/day)× **0.9** (9)

Equation 7, 8, 9 Calculate CO2 Production at Case of Coal Plant [34, and 35].

Calculate CO_2 production at case of mixed solar/fossil integrated solar combined plant mixed solar/fossil integrated solar combined plant (kg/m^2/day)

CO_2 Production in Summer = $\mathbf{E}_{\mathbf{Summer}}$ **(**kwh/m^2/day**)**× **0.3** (10)

CO_2 Production in Winter = $\mathbf{E}_{\mathbf{Winter}}$ **(**kwh/m^2/day**)** × **0.3** (11)

CO_2 Production in All Year = $\mathbf{E}_{\mathbf{Year}}$ **(**kwh/m^2/day**)** × **0.3** (12)

Equation 10, 11, 12: Calculate CO2 Production at Case of Mixed Solar/Fossil integrated solar combined plant [34, and 35].

By the end of this part Green Roof Sections Evaluation there are 96 green roof sections× 8 Egyptian (region-city) = 768 green roof sections.

With the following characterization:

- Rate of Heat Transfer in summer Watt/m^2.
- Rate of Heat Transfer in winter Watt/m^2.
- Average of Rate of Heat Transfer reduction % Watt/m^2.
- Rate of Electricity Consumption in summer kwh/m^2/day.
- Rate of Electricity Consumption in winter kwh/m^2/day.
- Electricity Consumption reduction %.
- CO2 reduction at Case of Coal Plant kg/m^2/day.
- CO2 reduction at Case of Mixed Solar/Fossil kg/m^2/day.
- Weight /m2 (kg/m2) with green roof layers.

As it previously explained, Green roof sections design methodology at residential Buildings according to Egyptian climate zones procedure, is divided into two main phases: 1) Green roofs sections design at residential Buildings in Egypt, 2) Evaluation of Green Roof Sections according to Egyptian climate zones.

The following flowchart concludes the previously discussed design methodology procedures in order to organize the design steps, see Figure (3).

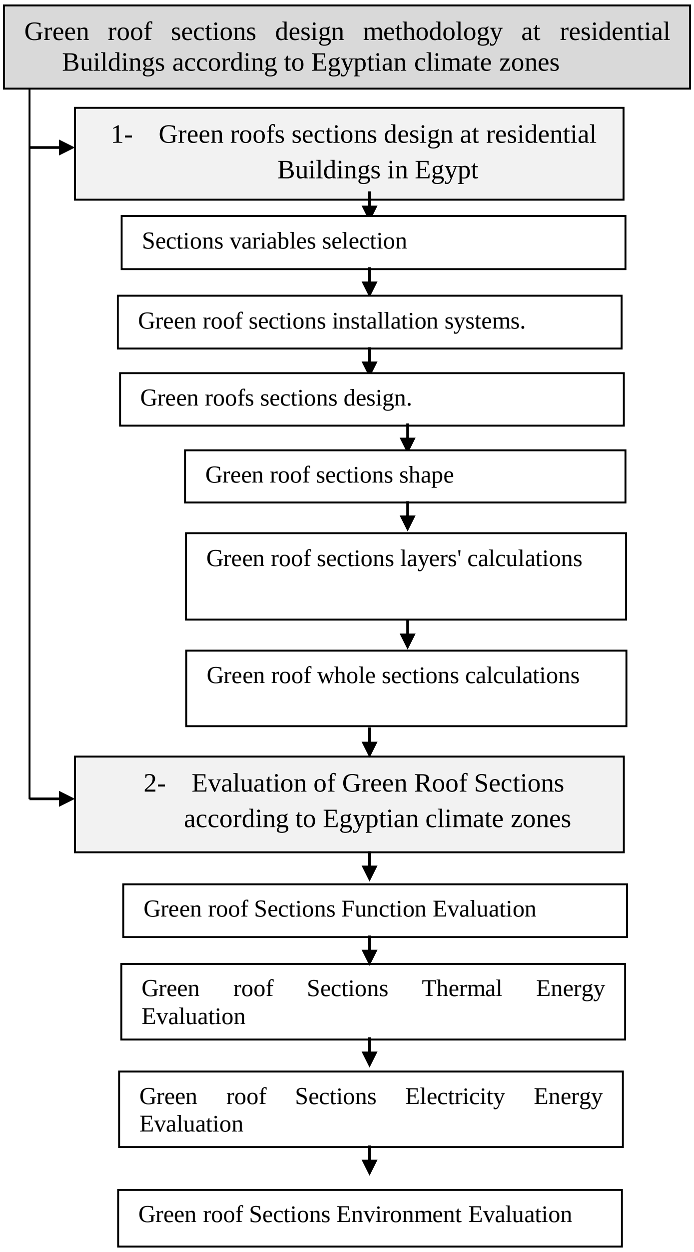


Figure 3: Green roof sections design methodology

4. Green roofs sections selection using green roofs analysis and design software program

A software program named green roofs analysis and design, is made to ease the process of green roof sections selection for the architects, where there are 784 designed and evaluated sections, a computer software program is designed to facilitate the selection, in which, the user enters his design requirements and the computer software program will calculate and analyze the appropriate section according to these requirements and variables.

