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Evaluation of Investment in Renovation to Increase the Quality of Buildings: A Specific Discounted Cash Flow (*DCF*) Approach of Appraisal

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Academic Editor: Giuseppe Ioppolo

Received: 24 January 2016; Accepted: 9 March 2016; Published: 15 March 2016

Abstract: The objective of this article is to develop and apply a specific discounting cash flow (*DCF*) approach to evaluate investment in renovation to improve building quality, thus increasing energy efficiency. In this article, we develop and apply a specific net present value (NPV) and an internal rate of return (IRR) approach to quantify the value created for the owners of the building by the investment in renovation via energy-saving investments that produce positive externalities. The model has an applied interest because, in recent years, a lot of investments in real estate were made by owners in order to increase the green quality of the buildings, and several funds of public aid were provided by the government to stimulate these energy-saving investments. The model proposed here is applied to a case study of a 16-apartment building located in northern Italy considers the model attempts to quantify the initial investment value, the energy savings, the tax deduction of the initial investment and the terminal value of the investment as the increase in building value. The analysis shows that the model is consistent in evaluating investments to improve building quality, and investments within the context of the specific case study considered in the research have IRRs ranging from a minimum of 4.907% to a maximum of 12.980%. It could even be useful to consider a sample of cases to verify whether our results are representative of this specific case study. The model could represent a useful tool for consumers in evaluating their own investments in building renovation, from a stand-alone perspective and even by comparing them with other types of investment. The research could be developed in the future to quantify the social welfare generated by public spending via tax deductions to reduce the costs of investment in energy savings for buildings and could even be applied to new real estate projects in comparing different construction technologies and even comparing the return of renovation investment with other investments not even in the real estate sector.

Keywords: investment in renovation; residential building; positive externalities; discounted cash flow (*DCF*) approach

1. Introduction

Energy savings construction systems applied to investments in building renovation have public aid with tax deductions, given the externalities provided by investments in sustainable construction. The evaluation of the convenience of the house purchase needs, to consider that technologies in construction have undergone a rapid change in recent times, proposes an approach to evaluate the return of investment in sustainable building technologies. To evaluate the investment, a life cycle cost (*LCC*) approach is frequently applied, as shown by several researchers [1–7]. In building renovation analyses, approaches aiming to quantify costs considering a single-year period are not suitable, as it is necessary to quantify costs during the total life of the investment, as provided in the *LCC* approach [8,9]. This approach is relevant for a consideration of discount values in assessments of fundamental importance in capital-intensive sectors, such as real estate. Three approaches are applied in the *LCC* analysis: (1) the conventional *LCC* approach, where costs are strictly considered in terms of the life cycle of a product; (2) the environmental *LCC* approach, where a complementary *LCA* is always considered based on an evaluation of externalities [10–14]; and (3) the social *LCC* approach, which assesses internal and external costs, thus considering environmental effects and social effects on net economic welfare [15,16]. Traditional *LCCs* were improved with a recently developed life cycle cost approach (*LCF*) aiming to quantify not the cost absorption of an investment over time but the cash outflow related to the investment [17]. The *LCF* application to building investment develops a previous approach [18] applied to food processing and follows the *LCC* method developed by other researchers [19] who have followed a traditional cost accounting approach. The *LCF* is based on the life cycle cost (*LCC*) and has been adapted to assess real estate investment in residential buildings for private use, even considering the effects of a tax deduction. The *LCF* is particularly useful to quantify financial outflow during time, even in the case of repaying financial debts, as often occurs in real estate investment. The approach is usefully applied again for the analysis of the investment in construction because this often has a high initial investment and is characterized by a long life cycle with relevant cash outflows during time (e.g., for maintenance and energy consumption). Regarding these themes, several researchers have focused their attention on building retrofits [20–22] and on energy savings in residential buildings by applying the *DCF* approach [23,24]. Other authors have focused their attention on restoring the environmental integrity of urban areas by assessing construction practices aiming to increase environmental characteristics, as rooftop vegetation, called green roofs, could be considered an alternative to traditional roofing [25,26]. When an investment could generate positive cash flow, a discounting cash flow (*DCF*) approach is applied to jointly evaluate cash inflow and outflow generated by the investment; a *DCF* approach is generally applied to investment, particularly for long-term investment in contest of risk, even if the *DCF* approach is judged to have limitations in the case of dichotomous choice and even regardless of the consistency of *DCF* ratios [27–31]. Moreover, the *DCF* approach is still considered to be the standard approach in financial evaluation. The article would develop and apply a *DCF* approach to evaluate renovation investment in residential buildings [32]; the approach was applied by several researchers in other types of real estate investments such as agrarian investment [33,34] and renewable energy plants [35–40]. The article considers investment to improve energy efficiency with the aim of quantifying the total monetary amount absorbed and generated in the whole life of the building. In fact, renovation needs a high initial investment and is characterized by a long life cycle, with relevant cash outflows over time. In regards to these themes, the article analyzes an investment in buildings' coverage aiming to reduce energy consumption over time by applying sustainable technologies. To evaluate the renovation investment, we apply a net present value (*NPV*) and an internal rate of return (*IRR*) approach to quantify the value created by the investment in renovation to increase the building quality via energy savings. For residential buildings, the choice of investment is made by the owner and should consider the amount paid at the beginning to restore the building, with a negative sign, and the future discounted benefit deriving from the investment throughout its useful life, with a positive sign; the objective of the investment is to create value for the owner by investing capital with a rate of return that is higher than the minimum required. This preliminary assessment is rarely performed by owners, even if it has great importance; the main home is, in fact, one of the most important investments for families in Italy, particularly in the second half of the twentieth century.

