The efficiency of the incentives for the public buildings energy retrofit. The case of the Italian Regions of the "Objective Convergence"

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parole chiave: energy retrofit, incentives, cash flow analysis, public buildings, risk analysis, Monte Carlo method

Abstract

The objective of energy use and emissions reductions, enunciated in many European Directives, has emphasized the need to promote the improvement of energy efficiency of existing buildings.

Local administrations, in particular, should submit their own buildings to energy retrofit, not only to respect the Directives, but also to make those buildings an example of an active environmental culture and to induce similar improvement in private buildings, on the basis of financial appraisal of feasibility, which can be facilitated by incentives.

The "Unione Province di Italia" (UPI) in 2013, within the POI Energy (Interregional Operative Program), requested energy audits and projects of the energy retrofit for 150 public buildings located in the 4 Italian Regions of the "Objective Convergence" (Campania, Puglia, Calabria and Sicily).

In this study, a methodological proposal is elaborated, including a Cash Flow Analysis and an analysis of risk and uncertainty through the Monte Carlo method, to appraise the cost-effectiveness of retrofit actions in public buildings. The methodology is applied to a sample of 36 actions and it allows getting some economic-financial indicators (Net Present Value NPV and Payback Period) able to support the public decision process for selecting the best alternatives to be realized. The evaluation model is direct to search those conditions that assure the profitability and to know how much the currently available incentives are a practical financial tool (not-refundable incentives of the Conto Termico 2.0, DM 16/02/2016).

The financial analysis is integrated with a risk analysis, which evaluates the sensibility of the results to the inputs of the model. The results of the study show that: a category of actions never get the financial profitability; some actions have a positive NPV but a quite long

Payback Period (higher than 15 years) only with the adequate incentives; finally, a category of actions has a positive NPV and short Payback Period (lower than 16 years) and are even profitable under low favorable market conditions. This last category could be particularly attractive for the Public Administration that intends to make actions that reach energy saving and economic-financial profitability.

1. INTRODUCTION

Environmental politics, oriented to the reduction of energy use and CO_2 emissions ("20-20-20 Strategy"), is applied in the European Union through many directives, programs, particularly the Energy Performance of Buildings Directive (EBDP, 2010/31/EC) on the improvement of energy performance of buildings and the Directive 2012/27/UE on energy efficiency. Within this context, according to the analysis made by the European Union, buildings are deemed to be responsible for a high proportion of both the final energy consumption (almost 40%, IEA, 2008) and the CO_2 emission (36%). The energy retrofit of the existing buildings is one of the tools that can significantly contribute to achieving the goals of the Directives.

The actual scientific debate is mainly focused on the development of technological and managerial solutions for new nearly-zero Energy Building (NZEB) as well as on the study of those conditions, which assure economic-financial profitability (Barthelmes *et al.*, 2016). However, it is also very important to pay attention to the enormous amount of existing buildings (Rosasco, Perini, 2014; Rosato *et al.*, 2016), because their energy retrofit may reach many objectives: the reduction of primary energy consumption; the reduction of management costs related to energy expenditures; the improvement of the level of comfort; the reduction of pollution (particularly the Green House Gas – GHG – emissions).

Public buildings, as places of collective use should be submitted to energy retrofit not only to respect the Directives (all public buildings have to be NZEB within 2018, EBDP, art. 9-1b). Such buildings, in fact, should be seen as a symbol representing the social values of fairness and equalization (Rizzo, 2003; Giuffrida *et al.*, 2016; Napoli et al., 2016a), as a demonstration of a typical active environmental culture and they should become examples of the tangible possibilities to improve the energy efficiency of the existing buildings (even with educational purpose) so that to induce similar improvement also in private buildings.

Within the POI Energy, the "Unione Province d'Italia" (UPI) in 2013 required to carry out the study of the energy requirements and the project of energy efficiency, improving 150 public buildings located in the four Italian Regions of the "Objective Convergence" (Campania, Puglia, Calabria and Sicily). This approach has divided the tender notice into 4 parts (one per region).

The implementation of the retrofit actions, based on the results of the energy audit and the improvement hypotheses about energy efficiency, is subject to the attainment of the financial feasibility (Nesticò *et al.*, 2015; Nesticò, Pipolo, 2015).

