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Energy Efficiency and Financial Performance of a Reference Hotel - Proposing a Global Cost-Benefit Analysis

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Abstract

Academic literature suggests a positive relationship between environmental and financial performance in property investments: in addition to the energy savings related to the building renovation, co-benefits can be reaped, ranging from being healthier to providing lower ownership risk. In this context, the paper describes the EU prescribed cost-optimality calculation performed for a hotel building and proposes an experimental revised version on the cost-optimal methodology, in which the co-benefits of energy retrofit are assessed and included in the calculation. An Italian existing Reference Hotel (RH) was selected as baseline model for the cost-optimal analysis. A number of Energy Efficiency Measures (EEMs) and packages of EEMs for the building envelope were applied to the RH, for which energy performances were assessed through a dynamic energy simulation software. Firstly, primary energy consumptions and global costs of the packages of EEMs were derived to identify the cost-optimal configuration from a financial point of view. The second step of the work dealt with the definition of a revised version of the formula for global cost. The proposed "global cost-benefit" formula was then applied to all the retrofit options. Results showed that including co-benefits can significantly reduce the global cost of retrofit projects and can transform the cost-optimal methodology in a useful tool for modifying investors' perception of the financial convenience of retrofit interventions.

Keywords - building energy retrofit; cost-optimality; global cost-benefit; reference hotel

1. Introduction

Energy efficiency has gained the floor in global policies as a key resource for economic and social development, procuring tangible and intangible benefits to many different stakeholders [1]. However, in the building sector energy efficiency potential remains mostly unexploited [1]. Indeed, in order to develop a lively market of energy efficiency investments, key decision makers have to have a clear understanding of the wide spectrum of improvements that energy efficiency upgrades may bring, as pre-condition for their voluntary involvement. A wide sample of academic literature and public reports lists, analyses and attempts to quantify such benefits, whose positive effects can be seen both at macro and micro economic scale [1, 2, 3].

Monetization of non-tangible benefits related to energy efficiency in buildings, here named co-benefits, is a complex task that requires deep understanding of countries' specific markets. Because of their inner complexity, co-benefits are currently not included in the cost-optimal methodology, recommended by the EPDB recast for the definition of minimum energy requirements in buildings in EU Member States. The methodology, by defining as "cost-optimal" the energy performance level which leads to the lowest cost during the building estimated economic lifecycle, has also the potential to become a useful decision making tool for stakeholders at the preliminary design stage. An increase in investments in energy efficiency may pass through this formula.

First proposals to include co-benefits in the well-established cost-optimal methodology can be found in [4] and [5]. The present paper follows these footsteps and focuses its attention on the inclusion in the global cost formula of co-benefits appreciated by private investors, with a specific focus on hotel businesses. Indeed, studies [6] reveal that the role of co-benefits in the decision of going green is a major issue in the hotel sector. Particularly interesting for this specific building category is the inclusion of increased guests' willingness to pay among the co-benefits. Green initiatives in hotels are perceived as ancillary services, for which guests may decide to pay more [7]. It must be specified that in the context of the hospitality sector, promoting a green image in strongly linked to green certifications. These hotel-related green certifications, such as Green Globe, Nordic Swan and Green Key, most often consider low energy use as one evaluation criteria of many and with no limit value to comply with. On the contrary, particular attention is paid to the use of eco-friendly materials [8].

In the next paragraphs, the evaluation of energy and economic performance of several retrofit options for the envelope of an Italian existing Reference Hotel (RH) is described. Capital intensive EEMs for passive strategies of retrofit were prioritized as they are the first step to increase energy efficiency in the context of an overall building renovation and reinvestment. First, the traditional cost-optimal analysis was performed. The second step entailed the definition and the hypothetical quantification of co-benefits to be included in a revised formula of global cost-benefit. Finally, the effect of this new formula was tested on the RH with respect to the previous analysis and different scenarios of co-benefits inclusions were compared and discussed.