Once again, the evaluation of the convenience in house renovation, via energy savings investment, is due to the quick development of new construction technologies that has changed the construction process and the energy performance of buildings, particularly in the last decade. In the article, we apply the *DCF* model to a case study of a 16-apartment building located in northern Italy, in the Emilia Romagna Region, in the city of Parma. The model considers the initial investment in renovation to improve energy efficiency; the model then considers, with a positive sign, the energy savings from the increased energy efficiency of the building and the tax deduction on the initial investment and, at the end, the terminal value of the investment as increasing in building value to quantify the value of the investment. The theme of tax deduction has a particularly relevant role in investment evaluation; in fact, sustainable interventions of renovations are encouraged with tax deductions, financed using public spending that is given the role of externalities for sustainable construction. In Italy, tax deductions for energy improvements of existing buildings were renewed by the government until 31 December 2015, following the publication in the Ordinary Supplement n. 99 of Italian Republic Official Gazette, n. 300, Law 23 December 2014 n. 190 (Stability Law 2015) [41]. The measure provides a tax deduction of 65% of the cost of the investment in improving the energy performance of the building, in ten equal annual payments, each amounting to 6.5% of the investment. The amounts of the tax deductions are not revalued for inflation. The public aid has the aim of stimulating the renovation of buildings, recognizing the role of positive externalities of energy savings for the real estate sector, as shown for other sectors by several researchers, even recently [42–45]. The proposed approaches could be useful to quantify the weight of the tax benefit in the value of the investment. The evaluation indices proposed and applied in the article may allow a better assessment, in advance, of renovation investment and could also be useful to limit the inefficient use of public expenditure when evaluating the efficiency of public aid.

2. Materials and Methods

Through an evaluation of the investment, we can quantify, in monetary terms, the convenience of its creation and management. An evaluation of a single (stand-alone) investment can be done by considering the asset, such as a property, plant, or equipment, or by considering the management of a firm as a particular type of investment. A financial approach is frequently applied to quantify the results of management in terms of cash flow. A financial approach is particularly useful in some cases of valuation: (1) when the investment could move its effect into the long term so that the pay-back period takes place over the long term, as expressed in years or in decades; (2) when the investment requires a large amount of initial capital to finance the asset so that the investment can be qualified as a capital-intensive investment, with its need to finance the initial amount of cash outflow with debt and equity capital; (3) when the investment is particularly risky, so the value of money over time changes due to risk premium and inflation. Discounting techniques are applied both to quantify cash outflow in a cost side approach or a cash outflow side approach and to quantify the creation of the value, jointly considering cash inflow and outflow. Cash flow side approaches are covered by the life cycle flow (*LCF*) approach, while value creation approaches are summarized by net present value (*NPV*) and internal rate of return (*IRR*), jointly called ratios of a discounted cash flow (*DCF*) approach. The *LCF* approach is applied to compare projects and to choose the one that minimizes the absorption of financial resources. The *LCF* model is adapted to assess a real estate investment, such as a residential building for private use, taking into account the effects of a tax benefit. In the article, we will apply another point of view to evaluate private investments in buildings. In fact, investments aiming to increase the energy efficiency of the buildings generate value for the owner, given that it is hoped that the amount of cash spent on the investment in increasing the energy efficiency will be covered by future savings. These savings could be considered as cash inflow, because they represent, at all stages, a decrease in cash outflow, so they are beneficial for the owner of the building. As developed in the article, a discounted cash flow approach (*DCF*) considers the occurrence of flows over time, expressing the present value of a future stream of discounted values during a given period of time, until a time horizon at the end of the investment. The time horizon is defined as the period in which occur the effects of the investment being valued. The time horizon takes into account elements of obsolescence in the investment, as well as legal or contractual constraints and even the personal judgments of the owner. In our article, we follow a *DCF* approach developed to evaluate plants in the case of production of positive externalities [32] and modified to take into account the tax benefit of the investment in building renovation. The *DCF* approach has recently been applied in the techno-economic evaluation method to optimize the retrofitting of buildings by maximizing *NPV* and by splitting incentives between building owners and users [22]. Other researchers have shown that the financial returns of green building renovation projects for commercial offices require additional building costs but offer an expected *IRR* of approximately 12% [46]. Even in Italy, several researchers have focused their attention on assessing initiatives for energy efficiency in building renovation, thus considering cost optimization methodologies and zero-energy building standards [47]. Again, given that building investments allocate resources for long time periods, other researchers have focused particularly on future uncertainties, showing that the best financial choice is an immediate investment in improving the energy efficiency of a building [48]. The renovation of existing buildings to reduce energy consumption and gas emissions has even recently been analyzed using a life-cycle assessment (*LCA*) and a life-cycle cost (*LCC*) application in a case study including eight scenarios to define the optimal investment solution [49]. The *DCF* evaluation considers the accumulation at the initial time zero of financial flows from the investment; the accumulation considers firstly the sum of financial inflow (*FI*), for every period t ∈[0, *OT*], discounted at a given discount rate (*i*), with t as time periods, since the investment time horizon is *OT*:

$$FI_0 = \sum_{t=0}^{OT} \frac{FI_t}{(1+i)^t}. \tag{1}$$

At the same time, the *DCF* approach considers the initial accumulation of financial outflow (*FO*), for every period t ∈[0, *OT*]:

