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Energy Evaluation and Economic Impact Analysis of Green Roofs Applied to a Pilot Region in Aegean Coast of Turkey

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Abstract

This paper examines the energy savings, environmental benefits, and economic impact of green roof systems applied to a "micro" region in Western Turkey. This subdivision (Artur) in Karaağaç, Izmir, consists of 1729 residential units, mostly used as summer homes. The units are in $45m^2$, $60m^2$, $90m^2$, and $105m^2$ sizes. Five different plant types were considered to be blended and planted in two different choices of growth media. Thermal benefits of the vegetated roofs to the pilot site were evaluated using appropriate heat transfer equations. For analyzing the impact of use of such systems on the local economy, monetary injection into the local economy was calculated and a multiplier effect of 2.66 was assumed. Net present value (NPV) of the generated income for the first 10 years was calculated to be approximately $14.5 million. In addition, approximately 300 new local jobs over a period of 10 years were estimated to be created.

Key Words: Green roofs, Economic impact, Energy conservation, Turkey
JEL Classification: Q2,Q4,Q5

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1. Introduction

Due to the carbon footprint and increasing costs of energy, its efficient use has become a major topic globally. Considering that 49% of the total energy consumption of a residential unit goes for HVAC (heating, ventilating, and air-conditioning) needs [1], building insulation has become increasingly important in recent years. To combat high insulation costs, new technologies have been developed, but most of the insulation materials available in the market are synthetic. However, there is an old, natural insulation technique that is again becoming popular. This technique involves installing green roofs (a.k.a. garden roofs, vegetated roofs, and live roofs), where the roofs are covered with vegetation. A green roof results in several benefits, such as saving on heating and cooling costs, reducing storm water run-off, filtering pollutants, capturing atmospheric CO_2, decreasing the heat-island effect in large cities, and increasing the lifespan of roofing materials.

Buildings with green roofs are already popular in Europe due to high energy costs and new European Union regulations. In Germany, 7% of all new roof constructions are green, summing up to 13 million m^2 of green roof area [2]. In Basel, Switzerland 20% of the flat roofs were turned into green roofs by 2005 [3]. The City of Chicago, Illinois in the U.S. has started an elaborate green roof initiative to green a significant portion of roof area in the city. Chicago today has about a quarter million $m^2$of green roof area [4].

Buildings with green roofs benefit significantly from the unique isolative property of this technique. According to Liu [5] and Sidwell et al. [6] who evaluated the thermal performance of rooftop gardens, in warm seasons the plants and growing medium of the green roof keep the roofing membrane cool by direct shading, by evaporative cooling from the plants and the growing medium, and by the added insulation from the plants and growing medium.

The widespread use of this relatively new technology has other economic impacts besides energy savings. Green roofs have greater longevity thus lower replacement costs, resulting in increased property values and marketability of property. If this new technology were to be adopted at a large scale in a relatively small area, multiplier effects could be significant, generating income, know-how, and employment.

This paper will present an example of how a community, including the homeowners, industrial people, engineers, architects, and the public, can benefit from green roofs. The pilot region that will be analyzed in this study is an Aegean site on the west coast of Turkey with 1729 residential units. It is expected that the outcome of this study can be extrapolated to broader regions within acceptable limits.

2. The Pilot Region and Statistical Approach

The Aegean region is one of the seven census-defined regions of Turkey. It is located in the west part of the country, bounded by the Aegean Sea on the west, the Marmara region on the north, the Mediterranean region on the south & southwest, and the Central Anatolia region on the east (Figure 1).

The Aegean coastal plain has an exceptionally mild climate, with soft, verdant springs, hot summers, sunny autumns, and warm winters marked by occasional showers. The Aegean region has perpendicular mountains to its shores and many valleys between them, thus permitting the sea climate to reach inner parts of the region, although some of the provinces inland also show the characteristics of the Continental climate.

