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GREEN-ROOF TECHNOLOGY (GRT) DEVELOPMENT FOR THE ABATEMENT OF POLLUTION AND RADIATION IN THE CITIES INFLUENCED WITH INDUSTRIAL POLLUTION

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ABSTRACT

As land continues to be replaced with impervious surfaces due to population growth and urbanization, the necessity to recover green space is becoming increasingly critical to maintain environmental quality especially influenced by industrial growth. The primary objective of this project by installing green roofs is one option that can reduce the negative impact of industrial development while providing numerous environmental, economic, and social benefits. They can reducing runoff and improving water quality, conserve energy, mitigate the urban heat island, increase longevity of roofing membranes, reduce noise and air pollution, sequester carbon, increase urban biodiversity by providing habitat for wildlife, provide space for urban agriculture, provide a more aesthetically pleasing and healthy environment to work and live, and improve return on investment compared to traditional roofs. Green roofs are known to reduce the electromagnetic radiation from wireless devices like mobile tower and mobile.

Rapid runoff from roof surfaces can exacerbate flooding, increase erosion, and may result in raw sewage that is discharged directly into our rivers. The larger amount of runoff also results in a greater quantity of water that must be treated before it is potable. A major benefit of green roofs is their ability to absorb rainwater and release it slowly over a period of several hours. Green roof systems have been shown to retain 40-60% of the rainwater they receive. In addition, green roofs have a longer life-span than standard roofs because they are protected from ultraviolet radiation and the extreme fluctuations in temperature that cause roof membranes to deteriorate. Vegetation helps cool the membrane and the building during the summer as the plants and growing substrate act as an insulation layer, they shade the roof and through evapo-transpiration. Furthermore, the construction and maintenance of green roofs provide business and employment opportunities for roofing contractors, plant producers, landscape designers and contractors, and other green industry members while addressing the issues of environmental stewardship.

This paper explains the concept which will helps in maintaining the local environment with healthy and aesthetic surroundings. Moreover, the idea in this paper will also covers the central government mission "Swakhsa Bharat", "Make in India", "Swarojgar Yogna" and "Kausal Vikash" with sustainable environmental development.

Keywords: Air pollution, eco-roofs, green roofs, roof gardens etc.

I. CITIES INFLUENCED WITH INDUSTRIAL POLLUTIONS

Mining in India is being surrounded by major industries, major power plants and coal washeries supporting power generation and major industrialization. Due to mining the land use changes from original topography and land degradation had taken place in great ways. Cumulative effects of intensive mining and old quarries had resultant air, noise, surface and ground water with land pollution reduced the vegetation and agriculture in this area. The utilization of coal in power plant generation fly ash as a waste product resultant air water and land pollution. This can be accessed through environmental impact assessment and environmental management plan. Overall this has resultant in the major changes in socio-economic. But the quality of life has been affected in this area with all other developments (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 45, 66, 78, 87, 100, 102, 105, 106, 107, 122, 123, 124, 129, 131, 132, 140, 142 and 145).

The effect of mining through modeling and simulation were assessed for effective environmental management to achieve sustainable development (47, 49, 69, 70, 71, 72 and 73).

Flora and fauna drastically affected due to many environmental pressure. This leads to changes in the availability of terrestrial and aquatic flora and fauna with avian species. In this connection a study has been undertaken to investigate the availability of different algal biodiversity which is a very good indicator of different type of environment. Algae have different potentiality for the sustainable development of this disturbed area (108, 110, 111, 113, 114, 115, 116, 118, 119, 120, 127, 133, 134 and 141).

Water environment is most concern in the mining areas. For the reclamation of wastewater with land, bio-approach is effective one to restore many things.

Through this approach solve the food and environmental problems in this area (31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 46, 48, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 65, 67, 74, 75, 79, 80, 81, 82, 83, 84, 85, 90, 91, 92, 93, 94, 96, 104, 109 and 135).

The bio-treatment of polluted water vis-a-vis socioeconomic development had found effective in this area. Bio-purification also include using algae (62, 63, 64, 68, 76, 77, 86, 88, 89, 95, 97, 98, 99, 101, 103, 112, 117, 121, 125, 126, 128, 130, 136, 137, 138 and 139).

The task of finding, developing and maintaining suitable water supplies has not been limited to modern times. It has had to be faced wherever large numbers of people have crowded together in small spaces; and therefore the popular indifference towards safe, clean water has prevailed.

Planning for the maximum development of our water resources for long time benefit of all our people when properly conceived, can bind together individual and the community, farmer and urbanate as few other conservation activities can do (143). Ponds are valuable water systems and intensively used for production of drinking water, for fisheries

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and bathing with washing of clothes. The ecological nature of many ponds, however have desecrated, mainly as a consequence of eutrophication. Algal diversity in ponds plays an important role in their conservation. More the diversity, more useful is a water body (144). In the present article it has been discussed that how importance the green roof technology for the pollution and radiations abatement (146). The pollution of these industrial city towns would be minimized with sustainable technological development of the green roof technology (GRT).

II. GREEN ROOF TECHNOLOGY (GRT)

The headings Green roofs and roof gardens are terms that are often used interchangeably when referring to a roof that supports vegetation. Professionals, however, draw a distinction between the two types (147); roof gardens are installed for the access and enjoyment of people. They are also costly to build, require intensive maintenance and are heavy in weight due to the deep soil profiles. In contrast, green roofs are lightweight with thin soil profiles and minimal maintenance requirements. They are cheaper to construct as they are installed for environmental performance and visual improvement only. The origin of green roofs can be traced back to the vernacular architecture of various regions, while roof gardens have been documented as being built by the affluent class since ancient times (148). Both green roofs and roof gardens have influenced the modern day green roofing system.

For centuries it has been common to use rooftops as a living space and as an extension of the interior. In hot and cold climates vegetated roofs have been a means of protection from the extreme weather (149). Vegetation on the roof not only provides insulation to the buildings but also additional thermal mass on the roof which offers protection from fluctuations in weather. Soil covered huts in warm climates of Tanzania are known to have reduced summer cooling requirements (147) while Northern European countries are protected from the cold (150). It was however, the development of new building materials; construction techniques that encouraged use of greenery on flat roofs.