$$FO_0 = \sum_{t=0}^{OT} \frac{FO_t}{(1+i)^t}. \tag{2}$$

In a *DCF* model, the discount rate is the user's cost of capital that could be assumed via a subjective evaluation approach of the opportunity cost of the capital, estimating exogenously, on a case-by-case basis, thus considering minimum required remuneration by the owner's capital. The most common objective methodology to estimate the discount rate, for a *DCF* model, is the weighted average cost of capital (*WACC*) approach. The *WACC* takes into account the cost of all sources of capital, whether they are equity capital (E) or debt (*D*); the *WACC* is calculated as the weighted average cost of debt (*Kd*) and equity (*Ke*). Generally, *Kd* is the net of a tax shield for the deduction of interest expenses (*1–Tm*), where Tm is the marginal tax rate. *Ke*, in the long run, could be estimated via the return on a treasury bond, without considering investment-specific risk and/or when the risk of the investment is affected only by country risk. The *WACC* formula is as follows:

$$WACC = Kd(1 - T_m)\frac{D}{D+E} + Ke\frac{E}{D+E}. \tag{3}$$

In a situation in which *E* is zero (full-debt approach), the discount rate is *Kd*, with ($0 < Tm \leqslant 1$) or without ($0 = Tm$) a tax deduction for the interest charge. The main investment evaluation index based on the financial flow is an *NPV* that expresses the value of the investment as the sum of the discounted cash flows and quantifies the wealth in monetary units that are created or destroyed by the investment. The *NPV* simultaneously considers the time of the flows, the investment time horizon and the discount rate. In the case of a simple investment, characterized by a concentration of investment in the initial year (F_0), the *NPV* is described as follows:

$$NPV_0 = \sum_{t=1}^{OT} \frac{FI_t}{(1+i)^t} - \sum_{t=1}^{OT} \frac{FO_t}{(1+i)^t} - F_0. \tag{4}$$

If it is not possible to isolate the investment to an initial period, or if the initial investment exceeds a one-year period, it is better to consider the actualization cash inflow and outflow separately. We can also consider the terminal value of the investment at a time horizon (TV_{OT}), expressed as follows:

$$NPV_0 = \sum_{t=0}^{OT} \frac{FI_t}{(1+i)^t} - \sum_{t=0}^{OT} \frac{FO_t}{(1+i)^t} \pm \frac{TV_{OT}}{(1+i)^{OT}} \tag{5}$$

The realization of the investment is convenient only if $NPV > 0$. When we have $0 \leqslant NPV$, the value generated from the investment is insufficient to cover the invested capital, given the time horizon and risk, synthesized at the discount rate. On the subject of this assessment, calculations should be carried out with several precautions. Firstly, it is not possible to grade projects using the criteria of maximum *NPV*. Indeed, *NPV* does not take into account the use of capital. To quantify the value created in terms of a percentage return, to be compared with the return on alternative investments, it is estimated by applying the internal rate of return (*IRR*) approach. The *IRR* is the rate that equalizes the positive and negative streams of cash, having $NPV = 0$ as follows:

$$\sum_{t=0}^{OT} \frac{FI_t}{(1+IRR)^t} - \sum_{t=0}^{OT} \frac{FO_t}{(1+IRR)^t} \pm \frac{TV_{OT}}{(1+IRR)^{OT}} = 0 \Rightarrow NPV_0 = 0 \tag{6}$$

In Equation (6), the *IRR* quantifies the return on investment using unlevered cash flows. The *IRR* must be greater than the opportunity cost of the capital employed in the investment, expressed by the discount rate (i); if and only if $IRR > i$, $NPV > 0$. The *IRR*, even if characterized by several limitations, is thus one of the most applied and well-known approaches in investment evaluation. Firstly, in fact, the *IRR* as a criterion for choosing between alternative investments (maximum *IRR*) suffers from a lack of consideration of the opportunity cost of capital in the calculation and risks of multiple solutions [30] and does not consider financial constraints [50,51]. To evaluate the convenience in building renovation via an energy saving investment, we will apply three different models and then compare the results. The first is as follows:

$$\begin{gathered} NPV_1 = \sum_{t=0}^{20} \frac{FIe_t}{(1+i)^t} - F_0 \\ \sum_{t=0}^{20} \frac{FIe_t}{(1+IRR_1)^t} - F_0 = 0 \Rightarrow \mathrm{NPV}_1 = 0 \end{gathered} \tag{7}$$

In Equation (7), NPV_1 is the value generated by F_0 during a period of 20 years, considering F_0 as outflow and *FIe* as inflow, where *FIe* is energy savings for every year of the investment effect period, from year 1 to year 20 (*OT*); *FIe* values are inflated at a 1.0% inflation rate per year; F_0 is the amount of cash required to finance investment in energy savings of the building at year 0; IRR_1 is the rate of return of the investment, as in case (1). To consider the time effect of monetary values, all financial flows are discounted using a discount rate, i, which is the same for all flow values. This hypothesis could be relaxed in further applications of the model, for example, by considering the weighted average cost of capital approach, thus considering the different financial fund strategies that are applied to finance the investment. In our model, the discount rate (i) is equal to a sample rate price of an Italian long-term treasury bond, as risk-free investment, that actually could be estimated in 2.50% per year in Italy. The second-model equation could be expressed as follows:

$$\begin{gathered} NPV_2 = \sum_{t=0}^{20} \frac{FIe_t}{(1+i)^t} + \sum_{t=0}^{10} \frac{Tb_t}{(1+i)^t} - F_0 \\ \sum_{t=0}^{20} \frac{FIe_t}{(1+IRR_2)^t} + \sum_{t=0}^{10} \frac{Tb_t}{(1+IRR_2)^t} - F_0 = 0 \Rightarrow NPV_2 = 0 \end{gathered} \tag{8}$$