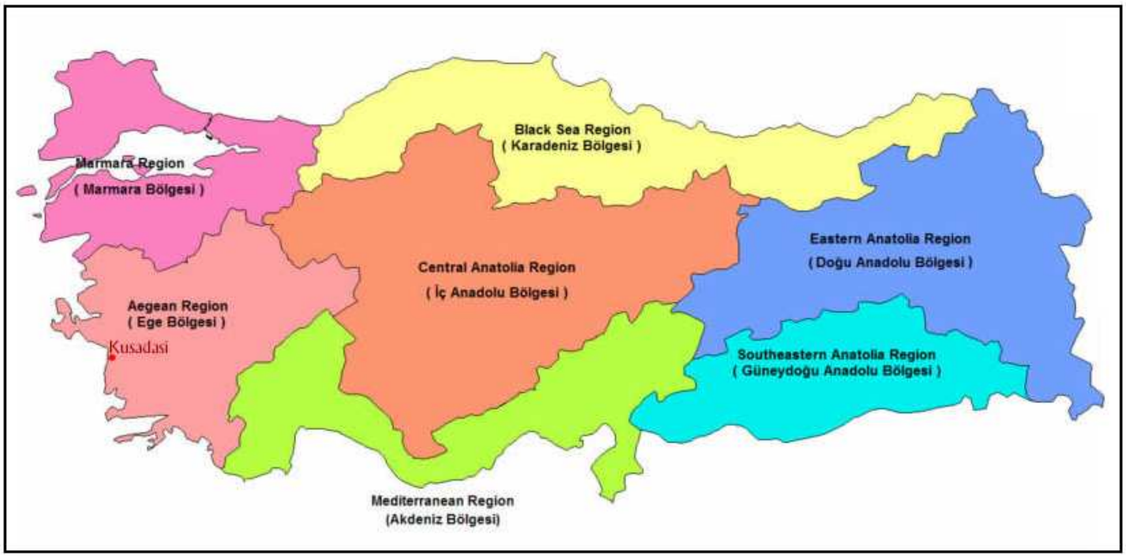

Figure 1. Regions of Turkey.

The region occupies 11% of the total area of Turkey with its 79,000 square kilometers of land. Most of the population and cities are concentrated on the coast line because of its convenience for sea transportation and tourism. Industrial and agricultural products are also produced in the Aegean region. The main products are textile, leather, carpet weaving, food, machinery and spare parts, marble, tobacco, sugar, olives, and olive oil. About half of the total olive trees of Turkey are in this region [7]. There are also many important rivers feeding the Aegean Sea.

The Artur Site is in the Gulf of Edremit in the Aegean region. The gulf is also known as the Olive Riviera and has a number of charming seaside resorts: Kucukkuyu, Altinoluk, Akcay (a thermal centre with numerous springs), Edremit and Oren. Artur is located in the south of the Gulf of Edremit, bounded by the Aegean Sea on the west (Figure 2). It consists of five types of residential units for a total number of 1729 in three different bays. Each residential unit has a deck roof (Figure 3).

Figure 2. Artur site on Gulf of Edremit.

Figure 3. Residential units with deck roofs at Artur.

Dimensional data of all deck roofs from the pilot site are given in Table 1. Total deck roof area of the site is 99,400 sqm.

Table 1. Residential unit data from the pilot region.

TYPE OF UNIT	NUMBER OF UNITS	ROOF AREA (m^2)	TOTAL ROOF AREA (m^2)
40 sqm	96	30	2,880
60 sqm	615	46	28,290
90 sqm	650	80	52,000
90 sqm-duplex	213	40	8,520
105 sqm	155	50	7,750
TOTAL UNIT	1729		99,440

3. Vegetation and Growth Media

Since this region of Turkey is similar in climate to many areas that have already implemented green roof systems, a typical green roof design will be utilized for this energy simulation analysis. Growth media depth was set to be 10 cm over the top of a drainage layer. Growth media consists of a blended aggregate (1 cm diameter) with a composted organic material in an 80:20 blend (typical of the aggregate with composted organic material used elsewhere). In the U.S. and Europe the aggregate used on green roof systems is typically a kiln-fired aggregate (Arkalyte – clay or Hadite – shale) or a natural aggregate (lava or pumice).

Five types of vegetation were chosen for the study (Figure 4): *Astragalus Membranaceus* (1), *Agave Americana* (2), *Chantholimon Venustum* (3), *Sedum tectractinum* (4), and *Orostachys* (5). To ensure quick coverage, a blend of the five species is used rather than a single species.

