Economic appraisal model of green roofs in residential buildings

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key words: green roofs, real estate market, market comparison approach, appraisal system approach

Abstract

Green roofs are sustainable solutions, widely used in urban environments in order to diminish the energy consumption of a building and decrease the risk of urban flooding on a large scale. Numerous researches and studies have demonstrated the effectiveness of such sustainable solution, yet there are barriers regarding market uptake of these systems because there isn't a systematic economic appraisal of green roofs which points out that these systems are also profitable.

This paper intends to evaluate system and management costs of a green roof and above all to quantify the added value provided by green roofs to buildings. To quantify in monetary terms the impact of green roofs on the market value of a real-estate property, the criteria and the appraisal methods based on the International Valuation Standards have been used. The study, experimentally tested, has demonstrated that the increase in value of the real-estate properties provided by the green roof is greater than the installation and management costs and is, therefore, economically convenient.

1. INTRODUCTION

To increase the energy efficiency of a building and control the risk of urban flooding, sustainable solutions, such as green roofs, have been widely used in urban environment (Piro *et al.*, 2013). Green roofs are "green" systems which allow to achieve high standards of environmental sustainability and more efficient management of water and energy resources (Mentens, *et al.*, 2006) on the building's scale (Dietz, 2007). In the last years, the increased interest in the use of "green" infrastructures, also from an architectural perspective, has led researchers and engineering companies to further investigate these practices. Nevertheless, the use of such approaches is still limited, since the costs required for their installation and maintenance have not been systematically evaluated yet. Differently from traditional roofs, green roofs are characterized by a top layer made of plant species and mineral soil (substrate), an underneath layer consisting of drainage and aeration system and a waterproof layer (ISPRA, 2012). Green roofs can be classified as intensive or extensive roofs. The first ones are characterized by a variety of vegetation ranging from herbaceous plants to small trees and the need of professional maintenance. The second, with a growing medium depth of 10 centimeters or less, are characterized by a vegetation, ranging from sedum to small grass, little maintenance and no permanent irrigation system (Abram, 2011). Green roofs can also be classified according to: 1) medium depth; 2) construction costs; 3) maintenance costs required for the conservation of the vegetative part.

A green roof brings benefits on a multiscale level. At the building scale, a green roof improves thermal insulation of the rooms underneath, consequently reducing temperature excursions (Lazzarin, 2005; Wong *et al.*, 2007; Liu, 2002; Dunnett and Kingsbury, 2004). Because of the presence of the medium layer, green roofs ensure an increase of the coverage functionality (Peri et al. 2012; Mann, 2002; Porsche and Köhler, 2003; Hermy et al, 2005; Saiz *et al.*, 2006). On the urban scale, so-called urban heat island phenomenon can be mitigated through the use of green roofs, as well as the risk of urban flooding. Such benefits can be easily turned into utilities, if their economic value is quantified. Indeed, green roofing is not only able to meet sustainable development criteria and to provide significant energy saving, but it also has a direct and significant impact on the housing market, especially on private households.

Nowadays, the real estate market is characterized by a substantially qualitative demand. The concept of the quality of a manufactured building is closely related to its energy saving feature, which represents a proxy of other estate features, related to the construction of a building. A building that is able to ensure a high level of comfort while abating energy loss, is more likely to be well-built, constructed with efficiently insulated and designed materials (De Ruggiero *et al.*, 2017).

Energy efficiency is the parameter that can best describe the construction quality of a building and, at the same time, provides a tangible measure of the costs of property management; thanks to such parameter, it is possible, in fact, to quantify the added value to the building (Quanjel et al. 2007), represented by the savings in energy and costs, achievable with a building constructed in accordance with the criteria of environmental sustainability.

The methodology used in this study to evaluate the contribution that a green roof brings to the market value of a building belongs to the Market Comparison Approach (MCA) and the Appraisal System Approach (ASA). The installation and maintenance costs have been quantified by making them comparable to the costs obtained through the Discount Cash Flow Analisys (DCFA). This methodology has been applied to a case study concerning buildings in the city of Arluno, Milan (Italy). The numerical application aims to practically show the theoretical approach, considering that this methodology can be applied to different geographical and typological contexts.