In Equation (8), NPV_2 is the value generated by F_0 during a period of 20 years, considering F_0 as outflow and *FIe* and *Tb* as inflow; in Equation (8), in addition, *Tb* is the tax benefit (65%) of F_0 in 10 equal payments, 6.5% of F_0 per year, for a 10-year period of fiscal allowance: $Tb = 0.065F_0$. To achieve *Tb*, a person must have an income and pay taxes, to which, via a tax benefit, a tax payment reduction (deduction) can be applied. IRR_2 is the rate of return of the investment as in case (2). The third-model equation could be expressed as follows:

$$
\begin{array}{l}
NPV_3 = \sum_{t=0}^{20} \frac{FIe_t}{(1+i)^t} + \sum_{t=0}^{10} \frac{Tb_t}{(1+i)^t} + \frac{TV_{20}}{(1+i)^{20}} - F_0 \\
\sum_{t=0}^{20} \frac{FIe_t}{(1+IRR_3)^t} + \sum_{t=0}^{10} \frac{Tb_t}{(1+IRR_3)^t} + \frac{TV_{20}}{(1+IRR_3)^{20}} - F_0 = 0 \Rightarrow \mathrm{NPV}_3 = 0
\end{array} \tag{9}
$$

In Equation (9), NPV_3 is the value generated by F_0 during a period of 20 years, considering F_0 as outflow and *FIe*, *Tb* and *TV* as inflow; in Equation (9), in addition, *TV* is the terminal value as the increased value of the building, which is the amount of F_0 investment ($TV_{20} = F_0$) discounted at time zero; TV is the estimated increase in value of the building obtainable by selling the building at year 20 thanks to the investment for energy savings issued at year 0; IRR_3 is the rate of return of the investment as in case (3). The discount rate (i) is again 2.50% per year. The Equation (7) model calculates NPV_1 and IRR_1 considering *FIe* as the only positive effects for building owners, while the Equation (8) model calculates NPV_2 and IRR_2 even considering the positive effect of *Tb* for building owners and the Equation (9) model calculates NPV_3 and IRR_3, then considering even the positive effects of *TV* for building owners. Particularly, the Equation (9) model specification is useful to ensure that the use of public resources is efficient given the positive externalities, thus ensuring efficient use of public resources. In every equation model, the tax benefit (*Tb*) is given to consumers given the effects of sustainable construction techniques on public goods production; the environmental effects of construction techniques are, in fact, considered to be a public good. The reduced emissions of pollutants and energy-saving investments are defined as externalities because they are freely accessible and do not pass through price mechanisms. The formulation given by Equations (7)–(9) could be applied to calculate the average *NPV* per year, as follows:

$$
NPV_{1,y} = \frac{NPV_1}{OT}, NPV_{2,y} = \frac{NPV_2}{OT}, NPV_{3,y} = \frac{NPV_3}{OT} \tag{10}
$$

In Equation (10), $NPV_{1,\mathrm{y}}$, $NPV_{2,\mathrm{y}}$ and $NPV_{3,\mathrm{y}}$ equations are respectively *NPV* per year, calculating NPV via Equations (7)–(9); we call, generically, NPV_y every *NPV* per year calculated by applying one of the equations in Equation (10). The *NPV* approach proposed in Equation (10) is useful to compare alternative options of investment in private housing investment, by comparing different NPV_y values of different property investment options and then choosing, ceteris paribus, the investment with the higher NPV_y (under the hypothesis of same risk, same *OT* and same capital absorption at the beginning of the investment plan to overcome the case of financial constraint). At the same time, under the same conditions, the *IRR* approach is applied to compare the same investments and then to choose, again *ceteris paribus*, the investment with the higher *IRR*. The *DCF* approach is considered the main approach to the valuation of the investments, although it is not without its critics. In fact, some authors [27] show that the *DCF* approach, in particular the calculation of *IRR*, does not take into account, among other criticalities, that: (a) multiple real-value *IRRs* may arise; (b) complex-valued *IRRs* may arise; (c) *IRR* ranking is generally different from *NPV* ranking; (d) *IRR* criterion is not applicable with variable cost of capital; (e) the *IRR* does not measure the return on initial investment; and (f) the *IRR* does not signal the loss of entire capital. To overcome these limits [28–31] a development of *IRR*'s approach defined as the "average internal rate of return" (*AIRR*) with the aim of achieving a conceptual shift where the rate of return does not depend on cash flows but on the invested capital is suggested.

3. Case Study

The case study is for a building constructed in 1962; it has 16 apartments, for a total surface area of 1368 square meters. The structure is made of reinforced concrete with brick infill. The building has central heating with natural gas, with a performance of energy absorption amounted to 391.2 kWh per square meter per year; the performance in heating is 330.1 kWh per square meter per year. The building is located in Italy, Emilia Romagna region, in the city of Parma (44°48′00″ N and 10°20′00″ E) at 57 meters above the sea; the maximum average temperature of the city is 17.6 degrees centigrade, and the minimum average temperature is 9.0 degrees centigrade; yearly rainfall is 777 mm with 88 days of rain per year. The climate of Parma is typically continental: The summers are hot and sultry, with daytime temperatures of approximately 30 degrees centigrade, with frequent spikes above 35 degrees during the day. Winters are harsh, with temperatures often below zero and minimum temperatures of −25 degrees centigrade in 1985 and −24 degrees centigrade in 2011. On average, 35 to 40 centimeters of snow fall over the city per year. October is the wettest month, with an average of 91 mm of rain. The driest month is July, with an average of 36 mm. The investment has a total cost of €138,450 (Table 1), with a construction period of four months aiming to improve the energy performance of the building, reducing the power consumption to 215.00 kWh per square meter per year; the roof of the building is of slabs of expanded polystyrene thermal insulation according to UNI EN 13163, with a weight of 35 kg per square meter and a thickness of 12 centimeters. The energy performance of buildings before and after energy-saving interventions was calculated at the time of construction by a chartered engineer, as Italian legislation provides that the calculation of energy savings be done to deliver fiscal advantages through a reduction of taxes. The renovation then has the aim of improving the energy performance of the building with a cover coat of outer insulation. The building is classified in energy class G, which represents buildings that consume more energy, with an energy absorption over 132.5 kWh per m^2 per year. In Italy, the classification used by law considers ten energy classes (from 4A up to G) with intervals depending on overall energy performance, a physical value measured in kWh per m^2 per year. In northern Italy, characterized by temperatures lower than central and southern Italy, energy certifications issued indicate that low-energy buildings are prevalent. Data from the Piemonte region [52] indicate that of 298,622 buildings, 58,375 are in class G (19.54%) and 42,592 are in class F (14.26%). In Emilia Romagna region [53], of 633,331 buildings, 230,860 are in class G (36.45%) and 103,106 are in class F (16.27%). In Lombardia region [54], of 1,484,424 surveyed buildings, 757,472 are in class G (50.99%) and 203,708 are in class F (13.71%). The buildings within the case study are expressive of a significant proportion of Italian buildings, particularly those located in the regions of northern Italy, which, on average, are still characterized by very low energy performance at minimum on the scale of energy efficiency (classes G and F).