The first known historical reference to a roof garden above grade is for the stone temples in the region of Mesopotamia (147). Civilizations in Mesopotamia built roof gardens thousands of years ago on the landings of Ziggurats, or stepped pyramids. The plantings of trees and shrubs softened the climb, provided shade and relief from the heat (151).

The next known successors to the roof gardens are the Hanging Gardens of Babylon built by the Persians around the 500 B.C (150). The roof gardens along with being a visual delight cooled the hot landscapes and provided greenery.

In the middle Ages and Renaissance, there were additional demands from the roof gardens and that was to meet the demands of Christian ecclesiastical architecture and wealthy families of the era (148). Palazzo Piccolomini, Pienza, Italy and the Cloister garden at Mont-Saint-Michel at France are classic examples of roof gardens that remain today (148). In Russia, under the czarist rule, roof gardens were considered a luxury by the nobility. Catherine II of Russia (1729-96) commissioned the famous roof garden on the Winter Palace in Saint Petersburg (148).

However it was the development of concrete as a roofing material in the mid 1800’s that lead to widespread creation of rooftop gardens. Planners, architects of the time envisioned cities with roof gardens on flat concrete roofs. The World Exhibition in Paris 1867 was one of the first demonstrations of a planted concrete roof in Western Europe

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(151). Created by Karl Rabbitz it was considered a breakthrough in addressing issues related to modern day green roof gardens, like waterproofing, drainage (148). Thereafter, apartments with planted terraces, gardens and restaurants with roof gardens followed all over the world. Frank Lloyd Wright, Walter Gropius, Le Corbusier further popularized the use roof gardens by using them extensively in their buildings. Corbusier even included them in his five elements towards a new architecture (147).

In the twentieth century, use of roof gardens was promoted through the modernist movement. Roof gardens and terraces fulfilled the demand for a habitable outdoor space at the roof level and at the same time alleviated the lack of hygienic green spaces associated with heavily urbanized areas (151). Gardens built in the 1930s like The Derry and Toms garden in the Kensington section of London and the gardens atop the Rockefeller Center roof in New York still influence modern roof gardens (148).

By end of the twentieth century, green roofs gained more importance as they offered various advantages over conventional roofs and old buildings could benefit too.

The popularity of modern day green roofs can be traced to the European countries where environmentalists, radical groups and scientific research utilized the technology of the time to develop green roof installations. Known to exist for centuries, in form of Sod roofs in Scandinavia, vegetated roofs provided extra warmth and insulation in the cold, wet climate (152). However the susceptibility to leaking, extensive maintenance and frequent replacement, lead to eventual rejection of sod roofs in favor of new leak proof construction techniques.

Other vernacular examples have been recorded in the traditional houses of tropical regions of China and Japan. The summer rainfall was often damaging for the region, but increase in summer humidity levels supported the growth of vegetation on roofs. Plant roots helped in bonding and strengthening of the structure (153) and protected the thatch from washing away. Development of modern building materials reduced the number of traditional green roofs as new roof assemblies were cheaper, easy to construct and required less maintenance.

Contemporary use of green roofs is often attributed to the development of modern building materials and techniques; however the scarcity of land in northern Europe popularized their use (147). In late 1960s groups involved in the counterculture movement of Germany experimented with new ways of living, which can be described as 'greening the city rooftops' movement (151).

Ecologists as well as writers, artists visualized what cities of the future would look like with enormous amounts of greenery. They imagined tower blocks with greenery; flat surfaces planted and plants hanging from balconies, rooftops. This accompanied by publication of books and articles on roof greening in the early 1970's, created awareness about the benefits of green roof systems (151).

III. HISTORY

Today green roofs are being installed in many regions of the world depending on the climate, culture and environmental reasons. In Europe where population is densely concentrated, green roofs are designed as recreational open spaces, in the form of plazas and playgrounds over underground parking garages (150). In this regard, Germany has been the center of green roof development throughout the world for a considerable period. The rapid urban development led to loss of vegetative cover in German cities and the green roofs compensated for the loss of

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landscape. In England, eco roofs are designed to provide habitat for bird species in populated areas (154). In contrast, green roofs in North America are installed for economical reasons, as a strategy for reducing energy consumption and long term savings for the owner (151).

In hot humid climate of South East Asia and parts of South America, roof greening is done to mitigate Urban Heat Island Effect (UHI). There is a growing interest in Singapore and Japan for the use of green roofs to overcome UHI and to provide green spaces for the public (150). The Japanese government has introduced a requirement that new buildings with more than 10,760 ft² floor space should have 20% of roof covered with vegetation (151). The introduction of new ordinances has popularized green roof installations. In Mexico, research is being undertaken to counter the environmental problems experienced by Mexico City, one of the largest metropolitan areas in the world (151).

Multiple benefits offered by green roofs make them a favorable passive technique in various geographic locations. Before these benefits may be understood, an understanding of the green roof components and systems will help capitalize on the advantages offered.

Traditional roof gardens restricted the planting to containers and planters or used a layer of ordinary soil spread on the roof (151). The contemporary roof greening systems are however much advanced as they use organic matter instead of soil for the plant growth. The modern green roofs are categorized by the substrate or growing media depth. There are three types of systems -intensive (deep), semi-intensive (moderate depth) and extensive (shallow) (155). These categories are derived from the contemporary German tradition of green roofs (151).

Intensive green roof systems use a wide variety of plant species. Designed to provide access to people, they support a variety of vegetation from trees and shrubs to herbaceous planting and lawns. Soil depth is at least 0.25 meter (10”) to support the various plant species describes the various green roof system along with their characteristics).

Saturated weight for intensive green is approximately 244.1 kg/m² (50 lb/sq ft) and varies thereafter (155). Intensive roofs are maintained on a rigorous level (150) and have more organic growing medium.

Semi intensive green roof systems use a combination of plant species that include small shrubs, grasses and herbs and are limited to low slope structure of 2:12 or less (155). A medium growth layer from 0.15 m (6”) to 0.25 m (10”) is required for plant propagation. Semi intensive green roof systems require less regular maintenance than an intensive system but are limited in plant selection due to shallower soil depths. Their saturated weights start at 170.9 kg/m² (35 lb/sq ft) and vary from there.

Extensive roofs are green roofs that are not meant for recreational use, but are intended to be ‘ecological’. Such green roofs provide greenery on the building roof and help preserve biodiversity at that height by providing natural habitat for plants, birds and insects.

