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2.1 Introduction

Buildings are the major consumers of energy and material resources and significant polluters of the environment during all stages of their entire life cycle. Buildings are responsible for more than thirty sixpercentof global energy use and contribute up to thirty percent of global annual greenhouse gas emissions [1]. Negative impacts from each stage of building life cycle on the environment are a result of the following factors: the depletion of non-renewable raw materials and energy sources, pollution and contamination by harmful emissions, the negative effect of technology on the environment (noise, vibration etc.), excessive water consumption and faster depletion of renewable sources than their ability to regenerate. [2]

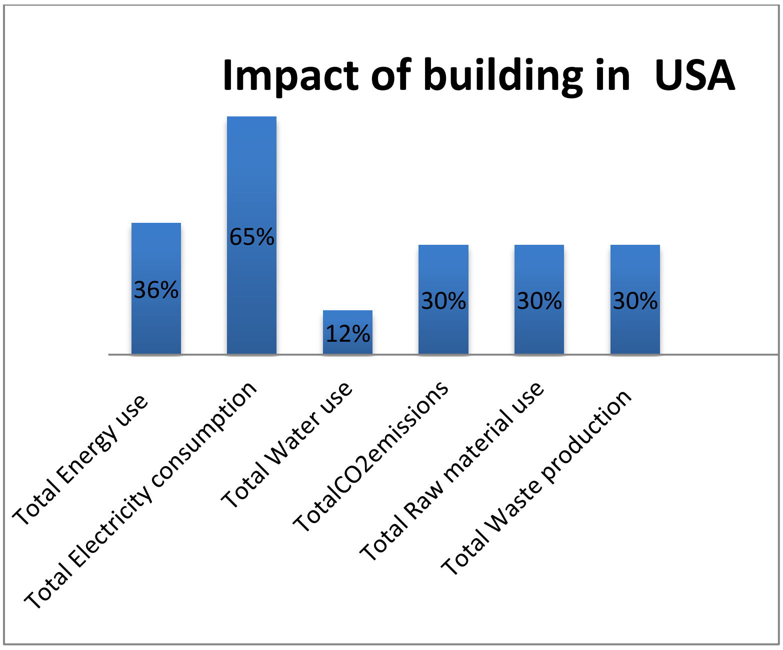

Figure 2.1 Impact of building (sources ,waste) on environment [1].

Green buildings are characterised as those providing the required building performance over the building life-cycle whilst minimising consumption of non-renewable resources and the environmental loadings to land, air and waters. [3]. However, the assessment of new buildings covers only performance aspects from the initial planning stage through to building completion. Actual performance during building use depends on what has been achieved in terms of improved design and construction quality, as confirmed by final testing and commissioning, the quality of management, operation and maintenance practices, as well as the activities of building users[4].

2.2 Sustainable Buildings

Buildings have massive direct and indirect impacts on the environment, society, and the economy, which are commonly referred to as the 3 P's ('People', 'Planet', 'Pocketbook') [5].

The main objectives of sustainable design are to reduce depletion of critical resources like energy, water, land, and raw materials; prevent environmental degradation caused by human activities, and create an environments that are safe and comfortable[6].

Buildings use resources (energy, water, raw materials, etc.) and generate waste (solid waste, wastewater), and emit potentially harmful atmospheric emissions, and fundamentally change the function of land, and the ability of that land to make self-purification [7].

Sustainable design attributes reduces operation costs and environmental impacts, and can increase building resiliency. The "embodied energy" of the existing building (a term expressing the cost of resources in both human labor and materials consumed during the building's construction[8].Table2.1 presents the most prominent Criteria of sustainable design.

Table 2. 1 set of three-dimensional sustainability criteria (environmental, social and economic) [5].

Social	Environmental	Economical
Convince for user	Waste recycling	Affordability
Safety	Green space	Business opportunities in the area
Community organization	Access to service	Resource conservation
Location	Resource conservation	Willing to pay more for environmentally friendly housing .
Inside housing condition	Building durability	Community energy tariff
Heritage value of the building	Renewable Energy	
External housing condition	Environmental quality	

2.3 Green Building

There is a need of concentrating on a Green Home, which is one of the most important and one of the most discussed topics throughout the globe, in the age of global warming and climate change worldwide[9].