4. Results

To evaluate the investment considered in the case study here, three different approaches are applied, as respectively exposed in Equations (7)–(9), respectively called approaches 1, 2 and 3. Approach 1 considers the initial investment with a negative sign and energy savings with a positive sign; the assessment applies the Equation (7) for the calculation of NPV_1 and IRR_1. Approach 2 considers the initial investment with a negative sign and the energy savings and tax benefits with a positive sign; the assessment applies Equation (8) for the calculation of NPV_2 and IRR_2. Approach 3 considers the initial investment with a negative sign and the energy savings, tax benefits and terminal value with a positive sign; the assessment applies Equation (9) for the calculation of NPV_3 and IRR_3. For the purpose of calculating the energy savings, a cost of natural gas of €0.07 per kWh was considered. To analyze a building's performance is considered its feasibility study. For each project alternative, we assume full equity coverage, and, therefore, the values in Table 1 involve an immediate financial output, without a gradual repayment with debt servicing.

Table 1. Financial outflow of the building—investment phase.

Financial Outflow of the Building	Type of Outflow	Value in €—Year 0—Construction Phase		
		Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3
Project	F_0	−4550	−4550	−4550
Site preparation and authorizations	F_0	−6600	−6600	−6600
Construction supervision	F_0	−6200	−6200	−6200
Drainage and insulation	F_0	−14,500	−14,500	−14,500
Materials	F_0	−39,550	−39,550	−39,550
Installations	F_0	−17,650	−17,650	−17,650
Labour	F_0	−27,500	−27,500	−27,500
Finishes	F_0	−5600	−5600	−5600
Plaster and painting	F_0	−16,300	−16,300	−16,300
Total Investment	F_0	−138,450	−138,450	−138,450
Square meters m^2 (available per housing)		1368	1368	1368

The total investment (F_0) is €138,450 for every analyzed case. In the total investment, major costs were for the purchasing of materials (€39,550), drainage and insulation (€14,500), and labor (€27,500). The company that carried out the work was a small firm with 18 workers, as is often the case among Italian construction firms, and therefore it was not equipped with tools to allow a reduction of labor costs. The firm was also not able to enjoy economies of scale in the shipyard and economies of size in the purchasing of materials. The cost savings of heating and cooling (*FIe*) is €11,022, (Table 2), which is inflated at an annual rate of 1.00% and discounted at a rate of 2.50% per year. The choice of the rate of discount has a great impact on the evaluation of projects, especially those with a long-term time horizon, as is typical of investments in buildings [55]. To reduce the subjectivity of our assessment of the discount rate (*k*), that is equal to the emissions of long-term treasury bonds from the Italian State in 2015 (*BTP*), that is 2.50% per year, we have applied an approach that considers the financial evaluation in terms of net present value (*NPV*), with an explicit discount rate, and even in terms of internal rate of return (*IRR*), where the *IRR* (the result of the analysis) should be compared to the given cost of capital use, the discount rate, to verify that the $IRR > k$. Frequently, in fact, it is difficult to properly calculate the value of the discount rate, as it depends on the financing choices of those who make the investment, using equity or debt, and on the levels of investment risk and investor risk tolerance. Regarding the effect of the tax deduction, it is limited only to final consumers, not firms, and aims to facilitate investment in renovation with public funds, that being a tax reduction in this case. Moreover, the tax deduction, in this case study, has a significant effect (as indicated by the comparison between IRR_1 and IRR_2) in determining the convenience of an investment. This effect ($IRR_2 >> IRR_1$) indicates that tax deductions could have a significant impact on the convenience of renovation in Italy, and, given the limitation of this article to a single case, future analyses should investigate the effect of tax deductions on the *IRR*s of investments in building renovation considering a larger sample of cases. In the article, we have considered a period of 20 years, as renovations are guaranteed by material suppliers and manufacturers for this minimum. Three caveats are necessary: (1) The lifespan of the renovation investment and its energy-saving effects is probably greater than 20 years, even if the useful life of the investment is reduced to 20 years for prudence, that is, paired to its guaranteed life; (2) A period of 20 years should be critically evaluated in the case of investors and/or owners of properties with a lesser payback time horizon, as in the case of elderly owners. In such cases, any terminal value of the property sale to a time $t < 20$ will, *ceteris paribus*, also consider the additional value resulting from discounting the energy savings from the year $t + 1$ to the year 20; (3) The time horizon of 20 years makes the valuation subject to uncertainty due to the difficulty of estimating energy costs, capital costs, inflation, and house price trends, and therefore in such cases a sensitivity analysis of explanatory variables, such as the Monte Carlo approach, should be applied and considered relevant.