2. Case study

The Italian existing Reference Hotel (RH) defined in [9] was used as baseline model for the study. The designated RH is a family-owned, 3-star, medium size hotel, open all year and built in an urban context in the Middle Climatic Zone (Turin, HDD=2617) between 1921-1945. Such a combination of features is statistically relevant in the Italian hotel buildings stock and it depicts a typical private investor's situation, with high potential for business improvements.

The building has a North-South oriented rectangular plan, developing in 4 floors above ground and in an half-basement area, where the extra facilities are located. With a total heated area of 1700 m^2, it offers to guests 49 rooms, a fitness area and a breakfast hall. The envelope thermal performance, focus of the present work, are summarized in column 2 of Table 1.

The hotel is heated by a condensing boiler powered by natural gas, with radiators as terminals units. Two condensing boilers are dedicated to domestic hot water production. A chiller is installed for cooling and the related terminals are two-pipes fan coils. Neither mechanical ventilation nor exploitation of on-site renewable energy sources are present.

Hotel's occupancy and operation values were taken from UNI 10339:2005 and EN 15232:2007, their schedules from [10]. Comfort conditions were set according to Comfort Category I defined by EN15251:2007.

In order to evaluate the energy performance of the so-defined virtual reference building, a simulation model was built and run in Energy Plus.

3. Method

a. Cost-optimal analysis

Applying the cost-optimal methodology requires three main stages, detailed in the followings for the specific case study.

Stage 1: definition of retrofit options. Energy Efficiency Measures (EEMs) and Packages of EEMs were applied to the RH envelope. Two different retrofit strategies were followed in parallel: the first foresees the use of standard materials and techniques to achieve the required energy performances levels (e.g. EPS insulation and PVC windows); the latter uses eco-friendly materials, such as recycled wood fiber insulating panels and windows with frames in local wood, to fulfil the same requirements. The implementation of eco strategies seeks to comply with hotels green certifications requirements. Coming to energy requirements, two levels of minimum performances for the envelope elements were established based on figures set by the Italian Decree "Requisiti Minimi" 26-06-2015. Table 1 presents the limit values for EEMs. Table 2 lists the ten resulting packages of measures.

Table 1. Energy Efficiency Measures (EEMs) applied to the baseline model

Envelope component	Perf. Level RH	Perf. Level 1	EEM Code	Perf. Level 2	EEM Code
External wall	U=1.1 W/(m^{2}K)	U ≤ 0.30 W/(m^{2}K)	E1.1	U ≤ 0.26 W/(m^{2}K)	E1.2
	U=0.8 W/(m^{2}K)		E1.1eco		E1.2eco
Ground floor	U=2.0 W/(m^{2}K)	U ≤ 0.30 W/(m^{2}K)	E2.1	U ≤ 0.26 W/(m^{2}K)	E2.2
			E2.1eco		E2.2eco
Roof	U=0.7 W/(m^{2}K)	U ≤ 0.25 W/(m^{2}K)	E3.1	U ≤ 0.22 W/(m^{2}K)	E3.2
			E3.1eco		E3.2eco
Windows/ doors	U_w=4.9 W/(m^{2}K)	U ≤ 1.80 W/(m^{2}K)	E4.1	U ≤ 1.40 W/(m^{2}K)	E4.2
	U_w=5.7 W/(m^{2}K)				
	U_w=3.8 W/(m^{2}K)		E4.1eco		E4.2eco
Shadings	-	overhangs	E5.1	automated blinds	E5.2

Table 2. Packages of EEMs applied to the baseline model

Code	EEMs included
PE1/PE1eco	E1.1(eco) + E2.1(eco) + E3.1(eco)
PE2/PE2eco	E1.2(eco) + E2.2(eco) + E3.2(eco)
PE3/PE3eco	E4.1(eco) + E5.1
PE4/PE4eco	E4.2(eco) + E5.1
PE5/E5eco	E1.1(eco) + E2.1(eco) + E3.1(eco) + E4.1(eco)
PE6/PE6eco	E1.2(eco) + E2.2(eco) + E3.2(eco) + E4.2(eco)
PE7/PE7eco	E1.1(eco) + E2.1(eco) + E3.1(eco) + E5.1
PE8/PE8eco	E1.2(eco) + E2.2(eco) + E3.2(eco) + E5.1
PE9/PE9eco	E1.1(eco) + E2.1(eco) + E3.1(eco) + E4.1(eco) + E5.1
PE10/PE10eco	E1.2(eco) + E2.2(eco) + E3.2(eco) + E4.2(eco) + E5.1

Stage 2: Energy Evaluation. EEMs and package of EEMs were implemented in the RH Energy Plus baseline model in order to evaluate their impact on primary energy uses.