The results of the financial analysis, however, are not univocal as they depend on the scenarios related to different economic and financial factors, e.g. the discount rate, the cost of financing, the energy price. Moreover, considering that these actions are investments (Rizzo, 2002), they also include risk and uncertainty that can be analyzed with technique able to internalize in the financial analysis the randomness proper of those variable used in the appraisal of different type of investments (French, Gabrielli, 2006). The most used techniques for the risk management are: the sensitivity analysis, which considers the variations of one variable at a time; or the Monte Carlo method that, through a more complicated process, examines the variations of many variables at the same time and monitors the risk during the planning and investment phases.

Incentives are a strategic factor to achieve the financial profitability of the energy retrofit actions. In fact, the European Directives (2012/27/EU) also suggest the use of financial tools, as the incentives, to reach the environmental and energy targets. In Italy, the "Conto Termico 2.0" (D.M. 16/02/2016 that replaces the former Conto Termico of 2012) is currently in force and foresees incentives for a vast range of actions of retrofit of public buildings (structures, technical installations, production of energy plants, etc.).

This study proposes a methodology of economica and financial analysis to be applied to a sample of those public buildings analyzed by UPI with the aim of making similar and comparable the results of the profitability of the energy retrofit actions. The critical elements of the appraisal process will be pointed out, and the alternative scenarios will be prefigured concerning the variability of energy prices, discount rates, and loan rates.

The proposed methodology could be a reference point for the editing of the contracts for economic-financial analysis of retrofit actions, given that the little-detailed contract documents generate a plurality of applications that preclude the comparability of the results (as in the case of the UPI's contract notice)[1].

[1] UPI, Tender notice - Services (TS13BFE2789), G.U. 5° serie speciale, n. 24 del 25/02/2013. "Procedura aperta per l'affidamento di servizi per la redazione di quattro piani d'indagine e di miglioramento del patrimonio pubblico sotto il profilo energetico finalizzati alla verifica della sostenibilità del ricorso a finanziamento tramite terzi e/o contratti di partenariato pubblico-privato per l'esecuzione di opera di efficientamento energetico", Edifici delle Province ricadenti nelle regioni Calabria, Campania, Puglia e Sicilia, Allegato 1, *Capitolato speciale* contenente le caratteristiche tecniche dei servizi valide per tutti i lotti in appalto, Atto n. 1, 20/01/2013.

The methodology considers, as an element of strategic importance, the disbursement of incentives with the purpose to verify the overall effectiveness of the Conto Termico 2.0 on the appraisal of profitability and to determine what are its consequences on the main financial performance indicators of the actions (NPV and Payback Period).

The methodology is aimed, therefore, at supporting the public decision process that could be: mono-criterion o multicriteria (Napoli, Schilleci, 2014; Napoli, 2014; Trovato, Giuffrida, 2014); expressed in financial, economic or extra-economic terms; oriented to public, private or mixed decision makers (Calabrò, Della Spina, 2014; Trovato, 2013); designed for different goals (Gabrielli *et al.,* 2016).

In this study, the methodology is oriented to support public decision makers to select the best and profitable actions of retrofit to submit to the other phases of the feasibility analysis (environmental and landscape sustainability, administrative-procedural sustainability, and economic-social feasibility) before accessing funding and carrying out their implementation.

2. METHODOLOGICAL APPROACH

The profitability of the retrofit actions of public buildings and the valuation of the effectiveness of the incentives are achieved with the application of financial analysis, which includes the Cash Flow Analysis and the analysis of risk and uncertainty with Monte Carlo simulation.

The methodology is applied based on the outcome of the energetic diagnosis of buildings (energy audits of first and second level) and from the proposals of actions for improving energy efficiency.

The valuation model translates the different actions in a tangible possibility of implementation and allows individualizing the best actions from the decision maker's point of view.

2.1 From database to scenarios

The first step of the methodology is the construction of the database of those actions that have to be evaluated. The database acquires a few selected data and results from the first and second level of energy audits as well as the actions of improving the energy efficiency commissioned by UPI[2]. This information is being reviewed and updated and is integrated with economic and financial data to proceed with the construction of the alternative scenarios and the corresponding cash flows.