Table 2. Financial inflow for energy saving—management phase.

Financial inflow for energy savings (*FIe*)		Not Discounted and Not Inflated Values			Discounted and Inflated Values		
		Value in €—Year 1/20—Management Phase			Value in €—Year 1/20—Management Phase		
FIe per Year (Inflation Rate 1.0%—Discount Rate 2.5%)	Type of Inflow	Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3	Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3
FIe year 1	FIe	11,022	11,022	11,022	10,861	10,861	10,861
FIe year 2	FIe	11,022	11,022	11,022	10,596	10,596	10,596
FIe year 3	FIe	11,022	11,022	11,022	10,337	10,337	10,337
FIe year 4	FIe	11,022	11,022	11,022	10,085	10,085	10,085
FIe year 5	FIe	11,022	11,022	11,022	9839	9839	9839
FIe year 6	FIe	11,022	11,022	11,022	9599	9599	9599
FIe year 7	FIe	11,022	11,022	11,022	9365	9365	9365
FIe year 8	FIe	11,022	11,022	11,022	9137	9137	9137
FIe year 9	FIe	11,022	11,022	11,022	8914	8914	8914
FIe year 10	FIe	11,022	11,022	11,022	8696	8696	8696
FIe year 11	FIe	11,022	11,022	11,022	8484	8484	8484
FIe year 12	FIe	11,022	11,022	11,022	8277	8277	8277
FIe year 13	FIe	11,022	11,022	11,022	8076	8076	8076
FIe year 14	FIe	11,022	11,022	11,022	7879	7879	7879
FIe year 15	FIe	11,022	11,022	11,022	7686	7686	7686
FIe year 16	FIe	11,022	11,022	11,022	7499	7499	7499
FIe year 17	FIe	11,022	11,022	11,022	7316	7316	7316
FIe year 18	FIe	11,022	11,022	11,022	7138	7138	7138
FIe year 19	FIe	11,022	11,022	11,022	6963	6963	6963
FIe year 20	FIe	11,022	11,022	11,022	6794	6794	6794
Total FIe financial flow	FIe	220,440	220,440	220,440	173,542	173,542	173,542
Financial flow per year		11,022	11,022	11,022	8677	8677	8677

In the assessment of the investment, we have considered rising energy costs equal to the average inflation rate estimated by the Italian Institute of Statistics (ISTAT), which is equal to 1.00%. We then reviewed energy costs based on this estimated inflation rate. In the presence of inflation, if the inflation rate for energy costs observed during years of planning (IRE_{obs}) is higher than the estimated inflation rate (IRE_{est}), we can observe greater energy savings. In fact, the action of reducing energy costs increasingly impacts cost reduction the greater the rate of energy inflation. If the inflation rate increases progressively over the 1.00% considered in the simulation, the energy savings would also progressively increase, by definition, if compared with the base case considered in the case study. Practically, variations are not provided for energy costs outside variations for inflation, as the intervention of energy savings in the structure shows no loss of efficiency and no need for maintenance interventions. The energy of sustainable technology applied allows an energy cost savings of €173,542 (€8677 per year). Tax benefit (*Tb*) analysis is performed in Table 3; *Tb* is calculated as a deduction of 65% from the renovation investment (€138,450), to be subtracted from the tax payment in 10 years, as the total amount of €89,993 is not discounted. Tb is calculated only for approach 2 and approach 3 and has a total amount, inflated and discounted, of €78,762. The terminal value (*TV*) is €138,450, that is €87,492 inflated and discounted. Our investment analysis of the building renovation does not consider the cost of maintenance because the investment is related to the improvement of the energy performance of the building by means of an insulating cover that does not require maintenance for a period of 20 years, equal to the duration of the warranty for the work by the developer. The investment does not consider other maintenance, for example, in the interior of the apartments. For these reasons, it was not considered necessary to include maintenance costs in the evaluation as costs that, in any case, would be equal for each alternative considered in the case study and therefore would be excluded, *ceteris paribus*.

This analysis (Table 4) shows that investment has a high efficiency of capital invested. The investment of approach 1 has an initial investment F_0 of €138.450, which determines an *FIe* of €173,542; NPV_1 has a positive value of €35,092, and IRR_1 is 4.097%. The investment, approach 2, has a F_0 of €138,450, which determines a *FIe* of €173,542, and the *Tb* is €78,672; NPV_2 has a positive value of €113,854, and IRR_2 is 11.296%. The investment, approach 3, has an F_0 of €138,450, which determines an *FIe* of €173,542, the *Tb* is €78,672 and the *TV* is €84,492; NPV_3 has a positive value of €198,346, and IRR_3 is 12.980%.

Table 3. Financial inflow for Tb—management phase.

