International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2013 | Issue 14 | Volume 5 | Number 1 | Pages 89-95

ENERGY SAVINGS POTENTIAL BY USING GREEN ROOFS

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Abstract- Green roof infrastructure promises to become an increasingly important option for building owners and community planners. Life cycle costing indicates that green roofs cost the same or less than conventional roofing and they are an investment which provides a significant number of social, environmental and economic benefits that are both public and private in nature. These benefits include increased energy efficiency (from cooling in the summer and added insulation in the winter), longer roof membrane life span, sound insulation, and the ability to turn wasted roof space into various types of amenity space for building occupants. Green roofs filter particulate matter from the air, retain and cleanse storm water and provide new opportunities for biodiversity preservation and habitat creation.

Keywords: Green Roofs, Energy, Energy Conservation.

I. INTRODUCTION

Green roofs offer a wide range of sustainability benefits, from water attenuation to climate change adaptation. Standard 'off the shelf' products, which tend to be sedum based green roofs, can provide some benefit for invertebrates and other wildlife. However, key research in the UK and Switzerland has shown that, by designing a green roof specifically with invertebrates in mind, it is possible to increase the overall ecological value of a roof. Furthermore it can also provide benefits associated with green infrastructure, improved building performance and amenity.

This report was prepared for the Planning Department as a study of ways in which a Green Roofs policy could support several key agenda within the city's Development Plan. While it can be seen that Green Roofs can provide a wide range of benefits with many synergies, the chief drivers from Dublin's perspective are climate change response, storm water management, support for urban biodiversity, provision of extra open space, and reductions in energy demands of buildings.

A green roof is vegetation on a rooftop which includes a vegetated layer, a growing medium, and a waterproof membrane.

A green wall is either free-standing or part of a building that is partially or completely covered with vegetation. The wall may incorporate soil and/or inorganic material as its growing medium.

Both green roofs and walls have the potential to make positive contributions to the environment, to the sustainability and functioning of the buildings where they are installed and to urban amenity more generally. The extent of this potential is very much influenced by local factors such as climate, extent and form of the built environment as well as the presence of natural features such as waterways and urban flora and fauna. It is also affected by policy and regulatory barriers of the existing statutory framework within which they would need to operate.

The use of vegetation on walls and roofs of buildings, particularly roofs, is a common practice in the architecture of older buildings in countries like Iceland, Scandinavia, Switzerland, Germany and Tanzania. Historically, people in these countries utilized vegetation in the form of vines on walls, shade trees near buildings and grass on roofs, hitherto known as green roofs, to provide protection from the wind and insulation for winter warmth, shade and cooling during hot summers, and to enhance the aesthetic value of the building. Today, a thriving green roof industry prevails in many parts of the world, as jurisdictions recognize the myriad environmental benefits associated with the technology.

II. BACKGROUND

Green roofs are not a new phenomenon. They have been standard construction practice in many countries for hundreds, if not thousands, of years, mainly due to the excellent insulative qualities of the combined plant and soil layers (sod). In the cold climates of Iceland and Scandinavia sod roofs helped to retain a building's heat, while in warm countries such as Tanzania, they keep buildings cool. Canadian examples of early green roofs, imported by the Vikings and later the French colonists, can be found in the provinces of Newfoundland and Nova Scotia, Canada [1].

Two modern advocates of green roof technology were the architects Le Corbusier and Frank Lloyd Wright. Although Le Corbusier encouraged rooftops as another location for urban green space, and Wright used green roofs as a tool to integrate his buildings more closely with the landscape, neither was aware of the profound environmental and economic impact that this technology could have on the urban landscape. Until the mid-20th century, green roofs were viewed mainly as a vernacular building practice.

However in the 1960's, rising concerns about the degraded quality of the urban environment and the rapid decline of green space in urban areas, renewed interest in green roofs as a "green solution" was sparked in Northern Europe. New technical research was carried out, ranging from studies on root-repelling agents, membranes, drainage, lightweight growing media, to plant suitability (Figure 1).