2. METHODOLOGY

According to the international valuation standards, the three classical methods of real-estate valuation are: the *Market Approach*, the *Income Approach* and the *Cost Approach* (of depreciated reproduction).

The *Market Approach* provides an indication of the value of a real-estate property by comparing the subject with other similar properties purchased or sold recently, therefore information about the prices of transactions and data are available. It includes a number of procedures and many variations. The main market-oriented procedures are: single-parameter appraisal procedure, Distribution System Method, Market Comparison Approach (MCA) (Salvo et al. 2016, Salvo *et al.*, 2013), Appraisal System Approach (ASA), mixed procedures (MCA and ASA) (Simonotti, 2006).

The *Income Approach* method is based on the capitalization of the financial income of the property. The appraisal procedure for the income capitalization (income capitalization approach) includes methods that analyse the ability to generate monetary benefits of a property and the ability to convert these benefits into values. The procedures within the financial method are Direct Capitalization (which converts the annual income expected in the market value of a property), Yield Capitalization (which applies the financial calculation to convert the series of income into a value through an essay capitalization), Discounted Cash Flow Analysis (considering the range of costs and revenues from the purchase date at the time of resale of the property to be appraised, providing a final market value).

The *Cost Approach* is based on the comparison of the property and similar properties by considering the features of the area and the differences in age, condition and utility of the building. The cost method applies the economic principle of substitution for which a buyer will not pay for a property a price higher than what you would pay for another property with the same degree of usefulness, whether as a result of the sale of that building.

Often the property, due to age or obsolescence, is less attractive than a modern equivalent property. In this case, the adjustment of the value is performed by means of depreciation. The cost method of reproduction (or reconstruction) depreciated (cost approach) is an appraisal procedure designed to determine the value of a property by adding the value of the land, built to the cost of reconstruction of the building, possibly depreciated. The cost approach appraises the value of the built, the cost of a new construction and depreciation.

The following paragraphs show the analysis of the installation and maintenance costs of an intensive green roof by using the DCFA method and the analysis of the marginal price of the green roof feature according to the MCA and ASA methodology.

2.1 Construction and Maintenance Costs

In the analysis of the construction costs of green roofs all the elements that are included in the stratigraphy must be considered. Besides, the safety actions to make the green roofs accessible and usable should not be neglected. All the additional works to realize the manholes, control the discharges, overlap the waterproofing layers and place the containment walls, that should be at least 15 cm higher than the green roof height, have influenced the final construction costs and demonstrated the necessity of specialized installers. In the following sections, the economic analysis is carried out by evaluating construction and maintenance costs.

The construction cost is given by the sum of the costs of the material necessary for the realization of a square meter of a green roof, the cost of the labour, measured in man-hours per square meter and the cost of freight and transportation of material, corresponding to the elementary prices deducted from official lists or current market prices.

To this sum, a percentage for expenses related to safety, a variable percentage (13-17%) for overheads, and finally a percentage (10%) profit for the contractor (Legislative Decree 207/2011) need to be added.

The most relevant parameters in the economic management of a green roof is the degree of maintenance, due to the presence of plants. In order to have all the features of a green roof preserved, and, in particular, all those related to the vegetable part, a good maintenance plan must be outlined. In the UNI 11235 e the FLL, an indication of the annual maintenance required is given according to the type of roof, as well as the levels of maintenance, such as start-up of controlling (testing); start-up of the system (only for extensive roofs); ordinary (routinely) and extraordinary (UNI 11235 and FLL).

In this work, the cost of ordinary (routinely) maintenance, which begins when an adequate coverage of the surface is achieved, is considered. The routine maintenance of green roofs consists of cutting the lawn, weeding, fertilizing the lawn, plant-health measures, etc.

For the type of green roof described in this study, the method of evaluation of the cost for routine maintenance involves the calculation of the annual labour required for one square meter of the system. Following the indications of the regulations on green roofs, the hours needed for routine maintenance are obtained and then multiplied by the hourly cost of a (gardener) worker, providing the total cost of the annual maintenance.

Based on the sum of the individual unit costs per square meter of the elements present in the stratigraphy.