2.1.1 Acquisition, verification and updating of the database

The acquired database concerns the results coming from the *first level of the energy audit* that analyzes the technological and typological characteristics of the buildings, as well as the electric and heat consumptions in the last few years. The *second level of the energy audit* defines the energy balance of the building, outlining the principal dispersion surfaces, the transmittance values, the calculation of the use of primary energy, and identifying the critical elements. The actions of energy efficiency, in terms of technological and management improvements, on the principal key elements, allow quantifying both the energy savings and the GHG reduction (Table1).

After the acquisition, those data and results, obtained by applying the same methodology and expressed in the same unit of measure, have to be verified. Some incongruities may happen, e.g. when the protocol for the tender notice, which requests an audit and financial analysis, is not adequately detailed, or if there is a lack of internal coordination between the different working groups. In these cases, it is necessary to get the data comparable through their transformation and redrafting.

2.1.2 Construction of the cash flows

The cash flow expresses the temporal and monetary form of the investment (action), and it consists of the distribution of costs and revenues over the economic life of an action. The costs and the revenues considered are:

- *the investment costs;*
  - *the cost of the action* of energy improving the building;
  - *the financing cost;*
- *the operating costs,* from the current energy consumption;
- *the operating revenues;*
  - *the revenues arising from energy saving;*
  - *the revenues originating from incentives* (Conto Termico 2.0).

The *cost of each action* is appraised on the basis of the specific technical characteristics provided in the improvement project. After assessing the amount of the investment, it is necessary to fix the equity and debt ratio. If the public authority, as an owner of the building, accesses to a third party capital financing that entirely covers the initial expense, this can be converted in repayments installments. The financing cost is a function of the loan rate (applied to the calculation of the

[2] *Sviluppo di una applicazione fondata sull'utilizzo di una rete neurale addestrata con i dati del audit energetico del campione analizzato in grado di costituire uno strumento di supporto alla decisione per le pubbliche amministrazioni per edifici di caratteristiche simili (Convenzione 23/03/2015)*, Project "Realizzazione dell'intervento di diagnosi energetica delle strutture pubbliche provinciali ai fini dell'efficientamento energetico" POI 2007-2013 "Energie Rinnovabili e Risparmio Energetico" Asse II Attività 2.2 – 2.5 Codice Operazione 00-160410-UPI CUP F76B11000010007. Scientific director: prof. M. Beccali, Working group: V. Lo Brano, G. Ciulla, A. Bonomolo, M. Galatioto.

Table 1 - *Description of the energy audits and the proposals of actions of energy improvement*

First level of energy audit
Building analysis (localization, building typology, use, technological characteristics of the building, heaters, electric system, etc.).
Analysis of thermal consumption (energy source, yearly consumptions, gross heated volume, net heated surface, dispersion surface, shape ratio, degree days, index of heat consumption, etc.).
Analysis of electric consumption (yearly consumptions per use, index of electric consumption, etc.).
Second level of energy audit
Climatic monitoring, classification of the elements of the opaque and transparent building envelope (typology, dimension, thickness, thermal transmittance, etc.).
Identification of thermal bridges and of critically parts of the building envelope. Thermal and electric systems, energy class, winter and summer energy requirement, requirement of primary energy, etc.
Proposals of actions of energy improvement
Proposals of actions of energy improvement (type of actions, characteristics of used materials, quantification of energy savings per energy source and primary energy, quantification of reduction of CO_2 emissions, etc.).

repayments installments) and it may vary considerably according to the type of funders, e.g. private (bank, financial company, etc.) or public (Cassa Depositi e Prestiti - CDP) and to the characteristics of the loan (e.g. entity and term of the loan, type of the loan rate).

The CDP's rules for Public Administrations (Municipality, Provinces, Regions, Health Authorities, University, etc.) are applied to the case study, assuming a single disbursal of a loan by CDP, with a 15-year repayment plan, using a fixed rate plus a spread. The financing is set at the 100% of the investment cost. The loan rate, according to the conditions previously described, is 1.84% at the time of the analysis (June 2016).