Extensive roofs have a narrower range of plant species limited to herbs, low growing grasses, mosses and drought tolerant succulents such as sedum (155). Substrate depths are relatively thin between 0.05 m (2”) to 0.15 m (6”) which are significantly lower than intensive roofs (156). Saturated weights for extensive green roof system are approximately in the range of 48.8 – 170.9 kg/m² (10-35 lb/sq ft). Extensive green roofs do not require regular input of resources like water, labor as required by an intensive roof and can be designed for steeper slopes (greater than 2:12) (155).

These systems can often be installed on existing buildings without additional structural costs and alterations, but an engineering analysis of the structure must be performed. Careful selection of plants and growth medium ensures the success of a green roof installation.

Green roofs consist of both horticultural elements and traditional roofing components. There are three distinct layers in a green roof from the bottom (157) – elements that provide structural integrity; an engineered growing medium (which may or may not include soil) and the plant canopy (components selected as per particular application).

The components of the structural layer consist of the roof deck (152); the protection layer to contain the roots and growing medium, while allowing water penetration; a drainage layer and retention layer (sometimes with built in water reservoirs); a root repellant filter layer (made up of filter mats to protect the growth media from moving); along with the waterproofing membrane (156).

The most important layer on a green roof is its decking, which can be concrete, wood, metal, plastic, gypsum or composite as it determines whether the structure is capable of taking the load of the green roof (158). Installation of a green roof requires additional structural support based on the increase in dead and live load (due to the growth medium); additional water retention.

Buildings with concrete decks are excellent contenders for green roofs as they can take the additional weight of the green roofs and do not require extra support which is otherwise for waterproofing a metal deck (151). A reliable waterproofing layer and insulation on the deck contribute towards the success of a green roof installation.

The primary purpose of waterproofing is to keep the unwanted moisture from rain and condensation away from the structure below. The waterproofing membrane is the primary protective element of the slab and is typically below all the components of a green roof system (150). There are three major roofing types for roofs – Built up membrane, single ply membrane and Fluid applied membrane (148). It is important that selection of waterproofing membrane is in accordance with specification of other components within the green roof system.

The roof is the primary location for heat transfer and the insulation restricts the transfer of heat energy through the roof by creating a barrier between spaces of different temperature (148). The insulation acts as a thermal break and reduces condensation on surfaces that are exposed to both hot and cold on opposite sides (151). Green roof systems add mass and insulation over the structural decking, but cannot replace the insulation because their insulating properties depend upon depth and moisture content of growing medium (150).

As green roofs contain living and growing materials, a protection layer and a root barrier are one of the most important elements of the assembly (159). As roots grow they can penetrate the waterproofing membrane and create leak locations. The root barrier placed above the membrane ensures that no roots pass through and harm the membrane (155). A protection course shields the waterproofing membrane from damage after it has been installed.

A drainage course allows moisture to move laterally through the green roof system. It prevents oversaturation, ensures root ventilation and provides additional space for the roots to grow. It is a porous, continuous layer over the entire roof surface just above the concrete slab (152). As moisture is essential for successful plant propagation, a

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moisture retention layer retains or stores moisture for plant growth. It is an absorptive mat and which is typically located above the drainage layer or above the aeration layer (155).

The filter layer separates the growing medium from the drainage layer and protects the medium from shifting and washing away. This layer restricts the flow of fine soil particles and other contaminants while allowing water to pass through freely to avoid clogging (151). They are often made of tightly woven fabric and are in the form of filter cloth or mats (150).

The growing media or substrate in a green roof should strike a balance between good moisture retention capacity and free draining properties of traditional soil (151). It should absorb and supply nutrients and retain its volume over time to encourage plant growth. Traditionally, well drained sandy loam was used as the growing medium for a green roof (158). Its weight and ability to clog drainage layers and fabric lead to use of organic matter as a growing media. Lighter less rich and more porous mixes than soil reduce weight of the growing medium and save cost of structural support (160).

There are four factors that govern the suitability of a growth media. They are – water holding capacity, degree of drainage, fertility for vegetation and density of the growing media. The growing media should also be able to resist heat and other factors that damage normal roof (152). As organic content; pH and nutrient levels, weight, porosity, and water retention capacity of the growing media affect the growth of plants (150) it is important to select the substrate carefully.

The selection of appropriate plants is essential to both the aesthetic and environmental function of the green roof. There is various planting propagation methods like pre cultivated mats, modular systems, plugs, cuttings and seeds, all of which vary by cost and type of coverage desired (161). Selection of plants requires consideration as traditional rules for ground level plant selection do not work on green roofs due to the environmental and geographical location. Microclimate conditions on the roof like sun, shade and wind patterns which do not affect the ground gardens influence the growth of plants on the rooftop (161). Thus, plant variety needs to be tougher and less nutrient reliant than ones on the ground (160).

Plants cool the air around the rooftop through evapo-transpiration and shading from the plant cover. Evapo-transpiration is the sum effect of evaporation and plant transpiration from the surface of the vegetation that results in the cooling of the surface as water evaporates from it. Reductions of up to 90% in solar gain on roof area shaded by plant cover compared to un-shaded location can be achieved and indoor temperature decrease of 3-4˚C (6-8 ˚F) may be attained (156).

Designers must select plants according to the zone in which the green roof system is designed to avail the entire benefits vegetated roofs offer. In addition to the thermal advantage which is the focus of this thesis, there are other advantages of a green roof installation. A green roof is a valuable amenity that enhances the worth of the structure it occupies and generates tangible benefits in the form of financial returns as well as quantifiable environmental benefits. By utilizing wasted roof spaces multiple objectives may be achieved including storm water management; Urban Heat Island Mitigation; longer life for roof membrane; habitation for urban wildlife and aesthetic value addition etc.

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Green roofs can be valuable assets that may help to mitigate water runoff problems by lowering the rate of surface runoff. This is especially useful in urban areas with combined storm and sanitary sewer systems. The absorption of rainwater by planted spaces also reduces the chance of the storm water from getting contaminated by pollutants, dust etc.

Vegetated roofs moderate the peak in runoff from rooftops in most of the cases except for intense storms. Even during intense storms, lower rate of runoff is recorded compared to a conventional roof (151).

At Portland, Oregon two years of storm water management study concluded, green roofs with 0.04 m of substrate retained as much as 69 percent of all rainwater falling on it, with 100 percent retention for most warm weather storms (162). Another study conducted in Belgium showed that water retention increased with increase in substrate depth and presence of vegetation (163).