Figure 4. Blended plants.

Species 1, 2, and 3 grow in the Aegean region and species 4 and 5 have already been used on green roof systems in similar climate zones. Plants were assumed to be irrigated once per week if not receiving weekly rainfall for the first 10 weeks following establishment. Once at establishment and once yearly thereafter, plants will be fertilized with a complete fertilizer.

4. Energy Analysis

Energy savings analysis for green roof applications is crucial in pointing out the thermal benefits of vegetated roofs. Celik et al. conducted thermal analysis studies on green roof applications with various growth media and vegetation types [8, 9]. An HVAC energy cost diagram for different roof applications is illustrated in Figure 5 [9]. In this analysis, an integration over the whole selected day showed that the energy consumption of a roof with black membrane can be 23% - 60% higher than a green roof application, depending on the growth medium and plant selection [9].

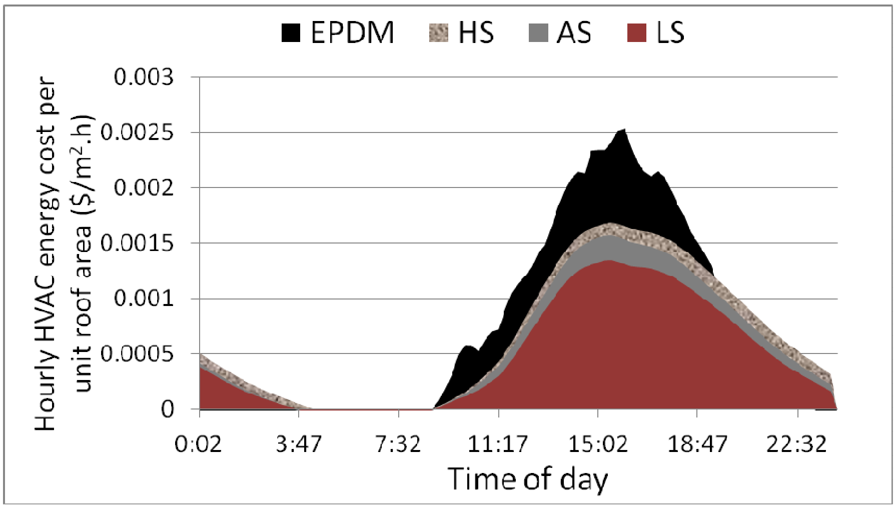

Figure 5. Air-conditioning energy costs in the Midwest USA; EPDM: Black roof membrane, HS: Hadite growth media with *Sedum spurium*, AS: Arkalyte growth media with *Sedum spurium*, LS: Red lava growth media with *Sedum spurium* [9].

With the same idea, an energy savings analysis for the Artur site can be done for two different conditions: a roof deck covered with a dark membrane and a vegetated roof deck. The unit price for electrical energy was taken as 18¢/kWh, which is representative of electricity costs in the Aegean region of Turkey. Assuming a green roof application with a blend of five species mentioned earlier with either red lava rocks or pumice as the growth media and assuming this green roof yields an energy consumption reduction of approximately 40% over the black roof, air-conditioning energy savings of the whole Artur site with 1729 units over one full summer season can be calculated. On a summer day of 35°C peak ambient temperature, if the residential unit owner was to set the thermostat of the air-conditioner to 25°C, which falls well within comfort conditions, daily cooling energy consumption for a unit surface area would be approximately 0.077 $/m^2$/day. For the whole pilot site with a total of 99,440 m^2 roof area, daily energy consumption for only air-conditioning needs would be 7,656.9 $/day for the hottest day of the season. With a green roof application on the whole site, this value would come down to 5,469.2 $/day, which means a daily energy savings of approximately $2,188 for that region. This value could change due to changing daily temperatures throughout the summer.

Although an experimental or statistical study has not been conducted for this region, these numbers were calculated based on experiments and prior studies performed at field sites in the Midwest USA. Hence the authors believe that the given values in this section reflect realistic numbers.

5. Economic Analysis

In this section, an economic impact analysis of green roofs at the Artur site is provided. The site consists of 1729 units that are mainly used as summer homes and thus remain empty for most of the year. However, increasingly retired couples are either settling down permanently in what used to be their summer houses or spending a large part of the year there. It is becoming increasingly more common to see retired people spend six months of the year in Artur.