Green buildings are characterised as those providing the required building performance over the building life-cycle whilst minimising consumption of non-renewable resources and the environmental loadings to land, air and waters[10]. However, the assessment of new buildings covers only performance aspects from the initial planning stage through to building completion. Actual performance during building use depends on what has been achieved in terms of improved design and construction quality, as confirmed by final testing and commissioning, the quality of management, operation and maintenance practices, as well as the activities of building users[11].

"A green building is one which uses less water, optimises energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building" [12] .The practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or 'high performance' building [13].

Buildings can incorporate many green features, but if they do not use energy efficiently, it is difficult to demonstrate that they are truly green. In fact, given that the term "green building" can be somewhat vague, some people prefer to use the term[14].

2.4 Environmental Impacts of Buildings

The buildings affect greatly the surrounding environment either because of its consumption of resources or because of pollution of the environment dramatically. The impact of buildings both in the period construction , operation of demolition is as follow [15].

1- Construction:

Materials Use

- Depletion of non-renewable resources
- Pollution and by products from materials manufacture
- Construction materialspackaging waste

Site Preparation and Use

- Disturbance of animal habitats.

- Destruction of natural vistas.
- Construction-related runoff.
- Soil erosion.
- Destruction of trees that absorb CO_2.
- Water quality degradation from using pesticides, fertilizers, and other.

2- Operation:

Energy Use

- Air pollution: emissions of SO_2, NO_x, mercury, and other heavy metals and particulate matter from power plants; the building's energy consumption; and transportation to the building
- Greenhouse gas (CO_2 and methane) emissions, which contribute to global warming
- Water pollution from coal mining and other fossil fuel extraction activities, and thermal pollution from power plants
- Habitat destruction from fuel extraction

Building Operations

- Runoff and other discharges to water bodies and groundwater
- Groundwater depletion
- Changes in microclimate around buildings and urban heat island effects
- Ozone-depleting substances from air conditioning and refrigeration
- Water consumption
- Production of wastewater that requires treatment
- Production of solid waste (garbage) for disposal
- Degradation of indoor air quality and water quality from using cleaning chemicals

3- Demolition

- Demolition waste (used steel, concrete, wood, glass, metals, etc.)
- Energy consumption for demolition
- Dust emissions
- Disturbance of neighboring properties
- Fuel use and air pollutant emissions associated with transporting demolition waste

2.5 Green Roof

A green roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a Water proofing membrane. It may also include layers such as a root barrier , drainage and irrigation systems.[16] Container gardens on roofs, where plants are maintained in pots, are not generally considered to be true green roofs, although this is debated. Rooftop ponds are another form of green roofs which are used to treat greywater.[17] Vegetation, soil, drainage layer, roof barrier and irrigation system constitute green roof.[18]

Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape, and helping to lower urban air temperatures and mitigate the heat island effect.[19] Green roofs are suitable for redevelopment projects as well as new buildings and can be installed on small garages or larger industrial, commercial and municipal buildings.[16] They effectively utilize the natural functions of plants to filter water and treat air in urban landscapes.[20] There are two types of green roof: intensive roofs, which are thicker, with a minimum depth of 12.8 cm (5.0 in), and can support a wider variety of plants but are heavier and require more maintenance, and extensive roofs, which are shallow, ranging in depth from 2 cm (0.79 in) to 12.7 cm (5.0 in), lighter than intensive green roofs, and require minimal maintenance.[21]

The term green roof may also be used to indicate roofs that use some form of green technology, such as, a roof with solar thermal collectors or photovoltaic panels.

2.6 History of Green roofs

In ancient times green roofs consisted of cave like structures or sod roofs covered with earth and plants commonly used for agriculture, dwelling, and ceremonial purposes. These early shelters provided protection from the elements, good insulation during the winter months, and a cool location in the summer. Unfortunately for modern conveniences, these were neither waterproof nor was there any system to keep out unwanted burrowing wildlife.[22]

The origins of green roofs began thousands of years ago. One of the seven wonders of the world, the Hanging Gardens of Babylon, are perhaps the first example of draping buildings in flora to make them more appealing. Built in what is now Iraq around 500 BC, they were designed by King Nebuchadnezzar II for his wife who missed the green fields and flowers of her homeland. The gardens were grown over stone pillars and roofs which were waterproofed with layers of reeds and tar. Plants and trees were then planted. In more recent times, people used sod to cover their roof tops for the purpose of insulation, it kept their homes cool in summer and warm in winter. Modern green roofs may have had their "roots" in ancient times but technological advances have made them far more efficient and expensive than their ancient counterparts.[23]

Modern green roofs, which are made of a system of manufactured layers deliberately placed over roofs to support growing medium and vegetation, are a relatively new phenomenon. However, green roofs or sod roofs in northern Scandinavia have been around for centuries. The modern trend started when green roofs were developed in Germany in the 1960s, and has since spread to many countries. Today, it is estimated that about 10% of all German roofs have been “greened”[24].