A decrease in volume and rate of runoff into the drainage system reduces the pressure from the treatment system and the bodies of water in which the system discharges the runoff (152) and green roles may help achieve this.

The loss of vegetative cover and increase in building activity in the form of pavements, roads and buildings results in higher urban temperatures than the suburban and rural areas. As impervious surfaces tend to be heat absorbing structures they increase urban temperature. This specific urban phenomenon termed as the Urban Heat Island Effect (UHI) (164), is identified by higher night time temperatures and humidity. To cope with this heat, air-conditioning is required which can burden the electric grid during peak hours, adding on to the UHI (151).

As rooftops make up a significant percentage of the reflective non vegetated surfaces in the city, heat gained through roofs can be substantial. Introduction of greenery through green roofs in the urban areas can reduce impervious surfaces and soften streetscapes.

Plants use heat energy for evapo-transpiration to achieve a cooling effect. By reducing the heat gain through the roof ambient temperature is lowered leading to less energy consumption (161). It is estimated that a decrease in internal building temperature by 0.5˚C may reduce electricity consumption for air conditioning (which is dependent on the building mass, volume and internal load profile) by up to 8 percent (151). Green roofs may be beneficial at night time also, as they radiate less amount of heat as compared to a dark or hard surface.

Green roof is effective at reflecting solar radiation and reducing heat absorption when compared to a conventional roof (151). Reduction of UHI is difficult to quantify as large area of green roofs are required to make a substantial impact.

Studies show that implementation of green roofs at a large scale in urban areas can have a significant impact on the reduction of UHI through lower air temperatures.

In urban areas where green spaces are lost at the ground level due to construction activities, green roofs are a means of supporting greenery at the roof level. They can sustain semi natural plant communities, create healthy, functioning habitat for certain kind of wildlife (165). As extensive roofs are not designed to be accessed they are isolated from people, and can be undisturbed habitat for plants, birds and insects (151).

Habitats that are otherwise endangered in urban or rural regions may be conserved in these locations. Studies from Europe on mature green roofs suggest that if green roofs are properly designed, needs of birds and insects may be

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accommodated on those roofs. They can play a pivotal role in preserving urban biodiversity for example in United Kingdom, extensive green roofs are a part of the London biodiversity Partnership's action plan to restore bird population (152). In the North America green roofs are designed to attract endangered species (166).

Research indicates that high level of diversity may be achieved on extensive green roofs. The ability of green roofs to support biodiversity is being explored alongside the thermal and hydrological studies but results are still in the nascent stage. If designed well green roofs can become a part of the functioning habitat and green space network of the city.

One of the major benefits of green roofs is their contribution in prolonging the life of both building insulation and roof surfaces (150). Plants and the growing media of the green roof moderate the temperature on the roof and protect the roof's waterproofing membrane. It shields roofing materials from ultra violet rays and higher temperature variation which cause degeneration of insulation and roofing felt.

Direct sun causes expansion and contraction of the membrane, thereby weakening it. It also accelerates aging in bituminous materials and reduces their durability.

Exposed roof membranes absorb solar radiation during the day which raises its temperature. The rise in temperature is dependent on the color of the membrane; a light colored membrane is cooler as it reflects solar radiation illustrates the rise in temperature in black, white and a green roof. Other studies also show that exposed roofs experience higher temperatures than green roofs. For example in a study for the city of Toronto , Canada membrane on the non green roof reached close to 70˚C (158˚F) in the afternoon while the membrane in green roof remained around 25˚C (75˚F) (151). The membrane on a conventional flat roof, if not protect by insulation, must be replaced every fifteen or twenty years (159). In direct contrast, membranes under green roofs may remain intact after decades of use (152).

Green roofs can play an important role in providing recreational spaces in urban regions where there is little ground level green areas. As these spaces are visible from many vantage points, it adds to the visual character of the urban fabric (147).

Green roofs that are accessible to the public or private owners add to the enjoyment of the property and provide more interest for the people living or working in neighboring high rise buildings, adding color and texture (167).

With the move towards compact and high density cities, there is immense pressure on green spaces at the ground level and high cost of acquisition for ground space makes it difficult to plan for ground level green areas. Roof spaces are highly underutilized resources in urban and suburban areas and have enormous potential in providing urban dwelling with recreational space (161). Recreational spaces at the roof level have controlled access making them safe from vandalism and other social problems common in public green spaces at ground level (150).

The provision of roof gardens, filled with greenery rather than paved surface, may become a positive selling point for the developers in future.

Roof surfaces offer the opportunity for growing food, particularly in high density urban areas where garden space may be limited. Food producing plants can substitute for ornamental plants in conventional roof gardens. Herb species are also known to perform well in free draining soils of extensive roofs and may become a viable option

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(161). In Haiti, Colombia, Thailand, Russia rooftops have been used to produce a range of fruits and vegetables (151).

Weight bearing capacity of the roof is a consideration for the successful plant growth. Soil depth of 0.3 – 0.45 m (12-18") may be required along with frequent irrigation (150). One of the examples of green roof food production is the Fairmont Hotel in Vancouver, Canada. The garden provides for all the herbs requirements of the hotel thereby making a yearly saving of Canadian $25,000-30,000. Apart from the food they also provide outdoor recreational space for the guests (150). The use of roof space for food production is still a new concept, but may become a commercial possibility in the future as no additional land purchase cost is associated with food production.

Hard surfaces of urban areas reflect sound and are unable to absorb it. Green roofs due to the nature of substrate and vegetation absorb sound waves (167). They are beneficial in two ways; they provide sound isolation due to the high mass and low stiffness and to a lesser extent reduce noise pollution through surface absorption (168). The depth of the green roof assembly acts as a acoustical barrier, the substrate blocks lower sound frequencies while the plants stop the higher frequency (151) thereby reducing noise of traffic, airplanes.

In a study at the Frankfurt airport, Germany a 0.10 m (4") deep green roof was able to reduce noise levels by 5dB (151). The installation of a green roof atop Gap's office in California which is situated next to a freeway and airport was designed to dampen noise transmission (169).