Stage 3: Economic evaluation. As prescribed by the EU standard EN 15459:2007, the global cost (C_G) was calculated for the baseline scenario and for each retrofit option by applying equation (1):

$$C_G(\tau) = C_I + \sum_j * \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) * R_d(i)\right) - V_{f,\tau}(j)\right], \quad (1)$$

where $C_G(\tau)$ represents the global cost referred to starting year τ_0, C_I is the initial investment cost, $C_{a,i}(j)$ is the annual cost for component j at the year i (including running costs and periodic or replacement costs), R_d (i) is the discount rate for year i, $V_{f,\tau}(j)$ is the final value of component j at the end of the calculation period (referred to year τ_0). The discount rate R_d, expressed in real terms (i.e. excluding inflation), is used to refer the costs to the starting year.

Being the calculation performed from a microeconomic point of view, Italian VAT and taxes were included in the calculation of investment and running costs. The calculation period was set as 20 years; 4% discount rate was used; investment costs were taken from Piedmont Price List 2015; replacement and maintenance costs were derived from EN 15459:2007; energy costs were calculated by applying to Energy Plus simulation results the following energy tariffs: natural gas cost = 0,08 €/kWh; electricity cost = 0,23 €/kWh.

b. Identification of co-benefits

The present paper focuses its attention on the inclusion in the global cost formula of co-benefits appreciated by private investors. The identified co-benefits can be grouped in initial, running and final value benefits. They are listed, briefly justified and explained in the followings. Being the monetization of co-benefits a currently pending big challenge, too much context-dependent to be summarized in exact figures, the paper gives different options of monetization for each co-benefit.

Incentives (I). As explained by [5], the inclusion of incentives in the cost-optimal analysis of specific buildings can play an important role in investors' decision making process. Here a null and two positive amount of incentives are considered, based on Italian dispositions. Benefits are quantified as a percentage of the initial investment costs and they are accounted as a negative value in the revised cost-optimal formula.

Reduced sick leave (SL). Academic literature reveals a strong link between indoor air quality and Sick Building Syndrome [11]. This impact can be quantified by relating the economic value of a day of sick leave and the building ventilation rate, as proposed by [12]. In the present study EEMs do not modify the ventilation rate, therefore sick leave is assumed as constant and is excluded from benefits calculation.

Productivity (P). It has been widely verified that indoor environmental quality (IEQ) affects employees' productivity. As summarized in [13], productivity has a clear link with indoor air temperature and ventilation rates. Being ventilation constant among the considered retrofit options, in this work only the effect of indoor air temperature was considered. The equation statistically determined by [14] was used to define the variation in productivity. The obtained variation was related to the average hourly salary of an Italian employee (Salary = 16.83€/h), derived from Istat, the Italian institute for statistics. Only thermal zones dedicated to employees work (reception and office) were considered. Depending on indoor air temperature, productivity variation may be a positive (i.e. a cost) or a negative value (i.e. a benefit) in the CB_G formula.