Tb Financial Inflow	Type of Inflow	Not Discounted and Not Inflated Values			Discounted and Inflated Values		
		Value in €—Year 1/20—Management Phase			Value in €—Year 1/20—Management Phase		
Tb per Year (Discount Rate 2.5%)		Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3	Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3
Tb year 1	Tb	0	8999	8999	0	8780	8780
Tb year 2	Tb	0	8999	8999	0	8566	8566
Tb year 3	Tb	0	8999	8999	0	8357	8357
Tb year 4	Tb	0	8999	8999	0	8153	8153
Tb year 5	Tb	0	8999	8999	0	7954	7954
Tb year 6	Tb	0	8999	8999	0	7760	7760
Tb year 7	Tb	0	8999	8999	0	7571	7571
Tb year 8	Tb	0	8999	8999	0	7386	7386
Tb year 9	Tb	0	8999	8999	0	7206	7206
Tb year 10	Tb	0	8999	8999	0	7030	7030
Year 11	-	0	0	0	0	0	0
Year 12	-	0	0	0	0	0	0
Year 13	-	0	0	0	0	0	0
Year 14	-	0	0	0	0	0	0
Year 15	-	0	0	0	0	0	0
Year 16	-	0	0	0	0	0	0
Year 17	-	0	0	0	0	0	0
Year 18	-	0	0	0	0	0	0
Year 19	-	0	0	0	0	0	0
TV year 20	TV	0	0	138,450	0	0	84,492
Total financial inflow	Tb + TV	0	89,993	228,443	0	78,762	163,254
Financial inflow per year		0	4500	11,422	0	3938	8163

Table 4. Financial flow analysis.

Financial Flow Analysis	Type of Flow	Not Discounted and Not Inflated Values			Discounted and Inflated Values		
		Value in €—Year 1/20—Management Phase			Value in €—Year 1/20—Management Phase		
Financial Flow (FF) per Year		Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3	Case Study—Approach 1	Case Study—Approach 2	Case Study—Approach 3
FF year 0	FF	−138,450	−138,450	−138,450	−138,450	−138,450	−138,450
FF year 1	FF	11,022	20,021	20,021	10,861	19,640	19,640
FF year 2	FF	11,022	20,021	20,021	10,596	19,161	19,161
FF year 3	FF	11,022	20,021	20,021	10,337	18,694	18,694
FF year 4	FF	11,022	20,021	20,021	10,085	18,238	18,238
FF year 5	FF	11,022	20,021	20,021	9839	17,793	17,793
FF year 6	FF	11,022	20,021	20,021	9599	17,359	17,359
FF year 7	FF	11,022	20,021	20,021	9365	16,936	16,936
FF year 8	FF	11,022	20,021	20,021	9137	16,523	16,523
FF year 9	FF	11,022	20,021	20,021	8914	16,120	16,120
FF year 10	FF	11,022	20,021	20,021	8696	15,727	15,727
FF year 11	FF	11,022	11,022	11,022	8484	8484	8484
FF year 12	FF	11,022	11,022	11,022	8277	8277	8277
FF year 13	FF	11,022	11,022	11,022	8076	8076	8076
FF year 14	FF	11,022	11,022	11,022	7879	7879	7879
FF year 15	FF	11,022	11,022	11,022	7686	7686	7686
FF year 16	FF	11,022	11,022	11,022	7499	7499	7499
FF year 17	FF	11,022	11,022	11,022	7316	7316	7316
FF year 18	FF	11,022	11,022	11,022	7138	7138	7138
FF year 19	FF	11,022	11,022	11,022	6963	6963	6963
FF year 20	FF	11,022	11,022	149,472	6794	6794	91,286
Total Financial Flow	FF	81,990	171,982	310,432	35,092	113,854	198,346
NPV_1, NPV_2, NPV_3					35,092	113,854	198,346
IRR_1, IRR_2, IRR_3		4.907%	11.296%	12.980%			
NPV_y					1755	5693	9917

5. Discussion

The application of the model of Equations (7)–(9) approaches to evaluate house building projects has allowed us to quantify (a) the NPV and total IRR for each project; (b) the alternative project characterized by a higher creation of financial resources that is, case study—approach 3 (sustainable intervention of renovation of the building with "green" technologies of construction, with tax benefits provided by Italian tax regulations for this type of building construction and with consideration of the TV of the investment); (c) The absorption of resources (or generation of resources due to tax benefits) at every stage of the life of the investment, dividing the absorption of resources by nature: project and construction in the initial phase (F_0), energy savings (IF_e), Tax benefit (Tb) and terminal value (TV). This quantification allows us to perform a relative comparison of the project with the maximum generation of financial resources, which highlights the advantage of alternative case study approach 3 over alternative approaches 1 and 2, in particular with regard to the effect of Tb. In particular, data show that the:

(1) Placed at 100%, the value NPV_1 for alternative case study—approach 1 (€35,092), the value of NPV_2 is 324.45% (€113,854) and the value of NPV_3 is 565.22% (€198,356). Analysis then showed that in sustainable construction projects, Tb plays an important role in NPV values, with $NPV_3 >> NPV_1$ and placed at 100% the value $NPV_{1,\text{y}}$ for alternative case study—approach 1 (€1755), the value of $NPV_{2,\text{y}}$ is 324.45% (€5,693) and the value of $NPV_{3,\text{y}}$ is 565.22% (€9917).

(2) Placed at 100%, the value IRR_1 for the case study (4.907%), the value of IRR_2 is 230.20% (11.296%) and the value of IRR_3 is 264.53% (12.980%). Analysis shows again the important effect of Tb in determining IRR values, with $IRR_3 >> IRR_1$.