The costs analysis is quantified by applying the DCFA procedure. The total cost of the green roof is obtained by updating the costs of ordinary and extraordinary maintenance through the following formula:

$$C = \sum_{t=0}^{n} C_t \cdot (1+i_k)^{-t} + \left[\frac{C_o}{i} + \frac{C_s}{(1+i)^p - 1}\right] \cdot (1+i_k)^{-n} \qquad (1)$$

in which:

- C is the updated total cost,
- C_t is the cost of installation,
- C_S is the cost of extraordinary maintenance,
- C_O is the cost of ordinary maintenance,
- i is the non-convertible rate per annum,
- i_K is the periodic rate,
- n number of instalments,
- p term of the annuality.

The cost of maintenance as function of the construction costs for different roofs, varying according to the types of vegetation, is reported below. The graph in Figure 1 shows that the studied green roof can be classified as a wild meadow (intensive green roof).

2.2 Economic appraisal model for a green roof

The methodological approach used for the present study is the ***Market Comparison Approach***, which involves the methods of the MCA and the ASA.

The MCA is a process that leads to the valuation of the market value of a property based on the comparison with the prices of properties similar (P_j) to the subject, traded on a date close to that of valuation. In particular, the process comes to the appraisal of the market value of the property through a series of adjustments (adjustments), calculated on the basis of the common property features. Through the adjustments you obtain the correct prices (P_{cj}) of the properties for comparison. The adjustment for the property j-th (j = 1,2, ..., m) and for the i-th feature (FET) (with i = 1,2, ..., n) is equal to the product of the hedonic price p_i (defined as the change in the total price corresponding to a unit change in the amount of real estate property) and the difference between the features of the property FET_{i0} and those of the building in comparison FET_{ij}:

$$P_{cj} = P_j + \sum_{i=1}^{n} p_i \left(FET_{i0} - FET_{ij}\right) \qquad (2)$$

The correct prices are traced to a single market value V usually obtained as the expected value of the correct prices, which in the case of equi-probability is equal to:

$$V = \frac{1}{m} \cdot \sum_{j=1}^{m} P_{cj} \qquad (3)$$

The ASA is an appraisal approach based on the comparison between the property to be assessed and the price of similar known properties. This approach is based on the setting and the resolution of a system consisting of m linear equations, one for each comparison property (price known), in n +1 unknowns, represented by the market value and the hedonic prices of the considered real estate properties. The ASA features aim to explain the price difference between the buildings through the differences in the presented property's features. Referring to two generic properties of indices j and k, the difference between the relative prices P_j and P_k is represented by the linear combination of the differences between the amounts of the respective FET_{jk} features, specifically:

$$V_{jk} = P_j - P_k = \left(FET_{j1} - FET_{h1}\right) \cdot p_1 + \ldots + \left(FET_{jn} - FET_{kn}\right) \cdot p_n \qquad (4)$$

where p_i are the hedonic prices of the considered real estate features (for i = 1, ..., n). The appraisal system is presented in the form:

$$\begin{cases} P_1 = V + \sum_{i=1}^{n} (FET_{1i} - FET_{0i}) \cdot p_i \\ P_2 = V + \sum_{i=1}^{n} (FET_{2i} - FET_{0i}) \cdot p_i \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ P_m = V + \sum_{i=1}^{n} (FET_{mi} - FET_{0i}) \cdot p_i \end{cases} \quad (5)$$

where:

P_j is the purchase price of the generic *j*-th housing unit, with $j = 1, 2, ..., m$, expressed in €;

V is the value of the subject property, expressed in €;

FET_{ji} represents the characteristic of the *i*-th, with $i = 1, 2, ..., n$, of the generic *j*-th transaction;

p_i is the hedonic price of the *i*-th feature.