The *operational costs* from the energy consumptions depend on the price of the energy sources that can be various: methane gas, diesel fuel, electric, etc. The buildings of the sample use various energy sources, therefore it is necessary to different in kWh the annual levels of the consumptions (and of the savings), whereas in origin there were different units of physic measure, applying the following coefficients of conversion: 10 liters of diesel fuel = 1 kWh; 12.8 kgs of liquefied gas = 1 kWh; 9.8 mcs of methane gas = 1 kWh. The consumptions and the savings are afterward translated in monetary terms multiplying them by the average price of the corresponding energy source.

The *operating revenues*, represented by the energy savings in kWh, are translated in monetary terms, as previously says for the costs, and they are distributed throughout the period of analysis, set in 25 years.

The revenues from the disbursement of the incentives are calculated and distributed over a five-years period, according to the rules of Conto Termico 2.0. The value of the incentive varies for the type of action and is calculated by both the percentages of admissible cost and the maximum value of the incentive. Table 2 shows the rules for calculating the incentives about the following categories of action: *Opaque horizontal structures* (roofs and floors), *Opaque vertical structures* (outer walls), *Replacement of window frames*, *Sunshade systems and devices*.

2.1.3 Definition of the scenarios

The definition of alternative scenarios allows evaluating the consequences on the financial profitability caused by the variation of some elements, supposed significant, of the cash flow (Napoli, 2015). An element that is fundamental -also for its links to economic, energy and environmental politics- is the trend of the energy price, which is assumed stable (constant price) or slightly increasing.

The payment of incentives is also an important environmental and energy political measure (which can be renewed, reduced, or, to the opposite, strengthened) and it can modify the cash flows. Regarding scenarios, it is supposed the confirmation or the absence of the incentives of Conto Termico 2.0.

2.2 Financial Analysis

The economic and financial analysis evaluates the feasibility of the actions considering their costs and revenues and providing results from an evaluation of the different angles (perspectives) involved, whether public or private or both.

The investigation of financial sustainability of the project aims to examine whether the expected incoming cash flow is able, based on the quantitative and temporal analysis, to cover cash outflows.

Suitable and more used indicators to provide an appropriate valuation on investment capacity to create worth and generate adequate profitability are:

- the *NPV (Net Present Value);*
- the *IRR (Internal Rate of Return);*
- the *Payback Period*.

The NPV is the discounted present value of the entire project, where the cash flow is discounted, with a proper discount rate, as if all incomes and costs were made available instantly. The NPV represents the value of all revenues calculated after costs:

Table 2 - *Incentives of Conto Termico 2.0*

TYPE OF ACTIONS	INCENTIVES (PERCENTAGE OF ADMISSIBLE COST)	MAXIMUM ADMISSIBLE COSTS	MAXIMUM VALUE OF INCENTIVE
i. Opaque horizontal structure Roof insulation: - external - internal - ventilated roof	40% (50% in zones E, F)	200 €/m² 100 €/m² 250 €/m²	*i* + *ii* + *iii* ≤ 400.000 €
ii. Opaque horizontal structure Flooring insulation: - external - internal	40% (50% in zones E, F)	120 €/m² 100 €/m²	
iii. Opaque vertical structure Outer walls insulation: - external - internal - ventilated facades	40% (50% in zones E, F)	100 €/m² 80 €/m² 150 €/mq	
Replacement of window frames, in temperature control rooms	40%	350 €/m² zone A, B, C 450 €/m² zone D, E, F	75,000 € 100,000 €
Sunshade systens Automatic Sunshade Devises	40%	150 €/m² 30 €/m²	30,000 € 5,000 €

$$NPV = \sum_{t=1}^{n} \frac{(R_t - C_t)}{(1+r)^t} \qquad (1)$$

Where: R_t - revenues for the year t; C_t - costs of the year t; r - discount rate; n – period of analysis.

The discount rate r was determined as the yield of an alternative investment without (or negligible) risk and, in our case, the rate has been equated to the yield of government securities (Btp) with the same duration of the investment, which is equal to 2.5% at the date of analysis (June 2016).

The feasibility of the investment is obtained when the NPV gives a number larger than zero, as the NPV represents the project's ability to generate monetary flows to repay the investment costs, remunerate the capital invested in the project and produce resources available for other uses. NPV ≥ 0 is the condition to be checked to establish that a retrofit is feasible (*absolute feasibility*) and to draw up a list of actions for NPV gradually decreasing (*relative feasibility*). The NPV is an indicator that can be easily used in the analysis of energy efficiency actions (Verbeeck, Hens, 2005; Petersen, Svendsen, 2012).