The analysis undertaken in this paper differs from economic analyses in most of the green roof literature. The literature compares the economic benefits and costs of green roofs to the owner over the life-cycle of a green roof [10, 11]. The economic impact analysis in this study is provided for a period of 10 years and assumes that green roofs are installed in all the units (for details on units, see Table 1) in the first four years. Then the impact of this new economic activity on the local area is analyzed. Greater economic impact would result when green roofs were to start being adapted by the nearby houses, which are not considered in this study. Hence the analysis discussed in this paper should be considered as a very conservative estimate of the potential economic impact on the locality.

Local prices on five different plants (Figure 4) which are considered to be blended on the green roofs in this pilot area were obtained from gardeners and checked against prices in other areas. The model assumes that the high demand for these plants due to Artur green roof project will not result in significantly different prices since it is assumed that green roofs will be constructed on each house when the owner decides and will be contracted and overseen by the owner. So large scale bargaining on price will be unlikely and, conversely, a sudden increase in demand that could raise the costs is unlikely.

Growth medium is a 10 cm layer of either pumice or red lava rocks. Initial costs of intalling a green roof is determined to be 50\$/m^2 based on estimates obtained from three different local roofing contractors for standard roof construction and estimates of green roof construction costs in other parts of the world with similar climate and economic development levels from published sources [10, 12, 13, 14]. Cost estimates and model assumptions are presented in Table 2.

Table 2. Estimated costs and model assumptions.

Cost Estimates		
Roofing material	50 \$/m^2	25% of dwellings are converted to green roofs every year for the first four years

Maintenance	120$/year	
Plants	10$/ m^2	
Growth Medium	50$/ m^2	Pumice or red lava rock (10 cm depth)
Labor (roofing and planting)	10$/ m^2	
Energy Savings	2,188$/day	For the 99,440 sqm area
Economic Assumptions		
Electricity price	$0.18/kWh	
Inflation rate	4.5 %	
Discount rate	4.5 %	
Initial exchange rate	1.5 TL/$	
Annual change in the exchange rate	2.9 %	Based on average annual US inflation rate of 1.6 %
Multiplier for the local economy	2.66	
Investment required to create employment for one person	$50,000	

In the first step of the analysis, construction and maintenance costs of green roofs for the 1729 units with a roof area of 99,440 m^2 were calculated for a period of 10 years. Then the local economic impact of this spending was calculated by estimating local income generated from this expenditure. It was assumed that plants and some growth media would be supplied locally, roof construction services would be provided locally, most roofing material however will be obtained from outside the region. Maintenance services would be provided locally. Based on this, the monetary injection into the local economy was calculated and a multiplier effect of 2.66 was assumed for the local economy. The net present value (NPV) of the amount of income generated in the local economy for the first 10 years was calculated to be approximately $14.5 million. An injection of this magnitude to the local economy is estimated to generate approximately 300 new local jobs (~30-50 jobs per year during the first four years when green roofs are constructed, and ~17-19 jobs per year thereafter) during the course of 10 years under the assumption that a $50,000 investment is necessary to create employment for one person in commerce or services. The economic benefits after the first 10 years needs to consider the losses to local roofing contractors due to longer life of green roofs. However, since the green roof construction is likely to take off in the region once the Artur experience creates a demand for green roofs in the area, the bulk of this new local and semi-local activity will benefit local roofing contractors. In addition, increased property values in the area and increased marketablility of properties in the area will continue to benefit not only property owners in Artur, but the entire locality. Besides the environmental benefits of energy savings, the savings of Artur summer dwellers will continue to support the local economy. The itemized economic impact analysis is illustrated in Table 3.

Table 3. Economic impact analysis (first 10 years only)

In 2009, US$		
Expenditures		12,976,909
Green Roof Installation	10,527,492	
Maintenance	2,449,417	
Energy Savings		1,673,820
Local expenditures		5,499,745
Green Roof Installation	2,631,873	
Maintenance	2,449,417	
Energy savings expended locally	418,455	
Multiplier		2.66
Local income generation		14,629,320
Local employment creation		292

6. Conclusion

A pilot region with 1729 residential units in the Aegean region of Turkey was analyzed in terms of economic impact for the case of all roofs being vegetated at this site. The whole site had a total roof area of 99,440 m^2. Economic impact analysis involved green roof installation, maintenance and energy savings over the first 10 years of such an application.