The appraisal system is presented in matrix form:

$$p = D^{-1} x\ P \quad (6)$$

where:

p is the appraising vector, consisting of *n*+1 elements (value and hedonic prices);

$$p = \begin{bmatrix} V \\ p_1 \\ \cdots \\ p_n \end{bmatrix} \quad (7)$$

P is the vector of known prices;

$$P = \begin{bmatrix} P_1 \\ P_2 \\ \cdots \\ P_m \end{bmatrix}, \quad (8)$$

D is the matrix of differences.

$$D = \begin{bmatrix} 1 & FET_{11} - FET_{01} & FET_{12} - FET_{02} & \dots & FET_{1n} - FET_{0n} \\ 1 & FET_{21} - FET_{01} & FET_{22} - FET_{02} & \dots & FET_{2n} - FET_{0n} \\ \dots & \dots & \dots & \dots & \dots \\ 1 & FET_{m1} - FET_{01} & FET_{m2} - FET_{02} & \dots & FET_{mn} - FET_{0n} \end{bmatrix}, \quad (9)$$

The total price of a property is a function of the amounts of quantitative and qualitative features. If it is possible to appraise the hedonic price in a direct way for the quantitative features, whereas for many qualitative features – landscape, views, pollution, historical and architectural quality – the appraising of the hedonic price takes place through the appraisal systems, with data samples sufficiently numerous, with statistical analysis. The appraisal method is a formalization of the MCA; as a result, the two procedures can be efficiently integrated, so that the hedonic prices of quantitative features are determined by the MCA, and the market value and the hedonic prices of quality features with the appraisal system.

3. RESULTS

In order to test accuracy, the proposed approach follows a numerical example based on a concrete appraisal sample concerning flats in condominium. We proceeded to carry out the market analysis, by collecting data related to contracts in recent sales of properties similar to the one being valued. Thus, the analysis identifies three trades of properties similar to the one being valued, all located in the same neighbourhood in order to delete the locational component.

Sale data of real estate units, which are located in multi-story buildings in residential areas in the center city of Arluno in the province of Milan, Italy were retrieved. For each housing unit the purchase price (PRZ) was detected and the following real estate features were considered:

- surface (SUR) commercial surface in square metres,
- restrooms (RES) number of bathrooms in each building unit, rendered in n°,
- floor level (LEV), is the floor on which the building unit is situated, expressed as floor,
- green roof (GRO), are the square metres of intensive green roof of each condominium.

All transactions took place in the first months of 2016 (from january to march), therefore the date of purchase is not considered in the marginal prices analysis of MCA. All the other features that were not considered in the tabulation of data represent caeteris paribus and therefore cannot be considered in the driver features in the evaluation.

Table 1 - *Data Table*

Sale Price and Real Estate Feature	A	B	C	S
PRZ (€)	146.000,00	177.800,00	538.000,00	
SUR (sq)	62,00	104,00	150,00	80,00
RES (n°)	1	2	2	1
LEV (level)	2	1	3	0
GRO (sq)	62,00	0,00	200,00	0,00

The hedonic prices of real estate properties were estimated as follows.

Surface

The calculation of the hedonic prices for the surface characteristic can be resolved based on the average price:

$$p_{SUR} = \frac{Prz}{S} \qquad (10)$$

where p_{SUR} is the hedonic price of the surface, expressed in €/sqm; *S* represents the surface of the property, expressed in square meters. Hedonic prices of the commercial surface feature are presented in table 2.

Restrooms

The restrooms feature refers to the number of toilets in the unit real estate. The hedonic price of the restrooms feature is evaluated according to the criteria of the depreciated cost of reconstruction, that is, as the cost of rebuilding, usually depreciated according to a linear law:

$$p_{RES} = C \cdot \left(1 - \frac{t}{n}\right) \qquad (11)$$

where:

p_{RES} is the hedonic price of the restrooms feature, expressed in €/n°;

C is the average cost for the installation of a new restroom, expressed in €;

t is the past life, expressed in years;

n is the economic life of toilets technological systems, in years.

In this specific case, marginal prices are defined as follows:

$$p_{RES_A} = 10.000,00\frac{€}{n°} \cdot \left(1 - \frac{2\,years}{15\,years}\right) = 8.666,67\frac{€}{n°} \qquad (12)$$

$$p_{RES_B} = 10.000,00\frac{€}{n°} \cdot \left(1 - \frac{7\,years}{15\,years}\right) = 5.333,33\frac{€}{n°} \qquad (13)$$

$$p_{RES_C} = 10.000,00\frac{€}{n°} \cdot \left(1 - \frac{2\,years}{15\,years}\right) = 8.666,67\frac{€}{n°} \qquad (14)$$

Level plan

The market price of a housing unit in a multi-storey building is linked to the level occupied inside the building, and then to its floor level. In principle, buyers prefer the intermediate levels compared to the first and the last, for environmental and climate reasons. The presence of the lift is one of the factors that most effect the consideration of the level of the.