The Green Roof analysis and design software program performs the green roof sections within a database of 784 green roof sections to estimate the residential roof building energy reduction in Egypt. The outputs from each user provide basic characteristics of a green roof project; produces information for two green roof systems (built-in system, module system). The program can be used in the design and analysis of green roofs sections in Egypt; also it can be used in the research field to compare the impact of different variables which effect on buildings thermal behavior.

5. Discussion and observations

Based on the research calculations by illustrated equations in previous section as well as direct applications through the proposed software program, the results of the green roofs sections have a positive thermal effect. The results showed different behavior depending on the different climate regions.

Best designed sections in terms of thermal performance and energy savings, which can be used in Egypt climate zones, are the sections that use rice husk as growing media with a lower moisture and 250 mm depth, and shrubs as a vegetation layer. It is ranging amount of the value of savings of energy between 67.53% in the northern region regions Delta, up to more than 98% in the desert region and the southern regions in Egypt, see Figure (4).

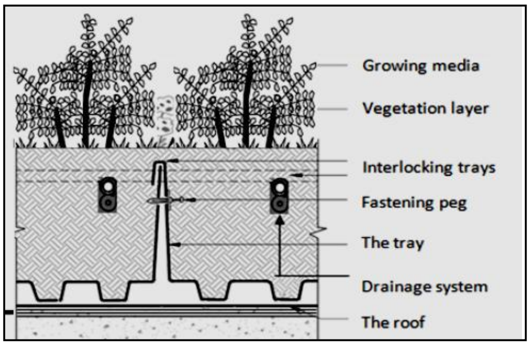


Figure 4: Green roofs section “shrubs as vegetation layer with rice husk as a growing media with 250mm depth”

Finally, Best results are obtained when using green roof sections in the south regions where it achieved maximum energy saving and efficiency insulation compared with the north regions, see Figure (5).

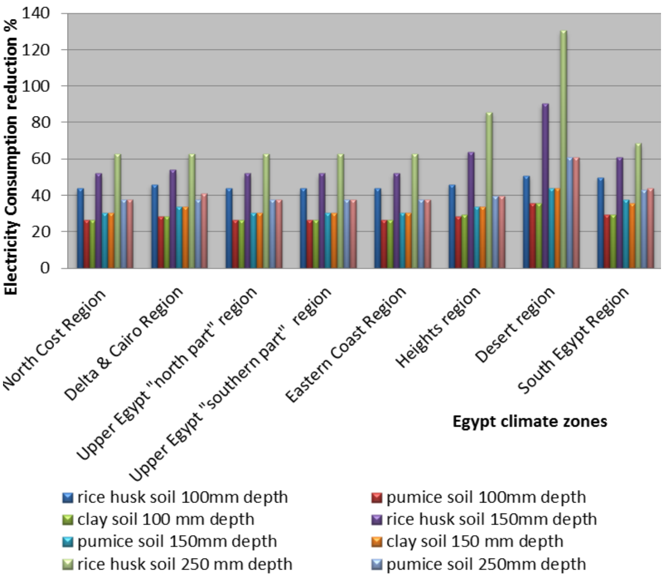


Figure 5: Assessment of the impact of green roofs sections of the climate regions in Egypt.

6. Concluding remarks

The present study mainly deals with design and analysis of the energy performance of green roofs sections in Egypt, and it shows that the green roof sections have a positive thermal impact on the building and have the potential to reduce the energy, especially in south regions at Egypt.

From the evaluation, the use of rice husk gave the best results in terms of the efficiency of insulation compared to the other types of growing media at the study.

7. References

1. United Nations Dept. of Economic and Social Affairs PD, World Urbanization Prospects: The 2014 Revision. New York: United Nations, 2014.
2. Takebayashi, Hideki, and Masakazu Moriyama. "Surface Heat Budget on Green Roof and High Reflection Roof for Mitigation of Urban Heat Island." Building and environment 42, no. 8 ,2007, p 2971-2979.
3. O. Buhairi, Diversion Project rooftops into gardens fruitful. Arab Republic ofEgypt: Hans Seidel Foundation, 2009.
4. M. Fahmy, M. M. Mahdy, and M. Nikolopoulou, "Prediction of future energy consumption reduction using GRC envelope optimization for residential buildings in Egypt," *Energy and Buildings,* vol. 70, pp. 186-193, 2014.
5. M. Assad, O. Hosny, A. Elhakeem, and S. El Haggar, "Green building design in Egypt from cost and energy perspectives," Architectural Engineering and Design Management, vol. 11, pp. 21-40, 2015.
6. A. E. S. Abdelsalam, "The future of green-roofs in Egypt: The economical and environmental benefits when installing green-roof on a residential building in Cairo," CU Theses, 2012.
7. P. Bevilacqua, J. Coma, G. Pérez, C. Chocarro, A. Juárez, C. Solé, M. De Simone, and L. F. Cabeza, "Plant cover and floristic composition effect on thermal behaviour of extensive green roofs," Building and environment, 2015.
8. Snodgrass, C. Edmund, and L. Lucie Snodgrass. Green Roof Plants: A Resource and Planting Guide. Vol. 487: Timber Press Portland, OR, 2006.
9. Carpenter, Sidonie. Growing Green Guide Melbourne and Victoria, Australia: National Library of Australia Cataloguing-in-Publication data, 2014.
10. Yi, Jing. "Economic Analysis of Turfgrass-Sod Production in Alabama." Auburn University, 2012.
11. S. Conti, G. Villari, S. Faugno, G. Melchionna, S. Somma, and G. Caruso, "Effects of organic vs. conventional farming system on yield and quality of huskberry grown as an annual or biennial crop in southern Italy," Scientia Horticulturae, vol. 180, pp. 63-71, 2014.
12. M. Santamouris, "Cooling the Cities–a Review of Reflective and Green Roof Mitigation Technologies to Fight Heat Island and Improve Comfort in Urban Environments." Solar Energy 103 (2014): 682-703.
13. Ministry of Agriculture and Land Reclamation, Agricultural Research Center, the Central Laboratory for Agricultural Climate, www.clac.edu.eg, 24/8/2015, 11:36pm.
14. D.J. Sailor and M.Hagos, "An updated and expanded set of thermal property data for green roof growing media," Energy and Buildings, pp. 2298–2303, 2011.