The IRR, Internal Rate of Return, is the discount rate that makes the NPV of revenues and costs equal to zero. This indicator provides that the IRR of a project is compared with a threshold r rate set by the investor (a minimum acceptable rate), or the rate used to finance the project, considering both bank interest rate and the opportunity cost of the investor. Whenever an investment presents a performance (as measured by IRR) higher than the cost of capital, the project is considered desirable.

$$\sum_{t=1}^{n} \frac{(R_t - C_t)}{(1+IRR)^t} = 0 \qquad (2)$$

A widely used indicator (Gabrielli, Bottarelli, 2016; Brown, Matysiak, 2000) is the Payback Period, which is the time needed to recover the initial investment. The feasibility and decision are based comparing different Payback Periods with a predetermined cut-off period defined by the decision maker, or the life cycle of a building component. The best projects are those with a lower Payback Period. The indicator does not express the profitability of the project but rather its liquidity, and it can be expressed without discounting the cash flows (simple Payback Period), or taking account of the time value of money (discounted Payback Period). The Payback Period lends itself to be often used in the analysis of energy retrofit investments (Malatji, Zhang, Xia, 2013).

The Payback Period is calculated as follows:

$$\sum_{t=0}^{n} \left(R_t - C_t\right) = Ci \qquad (3)$$

and it is the point in time where the cash inflow generated by the project is expected to cover the initial costs (Ci).

The discounted Payback Period is expressed thus:

$$\sum_{t=1}^{n} \frac{R_t - C_t}{(1+r)^t} = Ci \qquad (4)$$

where the discount factor is introduced in the denominator and identifies the discounted flows.

The feasibility conditions can, therefore, be summarized as follows:

- NPV greater than zero;
- IRR at least equal to the discount rate;
- Payback Period lower than the time of analysis.

These conditions, if met, testify to the ability of the project to free cash flow sufficient to cover the initial investment and to recover the capital contributed by all parties involved in the investment.

2.3 RISK ANALYSIS

The analysis of the risk associated with each investment can be carried out using some well-known techniques.

Among these, the sensitivity analysis (or analysis of "reactivity" or "sensitivity") is a method used to evaluate the influence and the weight (the effect) induced by input variables in a model (e.g. the function that describes it analytically) on the results provided by the model. This is also called analysis of (future) scenarios, where a scenario is one of the possible combinations of values of the independent variables, or "what-if analysis", as it is possible to assess what changes if the analyst modifies the values of the decision parameters.

The technique aims at identifying, for each variable, new values within a predetermined range: the alternative assumptions reflect a pessimistic and an optimistic scenario, inside of which, in addition to the "base case" (the value obtained by the deterministic approach), different states are evaluated, and outcomes are recalculated to determine the impact of a variable under sensitivity analysis.

One of the simplest and most common methods is that of changing one-factor-at-a-time, e.g., in the model, only one variable is changed at a time to see the effect on the output. The simplicity of the technique, which allows quickly verifying the variables of a greater impact on the final results, however, neglects no less important aspects in the calculation.

First, the different scenarios have the same probability of occurring: the "pessimistic" scenario, the "optimistic" and the "base case" have the same probability of occurrence, not being associated with them any frequency distribution. Also, variables such as discount rates, prices and time on the market, can show multicollinearity or correlation. Since each variable is modified independently of any other, the model does not take into account the simultaneous variation of the input variable, and so it cannot identify the presence of interaction between variables.

Risk analysis, to learn about a probability of occurrence of a certain event, can use stochastic Monte Carlo, which simulates a statistically high number of potential combinations of critical parameter resulting from the assumption of probability distributions. The Monte Carlo method is part of the non-parametric statistical methods and is used to analyze the results through those simulations.

The Monte Carlo technique, introduced in the 60s (Hertz, 1964), is used to solve a problem numerically when any random variable is involved. The simulation, on which is based the method, allows testing the effects of changes in the input variables of the model on in the output function (results), e.g. the values of the NPV.