A level rate can be used to express the percentage change in the total price going from one floor level to another. It is a quantitative parameter of the segment of the real estate market. It is generally presented as a percentage increase to the rise of the level (in the presence of the lift) or decrease (in the absence of the lift), or as a lump sum from one floor to another. These values are sometimes reported in the publications of the real estate industry.

The hedonic price of level rise can be calculated by multiplying the total price of the property by the ratio percentage represented by the level rate:

$$p_{LEV} = P \cdot \vartheta \qquad (15)$$

where:

p_{LEV} is the hedonic price of the level plan, expressed in €/level;

P is the total price of the property, expressed as a €;

ϑ is the level rate.

In this specific case a value has been assumed as 3%.

Once the hedonic prices were defined, valutation table was edited.

To take account of duplication in the analysis of hedonic prices we proceed to calculate the coefficient *r* for each comparable (Salvo *et al.*, 2016).

The r_j coefficient is calculated as follows:

$$r_A = \frac{SUR_{Subject} - SUR_A}{SUR_A} = \frac{mq80,00 - mq62,00}{mq62,00} = 0,29 \qquad (16)$$

$$r_B = \frac{SUR_{Subject} - SUR_B}{SUR_B} = \frac{mq80,00 - mq104,00}{mq104,00} = -0,23 \qquad (17)$$

$$r_C = \frac{SUR_{Subject} - SUR_C}{SUR_C} = \frac{mq80,00 - mq150,00}{mq150,00} = -0,47 \qquad (18)$$

The *rj* coefficients are significant in the hedonic price table (Table 2).

Table 2 - *Hedonic Price Table*

Hedonic Prices	A	B	C
SUR (€/sq)	2.354,84	1.709,61	3.586,67
RES (€/n°)	8.666,67	5.333,33	8.666,67
LEV (€/level)	4.380,00	1.709,61	3.586,67
r_j	0,29	-0,23	-0,47

Below, for each comparable and for each attribute are shown the corresponding adjustments.

Surface Adjustment

$$p_{SUR_A}\cdot[SUR_{Subject}\text{-}SUR_A]= \\ =\frac{€}{m^2}2.354,84\cdot[m^2(80,00-62,00)]= \\ =€\ 42.387,10, \quad (19)$$

$$p_{SUR_B}\cdot[SUR_{Subject}\text{-}SUR_B] \\ =\frac{€}{m^2}1.709,61\cdot[m^2(80,00-104,00)]= \\ =-€\ 41.030,77 \quad (20)$$

$$p_{SUR_C}\cdot[SUR_{Subject}\text{-}SUR_C]= \\ \frac{€}{m^2}3.586,67\cdot[m^2(80,00-150,00)]= \\ =-€\ 251.066,67. \quad (21)$$

Restroom adjustment

$$p_{RES_A}\cdot[RES_{Subject}\text{-}RES_A\cdot(1+r_A)]= \\ =\frac{€}{n°}8666,67\cdot[1,00-1,00\cdot(1+0,29)]=-€2.516,13, \quad (22)$$

$$p_{RES_B}\cdot[RES_{Subject}\text{-}RES_B\cdot(1+r_B)]= \\ =\frac{€}{n°}5.333,33\cdot[1,00-2,00\cdot(1-0,23)]=-€2.871,79 \quad (23)$$

$$p_{RES_C}\cdot[RES_{Subject}\text{-}RES_C\cdot(1+r_C)]= \\ =\frac{€}{n°}8666,67\cdot[1,00-2,00\cdot(1-0,47)]=-€577,78, \quad (24)$$