15. L. Carter, Timothy, and c.Todd Rasmussen."Hydrologic Behavior of Vegetated Roofs1" Wiley Online Library, 2006.
16. A. Bunt, Modern potting composts: a manual on the preparation and use of growing media for pot plants: Springer Science & Business Media, 2012.
17. N. Carroll, University of Strathclyde, p15-17. Thermal and Rainwater Runoff Performance of an Extensive Green Roof System,2010.
18. Mentens, Jeroen, Dirk Raes, and H. Martin. "Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st Century?". Landscape and Urban Planning 77, no. 3 2006, 217-26.
19. Guidelines on Design Loads for Rooftop Greenery Cuge Standards. Cs E, Skyrise Greenery; Cs E01: 1st ed. ed.: Singapore: Centre for Urban Greenery and Ecology, 2010, p1-22.
20. "Al-Ahram Weekly | Environment | May your roof be green". Weekly.ahram.org.eg. 8 June 2005. Retrieved 25 April 2012.
21. R. S. El-Emam and I. Dincer, "Modeling of Fluidized Bed Gasification of Rice Husk in Egypt," in Progress in Clean Energy, Volume 1, ed: Springer, 2015, pp. 57-71.
22. M. Allam, G. Garas, and H. El Kady, "Recycled Chopped Rice Husk-Cement Bricks: Mechanical, Fire Resistance & Economical Assessment," Australian Journal of Basic and Applied Sciences, vol. 5, pp. 27-33, 2011.
23. A. A. Ramezanianpour, "Rice Husk Ash," in Cement Replacement Materials, ed: Springer, 2014, pp. 257-298.
24. Y. Matsumura, T. Minowa, and H. Yamamoto, "Amount, availability, and potential use of rice husk (agricultural residue) biomass as an energy resource in Japan," *Biomass and Bioenergy*, vol. 29, pp. 347-354, 2005.
25. H. Gao, Y. Liu, G. Zeng, W. Xu, T. Li, and W. Xia, "Characterization of Cr (VI) removal from aqueous solutions by a surplus agricultural waste—rice husk," *Journal of Hazardous Materials*, vol. 150, pp. 446-452, 2008. 4 Abdel –Sattar, Mohamed Anwar and Hanan El-Marzooki.
26. Liu, Ziyang. "Prediction of Soil Layer R-Value Dependence on Moisture Content." (2011).
27. D. J. Mischo, "Modular green roof system, apparatus and methods, including pre-seeded modular panels," ed: Google Patents, 2005.
28. H., Doshi, et al., Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto, Ryerson University, Ontario, Canada, 2005.
29. N. Dunnett, N. Kingsbury, Planting Green Roofs and Living Walls, Timber Press, Oregon, 2004.
30. Utilities and Urban Development the Ministry of Housing, Egyptian Thermal Insulation Code, 2006.
31. R. Serway and J. Jewett, Physics for scientists and engineers with modern physics: Cengage learning, 2013, 6 th edition, p626.
32. National Center for Residential and Building Researches, Egyptian Thermal Insulation Code, Egypt, 2008.appendix D, p109.
33. M. Nassief. Evaluation of Electricity Consumption of a Residential Flat in Egypt American Journal of Electrical Power and Energy Systems. Vol. 3, No. 2, 2014, pp. 37-44. doi: 10.11648/j.epes.20140302.14
34. N. Abu-Samra, "Impact of Nano Technology on Building Envelope." PhD thesis Port Said University, 2013.p256
35. G. El-Rayies, Economic Maximizing the Exploitation of Daylight by Using the Green System to Achieve the Savings of Cost Energy, PhD thesis, Department of Architecture, Faculty of Engineering, University of Suez Canal, Port Said, 2010.