Figure 1. French fisherman's cottage fort, Louisbourg, Nova Scotia, Canada

In Germany, the green roof market expanded quickly in the 1980's, with an annual growth rate of 15-20%, ballooning from one to ten million square meters. This growth was stimulated largely by state legislation, municipal grants and incentives of 35-40 Deutsch Marks/m^2 of roof greened. Other European states have adopted similar types of support. Several cities now incorporate roof greening into regulations. Stuttgart, for example, requires green roofs on all new flat-roofed industrial buildings [2].

Vienna also provides subsidies and grants for new green roofs at the stages of planning, installation and 3 years post construction to ensure ongoing maintenance. Over 75 European municipalities currently provide incentives or requirements for green roof installation. A key motivator for this support has been the public benefits of storm water runoff reduction, air and water quality improvements. As a result, a new sector in the construction industry has been created, and green roofs have become a common feature in the urban landscape.

Canada and the United States are at least ten years behind Europe in investing in green roof infrastructure as a viable option for solving many quality of life challenges facing our cities.

During the early 1990's several large European green roof manufacturers started to venture into the North American markets. However, the systems were hard to sell without public education, local research on technical performance, and accessible examples, especially in a cultural and political climate where many individuals, businesses, and governments do not readily invest in green technologies. This has started to change.

In Canada, landscape architect Cornelia Hahn Oberlander, architects Doug Pollard and Charles Simon, and engineers Greg Allen and Mario Kani, are some of the people who have helped to establish the first green roofs. These include the Boyne River Education Centre in Southern Ontario and Robson Square in Vancouver. More recently, a volunteer group called the Rooftop Gardens Resource Group and an industry group called Green Roofs for Healthy Cities has been working to develop the green roof market in North America.

They provide information, implement demonstration projects and conduct technical research to show the benefits of this technology. At Laval University in Quebec, the roofing company Soprema is studying plant survivability in support of its Sopranature green roof product. A flurry of green roof-related research and demonstration activity is underway in Chicago, Portland, Winnipeg, and Ottawa. At IRC's Ottawa facilities a roof has been retrofitted to determine more detailed technical data on the performance of green roofs in areas such as energy efficiency and membrane life extension among others.

III. ELEMENTS OF GREEN ROOFS

For the purposes of this study, green roofs will refer to those conventional flat or sloped roofs that have been amended with some or all of the following layers or elements:

structural support, vapor control, thermal insulation, a water proofing membrane, a roof drainage layer, a root-protection layer, synthetic planting media and hardy, drought resistant plants.

These green roof layers can be adjusted or enhanced based on the needs of the designer or building owner. Typically, green roofs are classified as either extensive or intensive. Extensive green roofs tend to be lighter, require less maintenance but are not designed to be accessible green spaces. Intensive green roofs use more growing medium and can support a wider variety of plants and landscape designs. They can take the form of elaborate gardens or landscapes on a roof, even incorporating features such as wetlands and hills. In general, they are often designed to be accessible as green space in an urban area. The differences in weight, cost, structural preparation, water retention, predicted thermal benefit and public versus private benefits are particular in note (Figure 2).

Figure 2. Green roof

IV. INTENSIVE AND EXTENSIVE GREEN ROOFS

A green roof is a green space created by adding layers of growing medium and plants on top of a traditional roofing system. This should not be confused with the traditional roof garden, where planting is done in

freestanding containers and planters, located on an accessible roof terrace or deck. The layers of a contemporary green roof system, from the top down, include:
• the plants, often specially selected for particular applications,
• an engineered growing medium, which may not include soil,
• a landscape or filter cloth to contain the roots and the growing medium, while allowing for water penetration,
• a specialized drainage layer, sometimes with built-in water reservoirs,
• the waterproofing / roofing membrane, with an integral root repellent, and
• the roof structure, with traditional insulation either above or below.