The simulation model of Monte Carlo is grounded on the assumption that some variables, which strongly influence the economic value of the project, are characterized by different levels of risk, and their values are not sure, investigable, or it is not possible to have any information about their future trends. In this case, it will be possible to describe the risk associated with each variable through a probability distribution: after selecting the critical variables and attribute to them a distribution, it is possible to choose an input variable from within the probability distribution selected for each variable randomly.

Such random extraction is repeated for several thousand times until the process is considered statistically significant: the greater the number of calculation of the re-sampling process, the greater will be the degree of precision and accuracy obtainable from the approach. For each variable, it is possible to calculate those of the model and obtain the distribution of the results.

The results of the iterations can be represented by a frequency distribution or a cumulative probability function: the decision-maker can compare the different output probability distributions obtained through the simulation process. The Monte Carlo method allows obtaining a valuation of the output probability distribution chosen as the indicator of the feasibility (Net Present Value, a Rate of Return, etc.), and it does not produce a single point answer (value). The resulting frequency distribution permits to measure the risk of the project, or projects, investment by statistical dispersion of the defined set of input figures and results.

For the Monte Carlo technique, it is crucial to define:

- *the parameters*. The inputs specified by the decision maker or the investor, and controllable accordingly;
- *the exogenous input variables*. The model input variables that depend on events beyond the control and describable by the probability distribution;
- *the output variables*. The simulation results, the

indicators used to measure the economic and financial feasibility of the investment (NPV, IRR, Payback Period);
- *the model*. The set of mathematical equations (of the parameters and functions of the input variables) that describe the relationships between the components of the system and define the binding of the output with the input variables.

The process (Fig. 1) is distinguished in the following steps:

1. identification of the critical variables (inputs) that could have a significant impact on the results;
2. assignment of a probability distribution for each variable on the basis of quantitative data or by expert consultations with appropriate methods;
3. use of a random number generator (processor) and a random extraction of values from each probability distribution of the variables;
4. use of random values thus obtained to calculate the model output (economic and financial feasibility indicators such as the IRR, the Net Present Value, the Payback Period, etc.);
5. re-sample for a number *n* of times to enable statistically reliable results;
6. graphical representation of a probability distribution and a cumulative frequency curve; and calculation of some statistical parameters of the output (the mean and the standard deviation).

The probability distribution can be represented by a normal or Gaussian distribution. This distribution is when the data is perfectly normal, the mean, median and mode are identical. Furthermore, statistical measures such as variance or the standard deviation obtained from the distribution defined as the values are dispersed around the mean value and, therefore, the characteristic of greater or lesser concentration around this value.

The Monte Carlo analysis could be used to identify which is the optimal solution during the design phase. The random numbers can be employed to select alternative hypotheses of construction, structural systems, architectural-distribution solutions, etc. The processor will try, through the extraction of random numbers, to find the best solutions both from the architectonical point of view and from the economic one.

3. THE CASE STUDY: THE ENERGY RETROFIT ACTIONS IN THE "OBJECTIVE CONVERGENCE" REGIONS

The methodology, introduced in the previous paragraphs, is applied to the case study of 36 energy retrofit actions of public buildings located in the four "Objective Convergence" Regions of Italy (Campania, Puglia, Calabria and Sicily).

The methodology consists of the following phases:

- Phase 1 - Selection of the sample;

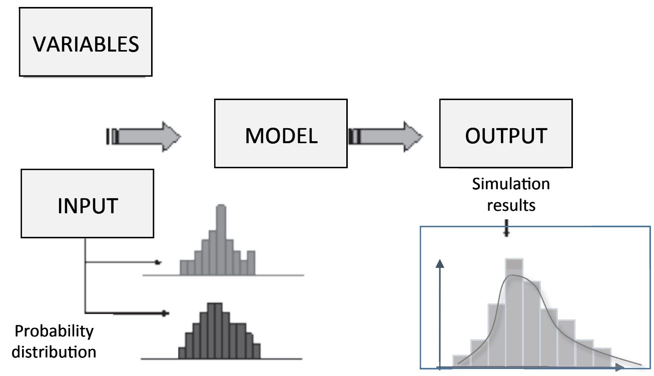

Figure 1 - *The elements of Monte Carlo simulation*

- Phase 2 - Construction of the database;
- Phase 3 - Definition of the scenarios;
- Phase 4 - Financial analysis (NPV, Payback Period);
- Phase 5 - Analysis of the risk (Monte Carlo simulation).