Modern green roof technology began in the early seventies in Germany when the first green roof systems were developed and marketed on a large scale. Unlike former “green roofs” this first approach offered reliable technology that provided sophisticated irrigation and protection against root ingress for rooftop gardens.[23]

The second big step was the development of extensive green roofs in the late eighties. The goal was to create lighter and cheaper systems which could be applied to large flat roofs. The main motivation for extensive green roofs was the restoration of nature and protection of the roof membranes from the elements and temperature fluctuations. [22]

In the 18 and 19th centuries in North America, prairie settlers took green roofing to the extreme when building their homes. Because there was a lack of trees to build cabins, many constructed dwellings out of pure sod, with the ‘bricks’ laid root side up so that they would grow into the one another, creating a more solid foundation.

By the early 1900s, Germany was building flat green roofs in urban areas and continued to do so throughout the century. In the 1970s, when the oil crisis was at its height, Germany was one of the first countries to investigate the use of green roofs for energy conservation and by the middle of the noughties there were an estimated 13 million square meters of roofing in the country covered with greenery.

In America, New York has made a big push for green roofs in the last few years to help create a better environment and reduce the effects of rain from storm downpours on the city’s infrastructure. The first green roof in New York, however, was actually built on the Rockefeller Centre in the mid-1930s.

There’s no doubt that in the historical sense green roofs were created either because of convenience or to create something aesthetic the owner could enjoy. More and more in recent years, we are coming to understand the ecological and energy efficiency properties of constructing something like a green roof in towns and cities across the world[23].

Figure2.2. Greenroof technology originated in Germany over 30 years ago[23].

2.7 Benefits of Green Roofs

- **Esthetic**

They offer an attractive alternative to standard roofs due to presence of vegetation that attracts different birds, insects, and similar animals[25].

Commercial and industrial roofs no longer need to be eyesores of endless concrete, asphalt or gravel. They certainly are unattractive, to say the least, and aesthetics are rarely considered in their design. intensive green roofs could alleviate the harsh, stark anddownrightuglyviews[26].

- **Environmental**

1. Green roofs reduce “heat island” effect, creating a favorable micro-climate. If constructed and maintained properly, they can lower the concrete temperature even for about 40°C in summer days. Therefore, the ambient temperature is lower for a couple of degrees during summer months.as it shown on figure2.3 [27]

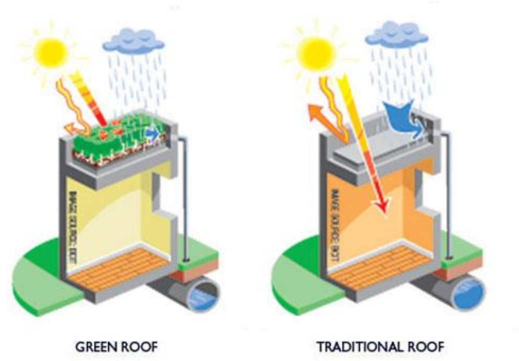

Figure 2.3 Green roofs reduce “heat island” effect[28].

2. Vegetation absorbs air pollution and, therefore, air is cleaned from carbon monoxide, lead and other adverse pollutants induced by traffic, industry, etc.
3. Green roofs absorb precipitation and reduce the excess weight on sewage system during rain and snow melting, and this water is being returned to the atmosphere through evaporation. Moreover, investment into sewage system to prevent possible flooding is not necessary, but the city authority also benefit from green roofs.as it shown on figure2.4

Figure2.4 Provides Rainwater Management[29]

4. Reduce noise level for about 50 dB (which is at the ado level in a restaurant).
5. Except esthetic effect, green roofs offer habitats for birds, insects and small animals, contributing to the conservation of biodiversity of these species.
6. They increase environmental awareness of local population.