The two basic types of green roof systems - extensive and intensive are differentiated mainly by the cost, depth of growing medium and choice of plants. Extensive green roofs are often not accessible and are characterized by:
• low weight,
• low capital cost,
• low plant diversity, and
• minimal maintenance requirements.

The growing medium, typically made up of a mineral based mixture of sand, gravel, crushed brick, leca, peat, organic matter, and some soil, varies in depth between 5-15 cm (2-6") with a weight increase of between 72.6-169.4 kg / m2 (16-35 lbs/sf) when fully saturated. Due to the shallowness of the growing medium and the extreme desert-like microclimate on many roofs, plants must be low and hardy, typically alpine, dryland, or indigenous. Typically the plants are watered and fertilized only until they are established, and after the first year, maintenance consists of two visits a year for weeding of invasive species, safety and membrane inspections. Intensive green roofs are often accessible and are characterized by:
• deeper soil and greater weight,
• higher capital costs,
• increased plant diversity, and
• more maintenance requirements
Table 1 delineates the major characteristics that differentiate extensive green roofs from intensive green roofs.

The growing medium is often soil based, ranging in depth from 20-60 cm (8-24"), with a saturated weight increase of between 290-967.7 kg/m^2 (60-200 lbs/sf). Due to the increased soil depth, the plant selection is more diverse and can include trees and shrubs, which allows for the development of a more complex ecosystem. Requirements for maintenance - especially watering - are more demanding and ongoing, and irrigation systems are usually specified. Structural and horticultural consultation and an experienced installer are recommended.

It should be noted that, depending on such site specific factors as location, structural capacity of the building, budget, client needs, and material and plant availability, each individual green roof will be different, likely a combination of intensive and extensive systems.

Table 1. Summarizes the advantages and disadvantages of extensive and intensive green roof systems

Intensive of Green Roofs	Extensive of Green Roofs
Advantages: -Greater diversity of plants and habitats. -Good insulation properties. -Can simulate a wildlife garden on the ground. -Can be made very attractive visually. -Often accessible, with more diverse utilization of the roof. (i.e. for recreation, growing food, as open space). -More energy efficiency and storm water retention capability. -Longer membrane life.	Advantages: -Lightweight; roof generally does not require reinforcement. -Suitable for large areas. -Suitable for roof slopes. -Low maintenance and long life. -Often no need for irrigation and specialized drainage systems. -Often suitable for retrofit projects. -Can leave vegetation to grow spontaneously. -Relatively inexpensive. -Looks more natural.
Disadvantages -Higher capital & maintenance costs. -More complex systems. -Greater weight loading on roof. -Need for irrigation and drainage systems requiring energy, water, and materials	Disadvantages -More limited choice of plants. -Usually no access for recreation or other uses. -Less energy efficiency and storm water retention benefits.

V. PRIVATE / BUILDING OWNER BENEFITS

One of the most valuable features of green roof infrastructure is that it generates a wide range of social, economic and environmental benefits, both public and private. Many of these are still being qualified in different North America climate zones through both field tests and the use of modeling. Since each green roof installation is unique, the key to success is finding the right mix of benefits for a particular client and for their project. The following describes some of the selling points of green roofs. Green roofs can provide numerous benefits, some of which are outlined in the diagram below (Figure 3):

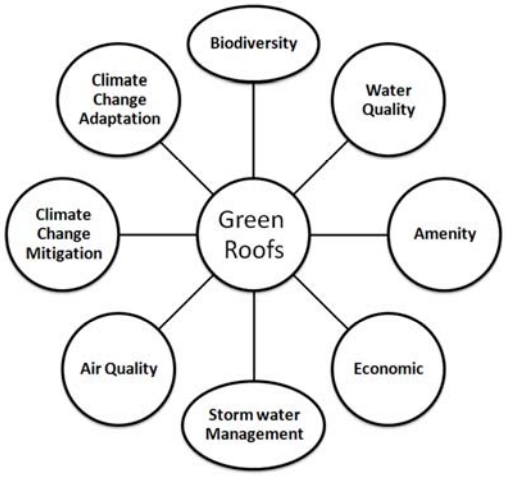

Figure 3. Benefits of Green Roofs

A. Energy Savings

In the summer, green roof planting shades the building from solar radiation and, through the process of evapotranspiration, can reduce, if not eliminate any net heat gain. This in turn helps to cool the surrounding area, as well as decreasing the amount of energy required to cool the building.