Increased Service Price (sp). Several studies investigated the relation between green hotels costumers' Willingness to Pay (WTP) and their level of environmental concerns. While some analysis identified a premium for booking a standard room in a green hotel [15], others did not agree with this correlation [7]. The present study takes into account both points of view by introducing null, medium and high market appreciation of the green services. Ho Kang et al. [16] performed a survey investigating guests' WTP extra for green initiatives in hotels. The most frequent answers deriving from it were used as hypothesis for increasing the profit of the baseline scenario. The effect of comfort in guestrooms on guests' WTP in green hotels was questioned as well. It is recognized that service quality is the main determinant of consumer satisfaction, while "non essential attributes" such as commitment to sustainability deliver secondary benefits [17]. On the other hand, monitoring studies [18] proved that, given the same comfort level, occupants' of green buildings tend to complain less about IEQ than occupants of standard building. Rahman et al. [19] identified this behavior in green hotels as "willingness to sacrifice", which leads guests to accept lower service quality for higher rates. In the present case study all retrofit measures did not improve guests' comfort conditions, constantly within EN15251 Comfort Category III ($10\% < PPD \leq 15\%$). Following [19], the effect of low comfort level was not considered in the monetization of service price. The Istat data about the average yearly profit of a small size Italian hotel (Profit = 387 k€/y) was used as starting value, to which the null/increased WTP percentage was applied. The extra profit is accounted as negative value in the global cost-benefit formula.

Increased Market Value (MV). Market appreciation of energy efficient buildings has been confirmed by many studies. Most of the evidences are related to the effect of green certification on the real-estate market [20, 21]. The effect of retrofit actions on the market value of existing “unlabelled” buildings was studied by Popescu et al. [22]. Based on the quoted literature, three options of added value– low, medium and high - were considered and applied to the final value $V_{f,\tau}(j)$. The value increase is added to the original $V_{f,\tau}(j)$ in CB_G formula.

Table 3 recaps formulas and monetization options for each considered co-benefit.

Table 3. Co-benefits included in the global cost-benefit formula and their monetization options

Benefits			Eq.	Monetization options			
Cat.	Subcategory			Null (0)	Low (L)	Medium (M)	High (H)
Initial	Incentives (I)	B_I	$B_I = I*C_I$	I_0= 0%	-	I_M= 36%	I_H= 65%
Running	Productivity variation (P)	B_P	$P = 0.1647524*T - 0.0058274*T^2 + 0.00000623T^3 - 0.4685328$ $B_P = P*Salary$				
Running	Increased service price (sp)	B_{sp}	B_{sp} = sp*Profit	sp_0= 0%	-	sp_M= 5%	sp_H= 10%
Final value	Increased Market Value (MV)	$V_{MV,\tau}(j)$	$V_{MV,\tau}(j) = V_{f,\tau}(j) * MV$	-	MV_L= 3%	MV_M= 9%	MV_H= 15%

c. Global cost-benefit formula and scenarios

The inclusion of the co-benefits listed above in the traditional global cost (C_G) formula resulted in a revised global cost-benefit (CB_G) formula, shown in Eq. (2).

$$CB_G(\tau) = (C_I - B_I) + \sum_j * \left\{\sum_{i=1}^{\tau} \left[\!\left[\left(C_{a,i}(j) + B_P - B_{sp}\right) * R_d(i)\right]\!\right] - \left(V_{f,\tau}(j) + V_{MV}\right)\right\} \quad (2)$$

The CB_G formula was implemented for all the considered retrofit options.

In order to provide an overview of the potential of each co-benefits category in modifying the global cost for the proposed interventions, scenarios combining different benefits monetization options were created. However, not all scenarios were applied to all retrofit options. Since evidences of higher market values are related to the effect of energy certification, the hypothesis of medium and high increased MV were applied only to eco EEMs and packages of EEMs. A low market value increase was applied to standard retrofit options only. The same principle applies for the application of service price benefits. As increased guests’ WTP depends on the green image of a hotel and green image is closely linked to green certification [7], increased service price was considered only in models with eco EEMs and packages of EEMs.

The implemented benefits scenarios are presented in Table 4.