3.1 Selection of the sample of buildings and actions

The sample of buildings, on which to verify the profitability of the energy retrofit actions, is selected so that to be representative of the variety of characteristics, but ensuring the comparability of the results. When the aim is to select a homogeneous sample, other tecniques may be applied, e.g., the cluster analysis (Napoli *et al.*, 2016b; Napoli, 2017).

The criteria for the selection of the sample are:

- *Type of actions*. The categories of actions included are "Building envelope Insulation" (CI), "Replacement/ Integration of Window Frames" (SI) and "Installation of Sunshade Systems" (SS).
- *Use of the buildings*. The select use of buildings is school.
- *Climatic Zone*. The location of the buildings of the sample is uniformly distributed in the climatic zones B, C, D, and E (Figure. 2).
- *Energy Class*. The buildings of energy class G have been included (they have the worst energy performances).
- *Form Factor*. The sample is formed by buildings whose form factor S/V (building surface area/volume) is between 0.20 and 0.65 (particularly it is equal to: 0.20; 0.35; 0.50; 0.65).

The application of these criteria to the retrofit actions of 150 buildings (located in 25 Provinces of the 4 "Objective Convergence" Regions) has allowed us to select 36 actions for energy efficiency improvement (in 24 buildings located in 8 Provinces) (Table 3):

- 14 actions of "Building envelope insulation".
- 13 actions of "Replacement/Integration of Window Frames".
- 9 actions of "Installation of Sunshade Systems".

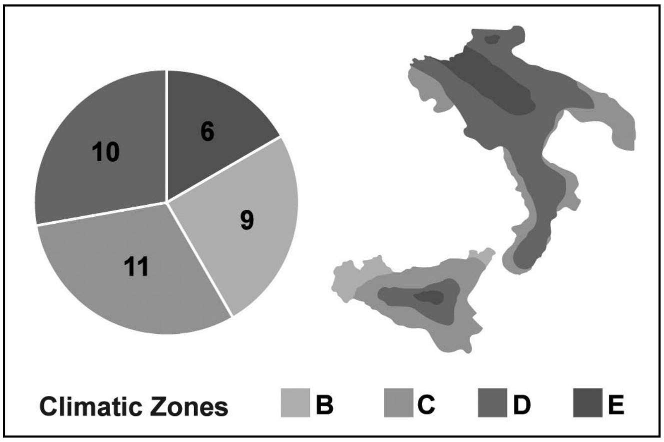

Figure 2 - *Distribution of the actions per climatic zone*

Table 3 - *Technological characteristics of the type of actions*

Technological characteristics of the actions
Building envelope insulation
Roof: polyurethane foam panels coated with bitumen felt paper and waterproofing double polymeric membranes (Calabria); layer of extruded polystyrene or cellular glass and waterproofing double bituminous sheath (Campania); polyurethane foam sandwich panels and waterproofing panels in extruded polystyrene (Puglia). External surfaces: single o double layers of extruded or expanded polystyrene and fiberglass armor.
Replacement/Integration of window frames
PVC window frames with double seals and insulated glazing (Calabria); double glazing window and aluminum window frames with thermal break and low thermal conductivity (Campania); 5 chambers PVC profile for window frames and double glazing window with Argon gas and thermal break raceways (Puglia).
Installation of sunshade systems
Sunshade system with aluminum movable lamellas.

3.2 Database construction

The Database of 36 actions has been formed selecting and redrawing the data from the results of the Audits according to the hypotheses of retrofit actions. Table 4 shows an extract of the database that is structured in:

- *General data*. Region, Province, building, use.
- *Physical-technical data*. Climatic zone, heated surface, form factor, average transmittance, etc.
- *Action data*. Type of action ("Building envelope insulation" CI, "Replacement/integration of window frames" SI and "Installation of sunshade systems" SS).
- *Energy data*. Energy class, consumption of primary energy per year, energy saving per year; reduction of CO_2 emissions, etc.
- *Financial data*. The price of the energy sources, monetary energy savings, costs of the action, etc.

The costs of the energy sources are updated to 2016, particularly, the costs and the corresponding savings related to the yearly energy use. The unitary costs of the electric energy, gas-oil and methane are respectively equal to 0.270 €/kWhs (last quarter 2015), 0.105 €/kWhs and 0.080 €/kWhs (1 October 2015 for 15,000 kWhs/year consumptions).