A cooler temperature on green roofs in hot weather makes them a valuable outdoor space for people who live or work in the building below (152). Green roofs act as recess spaces in offices where people come and relax during break time and connect with the outdoors. In residential units green roofs help in improving the quality of life for the residents, as they provide spaces for recreational activities. In an observation in Portland, of the various activities that could be performed on green roofs atop apartment blocks, exercise, barbecuing, lounging were most popular (151). In urban areas this may be the only outdoor space for people to use, and an extensive roof with sedum designed with landscaping elements like stepping stones, patio may make it a multifunctional low cost roof garden.

In the Indian culture it is believed that the processes of the cosmos are directly related to the human existence and that influence can be seen in the architecture (170). People have been respectful of their environment for centuries and this integration can be seen in the building tradition. Typical principles include climate responsive design, use of local and sustainable materials, water harvesting and others, all of which have been refined over time. With increase in the development of housing and commercial buildings, designing with the environment is often disregarded leading to immense pressure on energy resources, water, land, air and degradation of the environment.

The ninth Plan of the Government of India attempts to address the issue and stresses the improvement of urban areas as economically efficient, socially equitable and environmentally sustainable entities (171). Often this is not achieved, as growth and spread of cities requires the replacement of forests and green areas of the urban center by buildings, concrete roads, and parking lots. Presence of hard surfaces, along with loss of vegetative cover results in alteration of water and air quality, creation of Urban Heat Island, increase in pollution levels and increased energy Consumption (158). The introduction of vegetation in the urban fabric may help to mitigate these ill effects but space limitations around a building often pose a restriction.

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Vegetation may be superimposed onto the horizontal and vertical surfaces of the building. Green roofs and walls respond to this opportunity and can bring green spaces into urban areas while offering thermal benefits and energy savings for the user.

Sustainable design techniques and various socio cultural determinants of the nation have contributed to the plurality and unique architecture of India (170). The absence of a centralized rule in ancient India and coexistence of various schools of thought like Hinduism, Buddhism, Jainism shaped the architectural vocabulary (172). The cave and stone architecture utilize local materials and were determined by the cosmological connotations, myth and discourse (170).

With the coming of the Persians in the 7th Century A.D much of that changed and a sense of opulence and ostentations marked the building practices (173).

This continued until the Mughal period and the emergence of a new movement called the Indo Islamic style. The architectural style incorporated Islamic and pre Islamic expression into the architectural vocabulary (174). An example of this is the Moghul Emperor Akbar's city of Fatehpur Sikri, where vernacular expressions were adapted into Islamic vocabulary as a climate responsive strategy. The inclusion of deep overhangs, courts and water bodies helped achieve a cooling effect (172).

The arrival of the European colonialists in the 17th century coincided with the decline of the Mughal era and revival of Hinduism (170). The architecture became a statement of imperial power with its grandeur and stylistic elements borrowed from the Christian religion and European Classicism. Modern thought, brought by the British, included a new vocabulary of materials, technology, methods and processes. Construction during this time was an adaptation of the Indian form in the colonial works brought from Europe (174).

In major centers like Delhi colonial domestic and administrative building incorporated the Graeco Roman classical tradition with the north Indian Haveli. The Anglo- Indian style was used for government offices, schools, colleges and the bungalow (174). The distinct Bungalow architecture developed as a response to hot climate of the region. By integrating covered verandahs of the traditional house into the Bungalow private courtyards transformed into semi-public verandah for summer cooling.

Post independence Le Corbusier's design for the city of Chandigarh became the symbol of modern Indian architecture and exploration for a national identity. The climate responsive principles like extended overhangs and deep recesses lent a new architectural vocabulary.

In the 1980's, modernism expressed the realities of Indian society. Many architects felt it needed to be appropriated to the Indian context. Practitioners like Charles Correa, Balkrishna Doshi, J.A Stein attempted to incorporate 'Indianness' into modern architecture to bring about 'modern Indian architecture' (170).

In 1991, the liberalization of the economy influenced urban Indian architecture (170). The Indian economy was allowed to integrate with global realities and demand, supply and profitability became the determinants of architecture. Economic globalization and the affluence of the industrialists translated into glass and aluminum facades with universalized expressions of corporate and retail buildings leading to unsustainable building practices.

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Indiscriminate use of glass led to greater reliance on mechanical air conditioning and energy consumption. Leading to inclusion of concepts of sustainability and energy efficient building design, that trend continues today.

This argues that green roofs play a critical role in reducing energy costs and improving air quality in urban areas. The reduction is achieved by the increase in heat capacity and shade provided to the building roof. The lower ambient temperatures and heat gain through the roof may provide comfort to the occupants as the temperature reduction decreases the need for mechanical cooling.

Past studies on planted roofs have established the thermal benefits in extreme climates by emphasizing the reduction achieved in winter heating (176) and summer cooling (175). Theoretical models that relied on the analysis of planted roofs specifically the growing medium (177) and the canopy layer (157) were used to estimate the cooling effect of green roofs. The lack of experimental data for other climates such as composite climates, make it difficult to evaluate the suitability of green roofs as a heat mitigation strategy for Delhi.

An assessment of a green roof's performance in a composite climate is thus required to quantify the energy savings. Computer simulations can account for the difference in climate and variation in factors affecting the performance. The data collected will assist designers in their future decisions and establish the role of green roof as a passive cooling strategy for the region.

IV. TECHNIQUES FOR THE DEVELOPMENT OF ROOF TOP GARDEN

Planting vegetation at the building rooftop is an old technique. The most famous ancient green roofs were the Hanging Gardens of Babylon constructed around 500 BC. Green roofs can be viewed as a tool to enhance aesthetic application of any building. Green roofs also support to restore biodiversity that have been lost due to urban development. Green roofs offer a safe place for birds, insect and other plants to grow. Green roofs protect roof membrane from extreme heat, wind and ultra violet radiation. Due to the presence of vegetation and thick substrate layer, the daily expansion and contraction of the roofing membrane can be avoided. Green roofs are also named ‘‘eco-roofs’’, ‘‘living roofs’’ or ‘‘roof gardens’’, and are basically roofs with plants in their final layer (178; 179). Green roofs are generally built to enhance the energy efficiency of their buildings. Due to the high rate of energy and resource consumption of buildings, various sustainable approaches and environmentally responsive energy efficient technologies have been proposed and applied to realize low-energy buildings (180; 181). These include advanced eco-technologies, energy efficient systems and renewable energy sources. Green roofs are often identified as a valuable strategy for making buildings more sustainable (181).