Table 4. Monetization options included in different global-cost benefits analysis scenarios

Scenario	Monetization options	Applied to
00L	$I_0 + P + sp_0 + MV_L$	Standard EEMs and Packages of EEMs
M0L	$I_M + P + sp_0 + MV_L$	
H0L	$I_H + P + sp_0 + MV_L$	
00M	$I_0 + P + sp_0 + MV_M$	Eco EEMs and Packages of EEMs
00H	$I_0 + P + sp_0 + MV_M$	
0MM	$I_0 + P + sp_M + MV_M$	
0HH	$I_0 + P + sp_H + MV_H$	
MMM	$I_M + P + sp_M + MV_M$	
MHH	$I_M + P + sp_H + MV_H$	
HMM	$I_H + P + sp_M + MV_M$	
HHH	$I_H + P + sp_H + MV_H$	

4. Results and Discussion

a. Cost-optimal with global cost formula

In Figure 1 the primary energy uses of the RH and of all its variations implementing EEMs and Packages of EEMs are plotted versus their corresponding global costs.

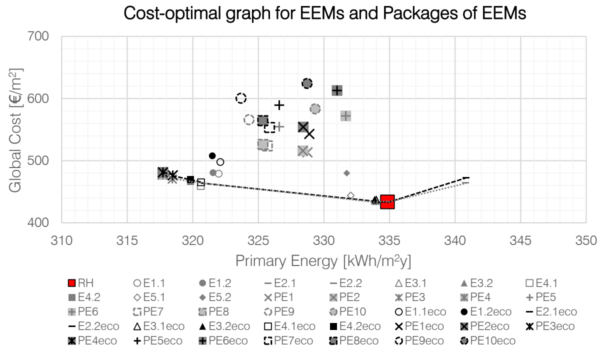

Figure 1. Global cost vs. primary energy for standard and eco EEMs and Packages of EEMs

Different kind of information can be inferred from the graph. The first deals with the difference in C_G between eco and standard EEMs and packages. Particularly, for interventions on the opaque envelope, extra 19 €/m^2 (e.g. $C_{G,E1.1eco} – C_{G,E1.1}$) to 41 €/m^2 (e.g. $C_{G,PE6eco}–C_{G,PE6}$) are accounted, meaning that, from a purely finance driven perspective, choosing eco-friendly retrofit options is not convenient.

Secondly, envelope retrofit options alone play a very limited role in reducing the total Primary Energy use of the building ($\Delta_{EP,max}$=23kWh/m^{2}y). Almost no difference can be noticed between the two levels of energy performance of each EEM and Package and very small variations are spotted among different retrofit options. Indeed the reduced heating energy consumption obtained by increased U-values were counterbalanced, and in some cases surpassed, in the simulation results, by increasing cooling energy consumption. With these premises, it not surprising that the most energy efficient options (PE4/PE4eco, PE3/PE3eco, E4.2/E4.2eco, E4.1/E4.1eco) include windows substitution, able to reduce both dispersions and solar gains. The very low decrease in Primary Energy, translated into almost constant running energy costs (C_E) among all the options, entails the cost-optimal curve to have its minimum corresponding to the RH, where no investment costs can be accounted. Being here C_I the major influencing factor in the C_G formula, the more invasive the retrofit option is, the higher its C_G (e.g. = PE10/PE10eco). By taking into account the traditional global cost formula, the most convenient retrofit option is not to retrofit at all.

a. Cost-optimal with global cost-benefit formula

As mentioned, cost-benefit analysis scenarios applied to standard retrofit options were different from cost-benefit analysis scenarios applied to eco retrofit options. Figure 2 displays the outcomes of the revised global cost-benefit formula for the scenarios involving standard measures; Figure 3 refers to eco measures. For the sake of visual clarity, in Figure 3 only the cost-optimal curves are shown.

The first remarks involve the effect of productivity (P), variable included in all scenarios. As a function of indoor air temperature, B_P reduces the global cost only in case the indoor temperature of the retrofit option is most favorable for employees' productivity than indoor temperature of the RH. This is not the case of the present study, where the increased thermal performance of the envelope caused overheating. If workers' well being was considered as single extra variable in the global cost-benefit analysis, a slight increase in the CB_G of each option would have been noticed. From Figure 2, it can be inferred that the single effect of a modest market appreciation of the retrofitted RH in terms of its final value it is not enough to convince investors to go for energy efficiency. Indeed, there is almost no variation from EEMs C_G and their C_{BG} for scenario 00L. Slightly more noticeable variations within the same EEMs with different benefit scenarios can be found by varying the incentives benefits B_I. This variable is able to "flatten" the previously drawn cost-optimal curve so that the most energy efficient options become, in terms of CB_G, as convenient as keeping the RH in its initial conditions. However, from the investors point of view, considering all the practical inconveniences that a renovation process entails, not even high public incentives can play the key role in modifying the profitability of a project toward energy efficiency.