Floor level adjustment

$$p_{FLO_A}\cdot[FLO_{Subject}\text{-}FLO_A\cdot(1+r_A)]= \\ \frac{€}{livello}4.380,00\cdot[3,00-2,00\cdot(1+0,29)]=€1.836,77, \quad (25)$$

$$p_{FLO_B}\cdot[FLO_{Subject}\text{-}FLO_B\cdot(1+r_B)]= \\ \frac{€}{livello}1.709,61\cdot[3,00-1,00\cdot(1-0,23)]=€3.813.75, \quad (26)$$

$$p_{FLO_C}\cdot[FLO_{Subject}\text{-}FLO_C\cdot(1+r_C)] \\ =\frac{€}{livello}3.586,67\cdot[3,00-6,00\cdot(1-0,05)]=-€717,33 \quad (27)$$

Adjustments table is given below.

To determine the hedonic price of the green roof and the appraised value of the property, the ASA is applied.

Table 3 - *Sales Adjustment Grid (€)*

Sale Price and Real Estate Feature	A	B	C
PRZ	146.000,00	177.800,00	538.000,00
SUR	42.387,10	-41.030,77	-251.066,70
RES	-2.516,13	-2.871,79	-577,78
LEV	1.836,77	3.813,75	-717,33
Correct Price (PRZ_C)	187.707,74	137.711,18	285.638,22

The ASA is presented in the form:

$$\begin{cases} P_{correctA} = V + (GRO_A - GRO_0)\cdot P_{GRO} \\ P_{correctB} = V + (GRO_B - GRO_0)\cdot P_{GRO} \\ P_{correctC} = V + (GRO_C - GRO_0)\cdot P_{GRO} \end{cases} \quad (28)$$

where:

- $P_{correctA}$, $P_{correctB}$ and $P_{correctC}$ are the correct prices of A, B, and C, expressed in €;
- V is the value of the subject property, expressed in €;
- G_{ROA}, G_{ROB}, G_{ROC} and G_{RO0} represent the characteristic green roofs for A, B, C, and 0 property;
- p_{GRO} is the hedonic price of the green roofs characteristic, expressed in €/ sq.

The ASA is reported:

$$P=\begin{bmatrix} V \\ P_{GRO} \end{bmatrix} \quad (11)$$

$$P=€\begin{bmatrix} 187.707,74 \\ 137.711,18 \\ 285.638,22 \end{bmatrix} \quad (29)$$

$$D=\begin{bmatrix} 1\ sq\ (62,00-0,00 \\ 1\ sq\ (0,00-0,00 \\ 1\ sq\ (200,00-0,00 \end{bmatrix} \quad (30)$$

Solving the system allows to appraise the incidence of the presence of the green roof quantified in 734,63 €/sq and the value of the property quantified at 139.527,77 €

The analysis of the costs is carried out by considering a green roof characterized by the following stratigraphy: (1) soil substrate of 30 cm; (2) 'egg box' drainage and storage layer in PEAD (storage capacity of 8,7 L/sq). The thickness of the entire package is 33 cm. On the green roof the following plants are implanted: Carpobrotus edulis, Dianthus gratianopolitanus, Cerastium tomentosum. Those vegetal species are selected due to their minimal water demand for irrigation and resilience to Mediterranean climate conditions. Figure 1 shows the stratigraphy of the green roof analyzed.

Table 4 - *Unit costs of the material needed for realizing the green roof*

Layer	Cost/m^2
Anti-roof sheet	€ 9,00
Mechanical protection Sheet meccanica	€ 3,50
Storage/drainage/Aeration	€14,00
Filtration	€ 2,00
Soil substrate	€72,00
Vegetation	€35,00