Incorporating vegetation, growth medium and other landscape components on the rooftop of buildings offer several direct and indirect environmental benefits. There are numerous operational environmental benefits of green roofs and they can be listed as follows: reduction of urban heat island, mitigation of energy demand for heating and cooling, reduction and delay of storm water runoff, improvement in air quality, replacement of displaced landscape, enhancement of biodiversity, provision of recreational and agricultural spaces, and insulation of a building for sound (182; 183). It has been reported that the establishment of Extensive Green Roof has an annual total value of USD 12.98 million with unit value of USD 10.77/m2 of green roof, and Intensive Green Roof, USD 22.02 million with

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unit value of USD 18.33/m (184). Extensive Green Roof is more economically attractive than Intensive Green Roof in terms of benefit cost ratio and payback period. The main benefits of implementing green roofs at the building scale are as follows: storm water infrastructure, energy savings (185).

Green roofs in urban and suburban areas act as green corridor, which are the stepping stones for wildlife to enter the nearby habitats. They can connect the fragmented habitats with each other so as to promote the urban biodiversity (185). A total number of 30 species or even more of organisms were observed in the green roof (187; 188). The distributions of organisms in soil were move away from young and old roofs. There are three factors contributing to the biodiversity in the green roof. First is the type of growing substrate; second is the process of soil formation during the maturation of substrate; and the last is the increasing biological activity as well as increasing organic matter from dead leaves or organisms. Nonetheless, it is suggested that green roof could not be a justification for put an end to the natural nor replace the nature (188).

The cooling performance of the green roof depends on the plant species chosen (189; 190). Green roofs cool down the temperature because of the direct coverage of plants and the opening of stomata that allows transpiration during daytime. The textures of leaf surface and albedo effect also take place. The vegetation stores the heat and cools down the air. The daily maximum temperature on the vegetated rooftops was reduced and reduces day time temperature fluctuations. Researches in US indicated that vegetated rooftops decreased the peak temperature from 0.5 K to 3.5 K; along with dropping of temperature, the albedo increased from 0.05 Up to 0.61 (191).

First of all, the definition of water retention means the water storage capacity of a green roof. Green roof characteristics including the growing medium and the drainage layer influence the water retention capacity as well as the runoff dynamics (192). The configurations for different types of green spaces vary from each other, and therefore the cooling effects are also different. The three different types of green lands, namely bushes and grass, shrub and grass, and turf, their surface temperatures are all lower than non-green lands, especially for bushes and grass, the average daily temperature is the lowest (193).

Green coverage rate is closely related with the concentration of CO_2 in the air. It has been proposed that when green coverage is less than 10%, the concentration of CO_2 in the air would be 40% higher than the one with 40% coverage rate, and when the coverage rate reached 50%, the concentration of CO_2 in the air can maintain a normal rate of 320 ppm (194). As there are different tree leaf area indices, the carbon fixation and oxygen release capabilities are also different (230). Bushes and grass, trees, grass and shrubs are much better in controlling the CO concentration at certain level, improving the environment and maintaining oxygen balance than the lawn and vines. Shrubs structure is the best in carbon fixation and oxygen release (195;196; 199).

Green roofs are known to retain rainwater and delay peak flow, thereby reduce the risk of flooding (200; 201). Plants play a significant role in the runoff reduction depending on each plant's capacity for water interception, water retention and transpiration (202; 203). This has been indicated that average runoff retention of 65.7% can be achieved on an intensive green roof (University of Manchester campus) compared to 33.6% on an adjacent paved roof (204; 202).

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Green roofs are attractive option for energy savings in building sector. They reduce building energy demand through improvement of thermal performance of buildings (205; 206). A study in Greece revealed that green roofs reduce the energy utilized for cooling between 2% and 48% depending on the area covered by the green roof, with an indoor temperature reduction up to 4 K (207).

Green roofs buffer acidic rain (208; 209) and theoretically retain pollutants thereby produce good quality storm water runoff. The green roof system is a popular approach that could help to moderate air pollution in urban environments. Urban air often contains elevated levels of pollutants that are harmful to human health and environment (210). Among several mitigation technologies, the ability of plants to clean the air is considered practical and environmentally benign technique (211). In general, plants mitigate air pollution through direct and indirect processes, i.e. directly put away gaseous pollutants through their stomata or indirectly by modifying microclimates (212).Green roofs act as a sink for nitrogen, lead and zinc (213); it is also the source of phosphorus (214; 231; 213). On the thin soil of extensive green roofs which does not affect the concentrations of heavy metals in runoff water, i.e. the concentrations of heavy metals in runoff water were the same as that in precipitation (214). Nonetheless, the green roof retained over 65% of the zinc from precipitation (213).

Dust capturing study began in the former Soviet Union, where researchers found that during the growing season, average dust concentration in the forest was 42.2% lower than that in the open plaza (215).

Plants can sterilize and inhibit the bacteria and other pathogenic microorganisms in their living environment to varying degrees. Garden plants as the major species in urban greening play a key role in reducing the amount of environmental harmful pathogenic microorganisms and improving the urban environment's ecological value and adding social benefits. High green coverage rate helps to reduce bacterial content in the air (216).

Water classification is a serious problem in China's urban drainage system. To resolve this problem, it requires a variety of ways to be applied at the same time, where reducing the water wastage is the key. Increasing the urban green area is a good approach to hold the water by the plants after the rain. Roof greening in the city basin helps to reduce the rainfall runoff and pollution load. At the same tune, the size and spatial distribution of green roof affect the quality of runoff water (217).

The noise levels of the buildings with green roof are lower compared with the ones without a vegetated roof. The plant and soil layers can absorb certain sound waves. Reduction of the noise level after application of green roof can be as high as 10 dB (218). Xu et al. (2004) expected a reduction of at least 3 dB for roof garden and up to 8 dB. This was studied the impact of indoor greening on the reduction of noise annoyance level, and the result proves that the decoration through potted green plants can help to reduce the noise annoyance level of the occupants (220). Considering that green roofs are constructed boundary between the natural exterior and indoor environments, they generally reduce noise pollution in urban spaces arising from road, rail and air traffic (221; 222). This may be providing increased insulation of the roof system and by absorption of sound waves spreading over roofs (223).