In the winter, the additional insulation provided by the growing medium helps to decrease the amount of energy required to heat the building. The extent of the energy cost savings impact is a function of:
• the size of the building,
• its location,
• the depth of the growing medium, and
• the type of plants and other variables.

Modeling research suggests that the reduced need for air conditioning in the summer is more substantial than the value of the added insulation in the winter. Building type is a key factor in determining overall cost savings. For example in one or two storey complexes where the roof is a large portion of the building envelope, the cooling energy savings in the summer have been modeled as high as 25%. A 20 cm (8") layer of growing medium and a thick layer of plants has a combined insulative value of RSI 0.14 (R20). Even when the growing media freezes, studies show that 30 cm (12") of growing medium will not experience temperature drops below 0 ºC (32 ºF), even when outside temperature is -20 ºC. Depending on the climate zone, the implementation of a green roof may also allow for a reduction in the requirements for traditional insulation. IRC and Environment Canada research is working to develop a model that will more accurately predict the energy efficiency gains of various green roof systems on different building types.

B. Roof Membrane Protection and Life Extension

Green roofs help to protect roofing membranes from extreme temperature fluctuations, the negative impact of ultraviolet radiation, and accidental damage from pedestrian traffic.

European evidence indicates that green roofs will easily double the life span of a conventional roof, and thus decrease the need for re-roofing and the amount of waste material bound for landfill. These are direct operational cost savings for the building owner. Life cycle costing data which includes the cost of deferred maintenance and replacement suggests that green roofs cost the same or less than conventional roof systems [4].

C. Sound Insulation

Green roofs can be designed to insulate for sound, with the growing medium blocking lower frequencies of sound, and the plants blocking the higher frequencies. Tests show that 12 cm (5") of growing medium alone can reduce sound by 40 db.

D. Fire Resistance

There is evidence from European manufacturers suggesting that green roofs can help slow the spread of fire to and from the building through the roof, particularly where the growing medium is saturated. However, the plants themselves, if dry, can present a fire hazard.

Similar to preventing grass fires at grade, the integration of "fire breaks" at regular intervals across the roof, at the roof perimeter, and around all roof penetrations is recommended.

These breaks would be made of a non-combustible material such as gravel or concrete pavers, 60 cm (24") wide, and located every 40 m (130 feet) in all directions. Other options would be the use of "fire retardant plants", such as sedums, which have high water content, or a sprinkler irrigation system connected to the fire alarm.

E. Urban Heat Island Effect

The urban heat island is the overheating of urban and suburban areas, relative to the surrounding countryside, due to increased paved, built-over, and hard surface areas. Average summer temperatures in major cities across North America have been on the rise over the past decade. These artificially high summer temperatures have a range of direct and indirect negative impacts on our quality of life [3].

The urban heat island effect increases the use of more electricity for air conditioners and it increases the rate at which chemical processes generate pollutants such as ground level ozone. It also exacerbates heat-related illnesses. Green roofs intercept the solar radiation that would strike dark roof surfaces and be converted into heat, thereby improving energy conservation. Like urban forests and reflective roofing surfaces they absorb and/or deflect solar radiation so that it does not produce heat [5].

An ASHRAE simulation conducted by the City of Chicago of their City Hall green roof showed that every one degree Fahrenheit decrease in ambient air temperature results in a 1.2% drop in cooling energy use. The study suggests that if, over a period of ten years or more, all of the buildings in Chicago were retrofitted with green roofs, (30% of the total land area), this would yield savings of $100,000,000 annually from reduced cooling load requirements in all of the buildings in Chicago. The cooling would also slow the chemical processes that produce ground level ozone, nitrous oxides and smog, and help offset the production of sculpture dioxides from coal fired utilities (Figure 4).