The analysis showed that, in the specific projects analyzed, building renovation projects aiming to increase building quality via reducing energy consumption have higher *IRRs* when the decisive effect of the Tb is considered. Even if in the approach of not considering Tb, NPV has a positive value (NPV_1) and is $IRR_1 > i$; IRR_2 and IRR_3 are higher by more than 10 percentage points compared to the emissions of long-term treasury bonds from the Italian State in 2015 (*BTP*). In our approach, the investment payback period is about 15 years without Tb (case study—approach 1) and about eight years with Tb (case study—approach 2). The calculated return on investment is higher, and this result is in contrast with a traditional view of building investments that are frequently characterized by a low return on capital and a very long pay-back period. In essence, the return of the considered investment is much higher than alternative investments, and on this, the effect of Tb has a particular influence. If the analysis is confirmed by future research, even expanding the sample, an *IRR* so high could attract investments in the building sector, particularly in private housing. With regard to the quantification of tax advantages, it is interesting to note that not only can owners claim tax benefits, so too can tenants and borrowers who pay for energy improvements to the building. In particular, the right to tax benefits applies to (a) owners or bare owners; (b) holders of a real right of enjoyment (usufruct, use, housing, or surface) and (c) tenants or borrowers. Italian tax law indicates that those who spend money on renovations to reduce energy consumption are entitled to tax advantages. If in the building in question there are 16 apartments, 13 of which are inhabited by the owner and three of which are for rent, tax advantages can be claimed in all 16 cases by the owners and even by the tenants. It should be recognized, however, that, for renters, it is not possible to achieve the benefit of a higher value of the building in the event that it is sold. However, renters can claim a partial deduction of costs incurred to improve energy efficiency through taxes. The analysis has some limitations because it does not take into account the following: (1) any difference in the cost of use of capital (discount rate) for every resident in the building; (2) the presence of a constraint of age for residents to conduct investment: in fact, some elderly residents might not have a useful life of 20 years (*OT*) and, therefore, the assessment would be valid only if these residents gave value to legacy; (3) the determination of the time horizon (*OT*) and the lack of consideration of any outflows over *OT*; (4) the consideration (or lack of consideration) of transaction costs related to investment property (costs of transferring ownership and/or expenses related to the signing of loans for financing the property and/or charges related to the preparation of tax returns for *Tb*); (5) the presence of possible claims by tax agencies related to tax requirements, with related effects on the values *Tb* during the *OT* period; (6) the presence of any unexpected charges due to the application of technologies or plant new and untested for durations in *OT*. These claims could make the DCF application subject to variability and subjectivity that should be exposed, if possible, during the construction of the model and dissemination of the results. We have suggested the application of the discounted cash flow (DCF) method, usually applied in the valuation of building investments for commercial or industrial purposes, even in the case of building investments made by private individuals. In fact, in buildings purchased for residential purposes, the *LCC* approach prevails when quantifying long-term costs. In the suggested approach, which can be expanded and applied in a larger sample to achieve general conclusions, it is evident that even the cost of energy improvements to houses could be considered a financial investment, since it allows the investor to obtain economic advantages at a deferred time and generates a measurable value. This evaluation could address two additional topics: (1) Houses are one of the largest investments of Italian families, so investments in housing, even for energy improvements, are an important choice for the majority of Italian families; (2) State strategies in terms of tax reductions can generate not only an incentive but also a distorting effect on competition if reductions allow excess returns compared with market average performance; in this way, the state, in supporting construction activities, could at the same time disadvantage other activities or sectors from which capital is subtracted to make subsidized investments by the state, although useful when generating positive externalities.

6. Conclusions

The valuation of investment in buildings makes it one of the fundamental investment choices for families; in particular, in Italy, the investment in a main residence has been, for a long time, the most important investment families can make, and it represents not only the solution to a housing need, but also a reserve of value, as a result of the revaluation that has always interested, at least in the past, the values of real estate properties. For this reason, research has developed a *DCF* approach that quantifies the convenience of making investments to improve quality in buildings by increasing energy efficiency. The *NPV* and *IRR* approach developed in the article improves the *DCF* traditional approach by considering *Tb* effects on renovation for energy savings in buildings. The proposed and applied DCF evaluation approach considers the following: (a) the investment in the home as a long-term investment for families; (b) the cost of the use of capital; (c) the reinvestment of cash flows of the investment at the same rate that expresses the cost of the use of capital; (d) the investment costs for improving the energy efficiency of the building; (e) the benefits in terms of saving energy costs resulting from the investment of energy improvements; (f) the tax benefits related to investment in energy improvements. The analyses have shown that investments improving the quality of the buildings have an *IRR* from a minimum of 4.907% to a maximum of 12.980% and particularly IRR_2, which considers *Tb*, and IRR_3, which considers *Tb* and *TV*, are about 10 percentage points higher than the emissions of long-term 2015 Italian treasury bonds (*BTP*), assumed to be a discounted rate. The investments in increasing building quality could ensure an *IRR* higher than the estimated discount rate, and even higher than the long term cost of debt of a loan with a real estate warranty, which actually is, in Italy, comparable with *BTP* rate. The results must, however, be received with caution, as they relate only to this case study. It may therefore be useful to extend the analysis to a sample of cases in order to check the results of the article on a broader basis in terms of *IRR*. The model is useful even if applied by consumers in evaluating investments in building renovation, in a stand-alone perspective and even comparing them with other types of investment, given that the home investment is the main investment of Italian families. Moreover, the *DCF* approach presented here could define a method that can be applied to a larger sample; further research could have the aim of deepening the *DCF* approach and considering explicitly equity capital cost of use. Given the results of the research and its limitations, the applied *DCF* model can be further developed particularly to quantify the values of positive externalities financed with public spending via tax benefits to buildings owners. In the end, we have prepared an open-sample spreadsheet, even for a single-consumer's application, and have made it freely available as an open-access software package.

Acknowledgments: The authors would like to thank analisiaziendale.it for IT assistance.

Author Contributions: The study is a result of the full collaboration of all the authors. However, Giuseppe Bonazzi wrote the sections titled "Introduction", "Discussion" and "Conclusion", and Mattia Iotti wrote the sections titled "Material and Methods" and "Case-Study" and "Results".

Conflicts of Interest: The authors declare no conflict of interest.

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