- **Economical**

1. Green roofs act as thermo-insulators so the building on which they are constructed is colder during summer and warmer during winter. This contributes to preservation of energy which would normally be spent for air conditioning and heating. as it shown in figure 2.5

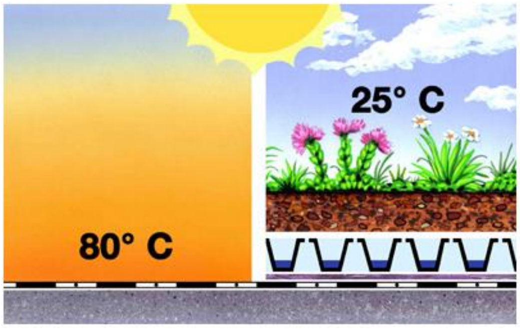

Figure 2.5 Green roofs act as thermo-insulators[30].

2. Buildings with this architectural solution have a higher market value so the invested funds often pay off when selling the property.
3. Green roofs protect the roof insulation and material from UV radiation and they reduce daily temperature fluctuations, which prolongs the roof system lifetime sometimes even double.

2.8Types of green roofs

According to the International Green Roof Association (IGRA), green roofs are divided into three types: **intensive**, **semi-intensive** and **extensive** green roofs. as shown on Figure 2.6 This division is based according to the green roof construction (which depends on the depth of the growing media). Construction choice depends on several conditions such as roof slope, financial investments, maintenance possibilities, climate conditions, purpose of use, construction of the building itself, etc.

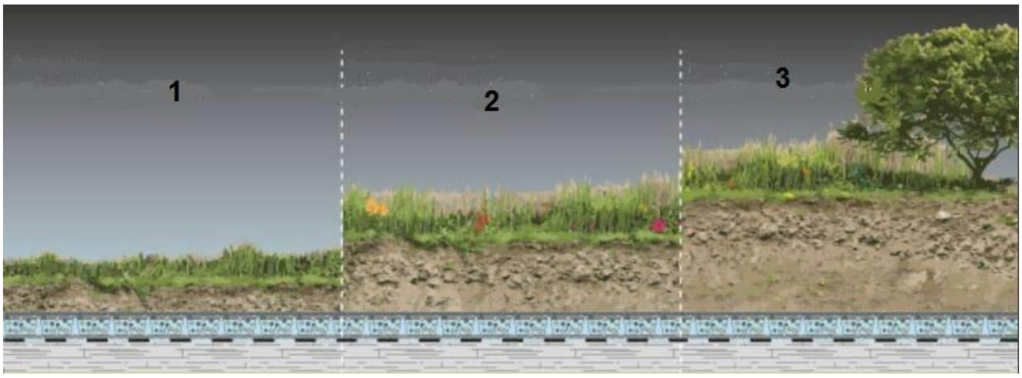

Figure 2.6 Green roof types: 1.extensive , 2.semi-intensive , 3.intensive

- **Extensive type**

Extensive green roofs are thinner, growing medium depth is from 2-10 cm, and they allow installation of vegetation that is less demanding in maintenance and is suitable for life in extreme environmental conditions (drought, direct sunlight, etc.). these plants are moss, grass, and low growing plants of 5-25 cm in height, and succulents (plants which retain higher amounts of water in their body) are also suitable. These roofs are relatively easy to install, they are economical, easier to maintain and often do not require an additional structural support (extra weight to the building accounts for around 100 kg/m2). Despite everything, extensive green roofs still have high ecologic and energy values. Their maintenance should be done once per year.

- **Semi-intensive type**

This type of green roofs is designed with vegetation of medium height, from 25-50 cm, and growing medium depth is around 20 cm (extra weight to the building accounts for around 250 kg/m2). This type is actually a combination of intensive and extensive green roofs. Maintenance is required every 6 months and plants are usually those from reed family as well as middle-growth sedums, which are easy to maintain.