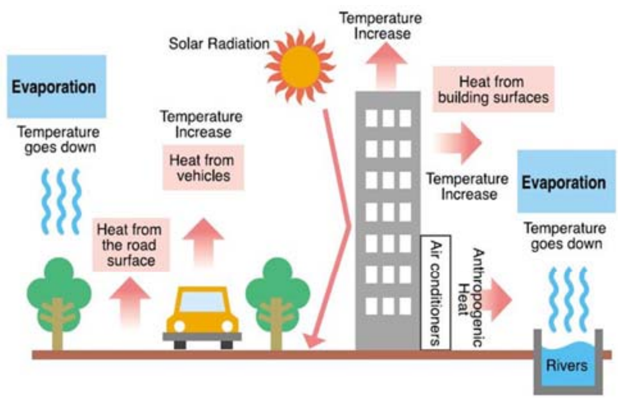

Figure 4. The urban heat island effect

F. Creation of Habitat

Green roofs can be designed as acceptable alternative habitats for some species, although they should never be considered as a justification to destroy natural habitat at grade. In Europe, two types of green roof habitats have been defined and implemented, as part of a larger system of wildlife corridors in urban areas. The first is a "stepping stone" habitat that connects natural isolated habitat pockets with each other. It is important to remember that this connection can be by air only (nesting and migrating birds, insects, airborne seeds). The second is an "island" habitat that remains isolated from habitat at grade. This type of habitat would be home to selected plant varieties whose seeds are not spread by air or over short distances.

Green roofs can also be specifically designed to mimic endangered ecosystems / habitats, including the prairie grasslands of the midwest United States or the rocky alvars of Manitoulin Island and the Great Lakes Region in Canada. Extensive green roofs, with their lack of human intervention, are more protected and can become home to sensitive plants that are easily damaged by walking, and to birds species that only nest on the ground. Since the soil on an inaccessible green roof is also less likely to be disturbed, it becomes a safer habitat for insects as well. The deeper the soil the more insect diversity the green roof will support.

G. Increases in Urban Biodiversity

The greater selection of habitat options than extensive green roofs due to their shallow substrate can only support limited habitat options. Long term monitoring of sites in Germany show green roofs planted with endemic species and left undisturbed replicate local landscapes and increase plant diversity in urban areas. Some investigations also report spontaneous establishment of rare plants and lichens.

Therefore, there is evidence to show green roofs have the capacity to replace lost habitat for a variety of native and endemic birds and invertebrates. This function of green roofs would increase biodiversity in fragmented urban regions. Hopkins and Goodwin propose the use of stepping stone corridors to link individual green roof projects together and form protected wildlife corridors across the city. This linkage restores migration patterns for birds and habitat ranges for some animals and insects. Figure 3 provides a visual representation of this concept and shows how green roofs could connect with parks, street trees, open spaces and vegetated median strips to create urban forests.

Various insects are also commonly found on green roofs. Several overseas studies find uncommon species of beetles and spiders on green roofs. Spiders and beetles are considered indicator species and their presence implies there is a high level of ecological biodiversity at a site.

Furthermore, green roofs in the UK and Europe show potential to provide protected habitat for endangered ground nesting birds. These birds benefit from protection green roofs offer against introduced predators such as cats. Introducing nesting boxes for birds and micro bats could make green roofs a suitable protected habitat for several native avian species found in urban and peri-urban environments.

However, even though green roofs increase availability of potential habitats, they only do so for a limited number of species which can access them or are introduced and contained on site. Furthermore, research shows some green roofs designed without a priority to promote biodiversity provide insufficient availability of resources needed to support ecological diversity of flora and fauna.

It is evident green roofs could provide a variety of habitat options and increase biodiversity in urban environments. Local research is required to determine if they could facilitate reintroduction of flora and flora endemic to the LGA and the greater Sydney area [6].