This graphs points out the aspect having the deepest impact on the economical convenience of a retrofit measure: the service price increase. Medium and high building market value increases alone do not modify, and in some cases slightly increase, the initial C_G, meaning that reduced productivity is able to neutralize market appreciation, if their effect is compared in economical terms. The role of B_I has the same trend as for standard measures. On the contrary, including service price benefits in the global cost-benefit formula, led to a reduction in global cost of 155€ for medium appreciation (+5% WTP), of 309€ for high appreciation (+10% WTP) for all the eco retrofit measures. While no retrofit strategy was convenient according to the C_G formula, the implementation of the CB_G draws a very different scenario for eco EEMs and packages. Taking into account medium or high increase in service price makes almost any retrofit option more profitable than the baseline scenario.

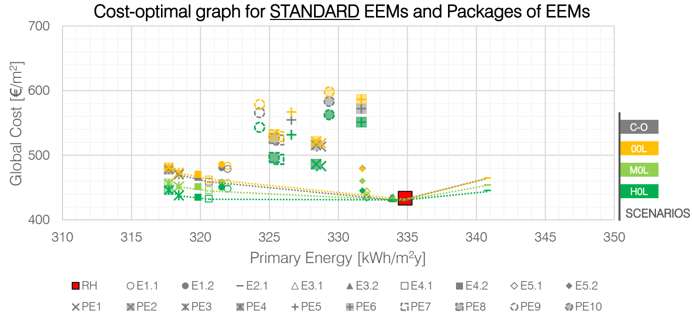

Figure 2. Global cost-benefit vs. primary energy for standard EEMs and Packages of EEMs

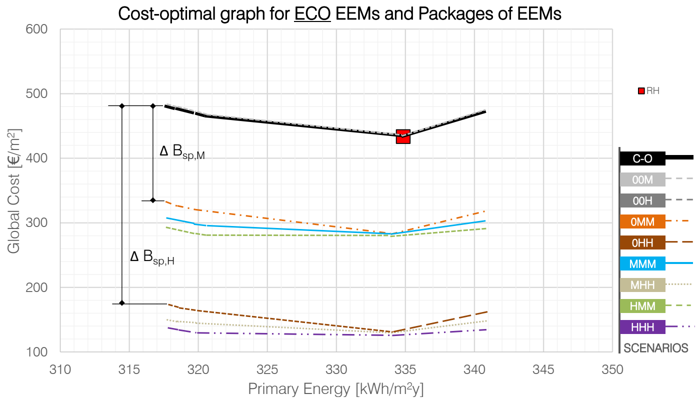

Figure 3. Global cost-benefit vs. primary energy for eco EEMs and Packages of EEMs

5. Conclusions

Aim of the present study was to address the problem of adding extra benefits to the traditional global-cost methodology, here intended as a decision making tool for investors at an early design stage. The inclusion of co-benefits in energy and economic evaluation is crucial for modifying investors' perception of the financial convenience of retrofit interventions.

Results showed that in a hotel building extra benefits related to increased service price (i.e. room rates) are the most effective factors for reducing the global cost of eco-friendly retrofit intervention. Despite the quantification of such market benefits is presented here via hypothesis based on literature review, their positive effect on green investment is a fact that the present research contributes to highlight. In addition, the study points out that employees' health and well-being have an important role, not just from an ethical point of view, but also in the financial performance of a building. Reduced productivity neutralized the impact of market appreciation for retrofitted and labelled buildings. Next steps of the research will take into account interventions to the building plants (such as mechanical ventilation) with the aim to investigate further the role of modified IAQ in affecting sick leave and productivity.

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