- **Intensive type**

The depth of intensive roofs' growing medium normally ranges from 10-50 cm but it can also be deeper. This allows for installation of vegetation that leaves the impression of real gardens, due to the presence of bushes, flowers, lawns and even small trees up to 4 meters in height, creating an ideal green oasis within urban environment. However, due to the depth of the growing medium, amount of vegetation and presence of drainage layers, these roofs are very heavy (extra weight to the building accounts for around 400 kg/m2). Therefore, it is necessary to install necessary structural elements which would support the green roof construction. A civil engineer should be consulted for these calculations. Moreover, trees have to be additionally secured as there is danger from plucking and falling during storms and high winds. This type of green roofs requires intensive maintenance (every month), irrigation, plant care, etc.

2.8.1 Comparative review

The following layers are other standard layers: roof thermal insulation, hydro insulation, etc. This construction applies for designing flat green roofs, where roof slope is less than 8 degrees.Table 2.2 shows a comparison among the three basic green roof types:

Table 2.2 Green roof types[31].

Type	Extensive	Semi-intensive	Intensive
Depth (growing medium+ vegetation)	6 – 20 cm	12 – 25 cm	15 – 60+ cm
Excess weight	60 – 150 kg/m²	120 – 200 kg/m²	180 – 400+ kg/m²
Plants	Mosses, sedums, cactus, herbs and some grasses	Several perennials, sedums, ornamental grasses, herbs and small shrubs	Perennials, lawns, shrubs and trees
Irrigation	No, not recommended	Partly, when needed	Yes, automatic/manual
Maintenance	Low	Middle	High

Construction	Fast	Fast	Slower
Use	Esthetic	Diversity, habitat	Garden, park
Costs	Low	Middle	High

2.9 Components of green roofs

When designing a green roof, the components required will depend on the type of vegetation specified and how the balance between water retention and drainage is achieved to meet the demands of the vegetation and of the local rainfall levels.In general it consists mainly of several components its shown on Figure 2.7.

Figure2.7 Green roof components

1. Vegetation – the choice of plants depends on the type of a green roof, climate conditions, roof slope, surrounding vegetation, etc. in general, intensive green roofs support a bigger amount and weight of vegetation (such as perennials, bushes, smaller trees, etc.), extensive green roofs support mainly lawns, sedums, smaller perennials, etc., while semi-intensive roofs are a transitional form between the two and support bulrush, smaller bushes, flowers, lawns, etc[27].

2. Growing medium – the depth of this layer depends on the green roof construction type. It is made of mineral and organic components in an appropriate ratio which is suitable for plant growth. Usually, additional mineral materials are added as the soil is shallow and plants are growing in unfavorable environmental conditions. When a plant has enough food in the soil (mineral materials) its roots will not spread extensively and damage other construction layers of the green roof. Moreover, soils with too much organic material should be avoided as they encourage extra energetic plant growth. The depth of this layer ranges from minimum 2 cm for extensive roofs, to more than 10 cm for intensive ones[27].

3. Filter material – prevents fine particles from being washed into the drainage layer, i.e. allows only water and a part of the roof to ..

The main function of the filter fabric/membrane is to hold the engineered soil in place and still prevent small media particles, such as plant debris and fines, from entering and clogging the drainage layer below. Air and water are thus permitted to flow through while the drainage layer and the actual drains are protected.[33]

.**4. Drainage layer** – drains the water surplus from the growing media and it allows the root to breathe as the air is available in cavities of this layer. This is important in order to prevent plant roots from rotting due to excess water in the soil. Moreover, it serves to store rainwater which plants use during dry periods. It can be made of different materials: several types of plastic channels, or simply any granulated material such as gravel, brick rubble, lava stone, sand, pumice, pebbles, vermiculite, etc. a special attention should be put to drainage layer material weight and find a compromise among the price, weight, and water retention capability. Drainage layer is not necessary for roofs with slope greater than 7 degrees; moreover, in that case it is unfavorable as it leads to the growing medium drying out too quickly[27].

6. Protection material – Protection materials or boards are used to protect the waterproof membrane from damage following installation. The most common materials used are water-permeable, hard wearing and dense synthetic fibers Protection matting is installed directly on the waterproofing layer (for root-resistant membranes) or atop the installed root barrier layer, providing further (uncertified) protection against root penetration and doubling as a separation sheet. The protection matting may provide some noise-absorbing capability[32]

7. Root-protection barrier – It is a plastic layer that prevents root expansion and prevent penetrating the roof of the building (Reinforced concrete) .The waterproof membrane can be dispensed If Root-protection barrier have sufficient features to protect surfaces from water leakage And coating the bottom layer to prevent surface rot.