VI. GREEN ROOF DEFINITION

A green roof is vegetation cover on at least 30 per cent of "available rooftop space" that is, space which is not occupied by structures housing plant, equipment or stairway accesses. A green roof should provide measurable environmental benefits to the City of Sydney. The green roof includes a vegetated layer, growing medium, and a waterproof membrane. Potted plants/planter boxes are acceptable as green roofs as long as they provide the minimum 30 per cent requirement of rooftop area as vegetation cover. In addition to the minimum 30 per cent vegetation cover, a green roof can include facilities for renewable energy, water collection infrastructure, walkways, furnishings, and the like. This definition makes a distinction between a rooftop garden and a green roof and therefore captures all potential benefits offered by green roofs.

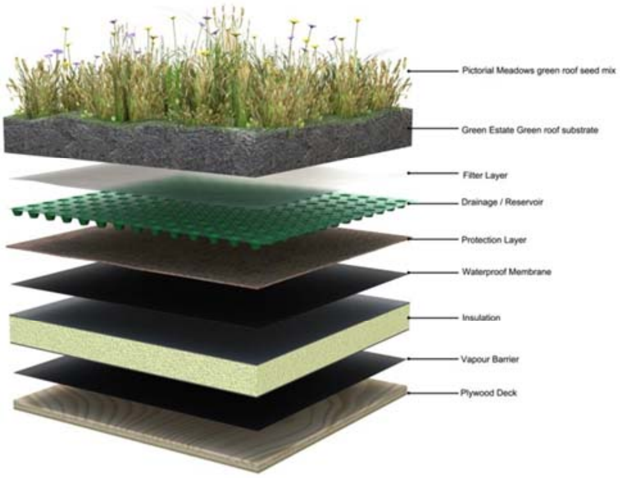

Figure 5. A schematic diagram of a typical green roof

Green roofs are generally made up of four essential layers: At the base of a system is a drainage layer for storing and removing all excess water. Next, and above the drainage layer, is a filtering layer for preventing particulates and plant roots from clogging the drainage layer. Following this is a soil substrate supporting growth of the final layer, which is the vegetation. Under all green roofs, and essential to the system, is a waterproofing layer preventing plant roots and water from damaging the building superstructure (Figure 5).

VII. DESIGNING

Green roofs conducted extensive way, are mostly devoid of irrigation. Very often in the hot summer months leads to completely dry ground. It's important to use proper kinds of plants, and use of appropriate soil substrates that allow store up a lot of moisture for a longer time.

Trying to determine what areas have similar natural characteristics will develop an initial selection of species. Perfectly suited in this case, therefore, alpine and mountain vegetation in their natural habitats by tolerating large variations in temperature throughout the day, water shortages, poor soil, and strong, drying winds. The species occurs in those areas will be sufficiently adapted to the conditions that may be encountered on green roofs. To improve the aesthetic qualities of the green roof, some perennial herbs and plants can also be used. On the intensive green roof also its aloud to put bigger plants, like trees and shrubs. Green may be the plant directly into the substrate, or inside of kind of containers, like in Diadem 150 system. In this case, this kind of roof must be watered [7].

The development of large cities leads to a drastic decline of green area in the center of such boundaries. New investments usually result in significant changes in the structure of the spatial layout of the center. These increase the negative effects of urban heat island, largely caused by heating the concrete and asphalt surfaces. An excellent way to improve the balance of greenery in the city is the installation of green roofs. Creating gardens on the roof of the building increase the attractiveness of the uniqueness and cause the reason that this solution is not so popular. It will change architectural element of the city like buildings, and made them more soft and smooth. In addition to aesthetic feelings and positive impact on the psyche of inhabitants green roofs are much more important than of economic and climate way [8].

All operations assumed to protect from the roofs, also protect it from the effects of biotic factors such as rain, wind or solar radiation. Used in the construction of the roof insulation layer and the soil itself increase the ceiling above factors. This leads to a reduction of the cost of repairing, and extends life of structure.