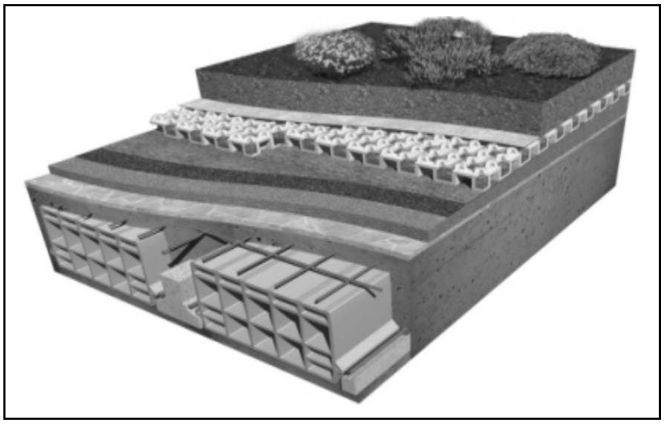

Figure 1 - *Stratigraphy of the green roof (case of study)*

The cost of construction per square meter of green roof, considering all the components that make up the type of intensive green roof, the supply of materials, installation to make the work in a correct manner, is equal from €/sq 157.50. Besides the cost of construction should also be considered that the cost of maintenance for the types in question has been quantified in 1.48 €/sq/year.

Assuming to pay the 10% of the installation cost as down payment, the 20% after a month, the 30% three months later and the remaining 40% after the third month.

To determine the capitalization rate we referred to the specific market segment defined as a range of values between 3,6% and 4,4%.

Applying formula 1, we can determine the total cost of a green roof serving to the current situation the costs of installation, those of ordinary and extraordinary maintenance.

$$C = 0{,}1 \cdot C_t + 0{,}2 \cdot C_t \cdot (1 + i_{12})^{-1} + 0.3 \cdot Ct \cdot (1 + i_{12})^{-2} + 0{,}4 \cdot Ct \cdot (1 + i_{12})^{-3} + \left[\frac{C_o}{i} + \frac{C_s}{(1+1)^3 - 1} \right] \cdot (1 + i_{22})^{-2} \quad (31)$$

with i=3,6

$$C = 0{,}1 \cdot 157{,}50 + 0{,}2 \cdot 157{,}5 \cdot (+0{,}0029)^{-1} + 0.3 \cdot 157{,}50 \cdot (1 + 0{,}0029)^{-2} + 0{,}4 \cdot 157{,}50 \cdot (1 + 0{,}0029)^{-3} + \left[\frac{1{,}48}{0{,}036} + \frac{2}{(1 + 0{,}036)^3 - 1} \right] \cdot (1 + 0{,}0029)^{-2} = 215{,}21 \frac{€}{sq} \quad (32)$$

with i=4,4

$$C = 0{,}1 \cdot 157{,}50 + 0{,}2 \cdot 157{,}5 \cdot (+0{,}0032)^{-1} + 0.3 \cdot 157{,}50 \cdot (1 + 0{,}00329)^{-2} + 0{,}4 \cdot 157{,}50 \cdot (1 + 0{,}0032)^{-3} + \left[\frac{1{,}48}{0{,}044} + \frac{2}{(1 + 0{,}044)^3 - 1} \right] \cdot (1 + 0{,}0032)^{-2} = 209{,}15 \frac{€}{sq} \quad (33)$$

The "presence of a green roof" is quantified in the segment of the real estate market of the city of Milan in the province of Arluno €734.63 €/sq. The total cost of a green roof goes from a minimum of 209,15 €/sq to a maximum of 215,21 €/sq.

As expected, the increase in value of the property is greater than the cost of installation.

4. CONCLUSIONS

In the last years, an increased interest in the use of "green" infrastructures in architectural design has led researchers and engineering companies to investigate the effect of such practices on mitigating stormwater volumes and energy consumptions. However, green roofing is not only able to meet sustainable development criteria, but it also has a direct and significant impact on the housing market, especially on private households.

Energy efficiency is the parameter that can best describe the construction quality of the building of interest and at the same time it provides a tangible measure of the costs of property management; thanks to such parameter, it is possible, in fact, to quantify the added value of the building, represented by the savings in energy and costs, achievable with a building constructed in accordance with the criteria of environmental sustainability.

This paper evaluates the added value provided by the green roofs to buildings from an economic perspective, identifying the criteria and the appraisal methods based on the International Valuation Standards for quantifying in monetary terms the impact of green roofs on the market value of the properties. The appraisal methodologies used in this study are the market comparison approach and the General System of Assessment. The current work also analyzed a case study in order to compute the costs of installation and maintenance of a green roof with specific features and to valuate the increase in value of the property after the intervention.

The analysis demonstrate that the increase in value of the property with the realization of a green roof is greater than the cost of installation.

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