Roof greening can create a micro-climate over the building envelop thus affecting the convective heat transfer over the roof surface, and it can help to improve the urban climate (224).

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Cooling effect. Thermal performance of the green roofs is ultimately reflected on its cooling and energy-saving effects on the buildings. The cooling effect is mainly due to the water evaporation and the plants that prevent the solar radiation from hitting the roof directly. Meanwhile, because the thermal mass for the soil is large, there is an effect of temperature wave reduction, and it can also delay the outdoor temperature variation on the indoor temperature.

The green roofs apparently can help reduce the building energy consumption. However, typically it only has a significant impact on the rooms on the top floor. As the number of floors increases, the energy-saving effect for the whole building decreases gradually. Researchers obtained different cooling and energy saving effects for green roofs. It can be explained by the following three reasons: 1-Configurations of the green roofs are different. Small shrubs have better cooling effect than Sedum. 2-Structure of the roof and the entire building structure are different 3-The regional climatic conditions are different (225; 226).

Environmental and Ecological benefits of green roofs reduction of urban heat island, mitigation of energy demand for heating and cooling, reduction and delay of storm water runoff, improvement in air quality, replacement of displaced landscape, enhancement of biodiversity, provision of recreational and agricultural spaces, and insulation of a building for sound (182). Green roofs are known to retain rainwater and delay peak flow, thereby reduce the risk of flooding.

V.BENEFITS OF ROOF TOP GARDEN

5.1 PUBLIC BENEFITS

5.1.1 Aesthetic Improvement

Urban greening has long been promoted as an easy and effective strategy for beautifying the built environment and increasing investment opportunity.

5.1.2 Waste Diversion

Green roofs can contribute to landfill diversion. The prolonging life of waterproofing membranes, reducing associated waste on the green roof top garden. The use of recycled materials in the growing medium will help a lot. The prolonging will help of the service life of heating, ventilation, and HVAC systems through decreased use.

A number of materials used in green roofs are from recycled sources, such as the membranes and growing mediums, such as crushed porous brick, which is used by some suppliers. In London, uniquely, there has been a move to use recycled secondary aggregate as the growing medium, preferably from the original site. This reduces the need for waste disposal to landfill and reduces the transport miles/distances for used for disposal of waste. This meets UK government targets for the reuse of secondary aggregates and where reuse from site can reduce the impact of lorries in terms of importation and exportation of materials.

5.1.3 Rainwater Management

With green roofs, water is stored by the substrate and then taken up by the plants from where it is returned to the atmosphere through transpiration and evaporation. In summer, depending on the plants and depth of growing medium, green roofs retain 70-90% of the precipitation that falls on them; in winter they retain between 25-40%. For

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example, a grass roof with a 4-20 cm (1.6 - 7.9 inches) layer of growing medium can hold 10-15 cm (3.9 - 5.9 inches) of water.

Green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off. Green roofs reduce the amount of rainwater runoff and also delay the time at which runoff occurs, resulting in decreased stress on sewer systems at peak flow periods.

5.1.4 Moderation of Urban Heat Island Effect

Through the daily dew and evaporation cycle, plants on vertical and horizontal surfaces are able to cool cities during hot summer months and reduce the Urban Heat Island (UHI) effect. The light absorbed by vegetation would otherwise be converted into heat energy. UHI is also mitigated by the covering some of the hottest surfaces in the urban environment through black rooftops.

Green roofs can also help reduce the distribution of dust and particulate matter throughout the city, as well as the production of smog. This can play a role in reducing greenhouse gas emissions and adapting urban areas to a future climate with warmer summers.

5.1.5 Improved Air Quality

The plants on green roofs can capture airborne pollutants and atmospheric deposition. They can also filter noxious gases. The temperature moderating effects of green roofs can reduce demand on power plants, and potentially decrease the amount of CO2 and other polluting by-products being released into the air.

5.1.6 New Amenity Spaces

Green roofs help to reach the principles of smart growth and positively affect the urban environment by increasing amenity and green space and reducing community resistance to infill projects. Green roofs can serve a number of functions and uses, including:

5.1.7 Community gardens (e.g. local food production or co-ops)

5.1.8 Commercial space (e.g. display areas and restaurant terraces)

5.1.9 Recreational space (e.g. lawn bowling and children’s playgrounds)

5.1.7 Local Job Creation

The growth of green roof and wall market gives new job opportunities related to manufacturing, plant growth, design, installation, and maintenance. American Rivers suggests that a USD $10B investment could create 190,000 jobs by building 48.5 billion-square-feet of green roof area, or just one percent of the United States’ roof space in every community over 50,000 in population. There is significant potential for new growth in dense urban areas that were previously unusable.

5.2 PRIVATE BENEFITS

5.2.1 Energy Efficiency

The greater insulation offered by green roofs can reduce the amount of energy needed to moderate the temperature of a building, as roofs are the sight of the greatest heat loss in the winter and the hottest temperatures in the summer. For example, research published by the National Research Council of Canada found that an extensive green roof reduced the daily energy demand for air conditioning in the summer by over 75% (227)

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5.2.2 Increased Roofing Membrane Durability

The presence of a green roof decreases the exposure of waterproofing membranes to large temperature fluctuations, that can cause micro-tearing, and ultraviolet radiation.

5.2.3 Fire Retardation

Green roofs have a much lower burning heat load (the heat generated when a substance burns) than do conventional roofs (228). GRHC has co-developed Fire Design Standards with SPRI (approved by ANSI) that ensure that green roofs offer fire protection and follow local fire codes.

5.2.4 Reduction of Electromagnetic Radiation

The risk posed by electromagnetic radiation (from wireless devices and mobile communication) to human health is still a question for debate. Nevertheless, green roofs are capable of reducing electromagnetic radiation penetration by 99.4% (229).

5.2.5 Noise Reduction

Green roofs have excellent noise attenuation, especially for low frequency sounds. An extensive green roof can reduce sound from outside by 40 decibels, while an intensive one can reduce sound by 46-50 decibels (198).

5.2.6 Marketing

Green roofs can increase a building's marketability. They are an easily identifiable symbol of the green building movement and can act as an incentive to those interested in the multiple benefits offered by green roofs. Green roofs, as part of the green building movement, have been identified as facilitating (197):

- Sales Lease outs
- Increased property value due to increased efficiency
- Easier employee recruiting
- Lower employee and tenant turnover Design-Specific Benefits

5.3 DESIGN-SPECIFIC BENEFITS

5.3.1 Increased Biodiversity

Green roofs can sustain a variety of plants and invertebrates, and provide a habitat for various bird species. By acting as a stepping stone habitat for migrating species they can link species together that would otherwise be fragmented.