VIII. PLANS FOR THE FUTURE

This technology is becoming more and more popular. It is interested to show just a few examples of proposed buildings and structures, where one of the more important thing is green area for a people. First project is Singapore's ecological EDITT tower designed by Hamzach and Yeang. The 26-story high rise will boast photovoltaic panel, natural ventilation, and a biogas generation plant all wrapped within an insulating living wall that covers half of its surface area. The verdant skyscraper was designed to increase its location's bio-diversity and rehabilitate the local ecosystem in Singapore's 'zero culture' metropolis (Figure 6).

Approximately half of the surface area of the EDITT TOWER will be wrapped in organic local vegetation, and passive architecture will allow for natural ventilation. Publicly accessible ramps will connect upper floors to the street level lined in shops, restaurants and plant life.

Figure 6. Singapore's ecological EDITT tower

The building has also been designed for future adaptability, with many walls and floors that can be moved or removed. In a city known for its downpours, the building will collect rainwater and integrate a grey-water system for both plant irrigation and toilet flushing with an estimated 55% self-sufficiency. 855 square meters of photovoltaic panels will provide for 39.7% of the building's energy needs, and plans also include the ability to convert sewage into biogas and fertilizer. The tower will be constructed using many recycled and recyclable materials, and a centralized recycling system will be accessible from each floor.

Next Project is Sky Village designed by MVRDV. Designed as an acropolis of stackable reenroofed units, the structure won a competition to construct a new high-rise in Rodovre, an independent municipality of Copenhagen. The high-rise incorporates lots of sustainable design elements to reduce its environmental impact, and its main concept is centered around a system of individual units that can be stacked in various configurations to maximize available space and allow for easy structural changes in response to market demand.

The base of the village was kept small in order to minimize the building's footprint as well as to maximize the public plaza and adjacent park. Retail space and restaurants take up the slim lower floors, offices are situated in the intermediary levels, and residential units are terraced towards the north to give the building a curved profile. These terraces give each residential unit a sky garden with a sunny southern aspect. Finally a hotel sits at the top of the high rise with views towards central Copenhagen (Figure 7).

Figure 7. Sky Village

IX. CONCLUSIONS

Unconventional roof technologies such as cool roofs and green roofs have been shown to reduce building heating and cooling load. Although previous studies suggest potential for energy savings through such technologies, many factors affect potential savings. To further investigate these factors, a tool has been developed to allow architects and designers the ability to quickly assess the energy saving potential of different roof technologies and roof constructions for various sites around the world. A first principles heat transfer model is developed for each of the roof technologies, with particular care for green roof heat and mass transfer. Two sets of experimental data from Japan and Florida validate the models by predicting roof surface temperature. The predicted roof surface temperatures in Japan agree with measured values within 10 and 26% of peak roof temperature fluctuations for the cool and green roof respectively, while the same models in Florida agree with measured values there within 7.2 and 14% for the cool and green roof respectively.

To sum up, the issue of the grassed roof’s sustainability has been raised by the prolonged drought conditions of recent years. By this report the several issues regarding sustainability such as green roofs have been explained. The meaning of green roofs, benefits, cost and construction are also explained.

The intention was to have a closer look at problems of polluted cities. Well, an eco-roof was put Rockefeller Center in New York City in the 1930's. They are appearing everywhere. Green roof research is conducted in universities and research centers in Germany, USA, UK, and Canada. The pressures of effects of global warming, energy shortages and climate change mean that vegetated roofs will bloom. Green technology in the future will be used not only to create more green public or private space. Even now, in architecture magazines or web sites we can find new ideas of using green roofs as a solution for deficiency of food in big cities. One of this idea is to create vertical farms, and vertical sustainable cities, were every single apartment will have his own garden. However this technology is still young, nowadays architects have ambitious, bright plans for the future.

Nevertheless technology of green roofs not belongs to the cheapest ones, there more is a benefit of having them, and it is obvious that we will need a solution in our overcrowded cities.

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BIOGRAPHY

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