Five different types of vegetation (*Astragalus Membranaceus*, *Agave Americana*, *Chantholimon Venustum*, *Sedum tectractinum*, and *Orostachys*) blended on a 10 cm deep growth medium of either pumice or red lava rocks blended with organic material were considered. The selected plants either grow in the Aegean region or have been tested before in similar climate zones.

Air-conditioning energy savings analysis was conducted for the whole pilot site and it was found out that daily energy savings of an average green roof application would be approximately $2,188 for the whole site for 25°C indoor - 35°C outdoor air-conditioning design conditions.

In terms of the impact on local economy, monetary injection into the local economy was calculated and a multiplier effect of 2.66 was assumed. Net present value (NPV) of the generated income for the first 10 years was calculated to be approximately $14.5 million which could generate approximately 300 new local jobs over the course of 10 years assuming that a $50,000 investment is required to create employment for a single person.

This study lays out potential benefits of green roof applications to the local environment in terms of economic development and energy savings. Although some assumptions exist in the analyses performed, the results are considered as realistic as the assumed values came from prior studies which involve theoretical and experimental analyses.

References

[1] Residential energy consumption survey 2009, Energy Star website.

[2] Dawson, D., Plant-covered roofs ease urban heat, National Geographic News, 2002.

[3] Brenneisen, S., The World Green Roof Congress, Opening Session, Basel, Switzerland, 2005.

[4] Pilloton, E., 2006, “Chicago Green Roof Program”, an article in Inhabitat.

[5] Liu, K., “Engineering performance of rooftop gardens through field evaluation”, National Research Council Canada: Institute for Research in Construction, 2003.

[6] Sidwell, A., Gibbs-Alley, J., Forrester, K., Jost, V., Luckett, K., Morgan, S., Yan, T., Noble, B. and Retzlaff, W.A., “Evaluation of the thermal benefits of green roof systems”, Proceedings of the 6th Annual Greening Rooftops for Sustainable Communities Conference, pp. 12, Baltimore, MD, 2008.

[7] http://www.allaboutturkey.com/aegean.htm

[8] Celik, S., Morgan, S. and Retzlaff, W. A., “Energy Conservation Analysis of Various Green Roof Systems”, IEEE Green Technologies Conference, Grapevine, TX, April 15-16, 2010.

[9] Celik, S., Retzlaff, W. A. and Morgan, S., “Evaluation of Energy Savings for Buildings with Green Roofs Having Different Vegetation”, 1st International High Performance & Green Buildings Conference at Purdue, West Lafayette, IN, July 12-15, 2010.

[10] Wong, N. H., Taya, S. F., Wong, R., Chui Leng Ong, C.L., Siab, A., 2003. “Life cycle cost analysis of rooftop gardens in Singapore”, Building and Environment 38:499 – 509.

[11] Carter, T., Keeler, A., 2008. “Life-cycle cost–benefit analysis of extensive vegetated roof systems”. Journal of Environmental Management 87: 350–363.

[12] Rosensweig, C., Hillel, D. and Parshall, L., 2006. “Green Roof Research Station: Rationale, Experimental Design, Equipment, and Estimated Costs”. In Rosenzweig, C., Gaffin, S. and Parshall, L. (Eds.) Green Roofs in the New York Metropolitan Region: Research Report. Columbia University Center for Climate Systems Research and NASA Goddard Institute for Space Studies. New York.

[13] Acks, K., 2006. “A Framework of Green Roof Cost-Benefit Analysis: Initial Estimates, in Green Roofs in the New York Metropolitan Region”. In Rosenzweig, C., Gaffin, S., and Parshall, L. (Eds.) NASA/Goddard Institute for Space Studies and Columbia University Center for Climate Systems Research.

[14] Ekaterini, E. and Dimitris, A., 1998. “The contribution of a planted roof to the thermal protection of buildings in Greece”. Energy and Buildings; 27(3):29–36.