Increasing biodiversity can positively affect three realms:

(a) Ecosystem: Diverse ecosystems are better able to maintain high levels of productivity during periods of environmental variation than those with fewer species

(b) Economic: Stabilized ecosystems ensure the delivery of ecological goods (e.g. food, construction materials, and medicinal plants) and services (e.g. maintain hydrological cycles, cleanse water and air, and store and cycle nutrients)

(c) Social: Visual and environmental diversity can have positive impacts on community and psychological well-being

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5.3.2 Improved Health and Well-Being

The reduced pollution and increased water quality that green roofs bring can decrease demands for health care. Green roofs can serve as community hubs, increasing social cohesion, sense of community, and public safety.

5.3.3 Urban Agriculture

Using green roofs as the site for an urban agriculture project can reduce a community's urban footprint through the creation of a local food system. These projects can serve as a source of community empowerment, give increased feelings of self-reliance, and improve levels of nutrition.

5.3.4 Educational Opportunities

Green roofs on educational facilities can provide an easily accessible sight to teach students and visitors about biology, green roof technology, and the benefits of green roofs.

VI. TECHNO-COMMERCIAL FEASIBILITY

Contribute to the complexity of a green roof. Building systems create shaded, damp areas that can increase the diversity of a roof's population of invertebrates. Designers may purposely create microclimates by adding branches, stones, sand piles and rubble to a green roof. Branches can be used to encourage birds to rest, and structures like bird and bat boxes can be used to encourage animals to nest and breed on a roof. An intensive roof with a mix of plant types and variations in depth and surface structure may outperform an intensive monoculture roof of uniform height in terms of increasing biodiversity. Such roofs also produce a greater reduction of storm water runoff and summer surface temperatures, as observed on green roofs in Halifax, Canada and Toronto, Canada. Plants like sedums with lower evapo-transpiration rates have a smaller effect on reducing summer surface temperatures than other vegetation types. Green roofs show greater biodiversity as they get older. Growth medium degrades over time, as does natural terrain. Over time, growth medium will lose bulk, gain organic matter, and show a greater abundance of a wider variety of species.

A green roof's contribution to biodiversity is difficult to measure economically. One way to measure the value of biodiversity on a roof is to compare the value it adds to the overall diversity of an area with that of a wildlife corridor or open space. In practice, regulators, investors and building occupants determine the value of green roof biodiversity, and the way in which biodiversity contributes to their sustainability goals. The green roof requirements of certain Swiss cantons, or states, were motivated predominantly by the desire to protect (and reintroduce) biodiversity.* Governments and organizations are working to develop ways to measure the financial value of a natural ecosystem. For example, Australia's Bush Broker scheme provides credits for "pre-vegetating" previously cleared areas like impervious urban sites with native species.† The price of a credit under this scheme ranges from US$0.42–$1.46 per square foot ($42,000 to $157,000/ hectare), and is applied once over a 10-year period. In the United States, a biodiversity banking system exists to protect threatened or endangered species.‡ The sale price for these credits averages approximately $0.41 per square foot.§ Pollination by bees attracted to green roofs of flowers and crops is another potential benefit of economic importance.

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VII. COST–BENEFIT ANALYSIS IN TERMS OF PHYSICAL OUTPUTS AND ENVIRONMENTAL BENEFITS

From the standardization of rooftop costing for rooftop greening the possibility cost of a 1000 sq. ft. roof where used space is 500 sq. ft. is:

Construction Cost	Species/plant cost	Maintenance cost	Other cost	Total
500$	300$	100$	100$	**1000$**

So the per sq. ft. cost for rooftop greening =1000/500= 2$

Net Present Value

- It correctly considers that cash inflows arising at different time periods differ in value and are comparable only when their equivalents-present values are found
- It is one of the best methods
- NPV = PVIF-PVOF
- **If NPV> 0 Accepted; <0 Rejected**

Year	Inflow($)	Deviation factor	Inflow present value($)	Outflow($)	Outflow present value($)
0		1/1.1		10000	10000
1	2000	1/1.21	1818		
2	3000	1/1.331	2479		
3	4000	1/1.464	3005		
4	5000	1/1.611	3415		
5	5000	1/1.611	3194		
Total	19000		13911		

- Net present value, (NPV) = 13911-10000 = 3911

Profitability Index

- It is the ratio of discounted benefit to discounted cost.
- It is also a good measure for comparison
- PI = DB/DC or DIF/DOF
- If PI> 1 Accepted; < 1 Rejected

Here,

Profitability Index, (PI) = 13911/10000

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= 1.391>1,

So the project is economically viable.

Here inflow comes from the environmental benefits from rooftop greening which has been converted hypothetically.

Indirect measurement of benefits deals with the benefits comes from the energy and water consumption. Residents' use air cooler and extract ground water for daily consumption. If residents' will be willing to practice green roofing then consumption of energy and water will decrease on a high note. In warm season at a particular residential building of the area an air conditioner has been used for 8 hours which aggregate monthly bill of Rs.2000 as per cost of the unit of electricity. If the use of air conditioner will be decreasing in 4 hours per day because of green roofing then the calculation brings that monthly saving will be Rs.1000.

VIII. CONCLUSION

Once this concept will have a success story, the outcomes and findings can be applicable to all the buildings. The design and cost with complete set of methodology will help building owners, builders, construction companies, government and private organizations to develop roof top garden on their infrastructures to receive the benefits through economical investments'. This will not only help in bringing down the environmental pollution in and around industrial advancement area but also help in generating employment, and lowering down the energy conservation with carbon sequestration.

Standardization of the design parameters for technology and preparation of protocols/prototypes for achieving reliable and replicable processes has to be developed which will help the state and central government to prepare the guidelines and statutory norms for the development of Green Roof Technology (GRT) for the Cities influenced with Industrial Pollution in order to comply on each and every infrastructures developed. A complete set of package containing methodology (technology) with guidelines and financial implication has to be developed. The rule frame work with technical feasibility may be defined in such a way to help every category of infrastructures in easy way for the green roof top development.

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