3.3 Alternative scenarios and financial analysis

Before proceeding to the economic-financial analysis of the energy retrofit actions, different scenarios are outlined. In the "basic scenario" (CF), it is supposed that the Public Administrations, in order to have the capital to finance the actions, accesses the CDP's financing in which a fixed rate of 1.84% (June 2016) has been applied to the loans to Municipality and Provinces. The first element of variation of the "basic scenario" is the possibility to get incentives according to the rules of Conto Termico 2.0, which is in force from 2016 May 31 (replacing the 2012 Conto Termico) (Tab. 2).

Each of the two scenarios "With Financing-without incentives" (CF-SC) and "With Financing-with incentives" (CF-CT) are organized introducing three different hypotheses concerning the trend of the energy price:

- *hypothesis 1*. constant price;
- *hypothesis 2*. +0.5% per year;
- *hypothesis 3*. +1.0% per year.

Combining the previous elements, 6 possible scenarios are outlined, as shown in Table 5.

The cash flows of the 6 scenarios are calculated for the 36 actions (216 cash flows). The following items are present in each cash flow (Table. 6):

- Cost of the action divided into installments (calculated according to the CDP's rules of financing).
- Energy savings in kWh per year.
- Cost of the energy source (hypothesis 1, 2 and 3).
- Money savings (related to the energy savings in the hypotheses 1, 2 and 3).
- Payments of the incentive (Conto termico 2.0).

On the basis of the cash flows:

- Net Present Value.
- Payback Period;

are calculated applying the formulas (1) and (3).

The Figure 3 illustrates that, for the action RC2-CI, the curve of the NPV changes and tends to move upward in response to the differences among the scenarios. The group of the three curves corresponding to the scenarios

Table 4 - *Extract of the database*

General data				Phisical-technical data						Action Data		
Region	Province	Building	Use	Climatic Zone	Degree days	Gross heated volume V (m^3)	Net heated surface (m^2)	Form Factor S/V (m^{-1})	Average thermal trasmittance (W/m^2K)	Building envelope insulation (CI)	Replacement /Integration of window frames (SI)	Installation of sunshade systems (SS)
Puglia	BT	BT3	E. 7	C	1,306	26,576	5,395	0.46	2.02		X	
Puglia	BT	BT2	E. 7	C	1,377	24,434	4,446	0.40	1.45	X		
Puglia	BT	BT6	E. 7	C	1,187	10,447	2,412	0.47	2.06	X		
Puglia	FG	FG5	E. 7	D	1,473	38,015	7,242	0.33	1.65	X		
Puglia	FG	FG5	E. 7	D	1,473	38,015	7,242	0.33	1.65		X	
Sicily	TP	TP4	E. 7	D	1,648	10,702	2,149	0.40	1.72		X	
Energy data						Financial data						
Energy Class	Energy source	Comsupion of energy primary Ante-action (kWh per year)	Comsupion of energy primary Post-action (kWh per year)	Energy saving (kWh per year)	Riduction of CO_2 emissions (tCO_2 per year)	Energy source prize (€)	Energy saving (€ per year)	Energy saving (% per year)	Cost of the action (€)	Unitary cost of the action (€/net heated (m2)	Surface of the action (m^2)	Unitary cost of the action (€/m2 of action)
G	Gas-oil	1,145,162	1,048,840	96,322	0.70	0.105	10,114	41.2%	810,743	23.7	1,734	467.5
G	Methane	929,785	661,394	268,392	2.20	0.08	21,471	114.7%	732,416	164.7	6,990	104.8
G	Methane	679,049	488,915	190,134	3.70	0.08	15,211	109.5%	312,409	129.5	3,715	84.1
G	Methane	1,205,077	437,173	767,904	3.40	0.08	61,432	79.5%	1,379,746	190.5	10,292	134.1
G	Methane	1,205,077	885,751	319,326	1.00	0.08	25,546	33.1%	433,036	59.8	948	456.9
G	Methane	131,821	125,076	6,745	0.53	0.08	540	63.6%	69,646	32.4	937	74.3

Table 5 - *The six scenarios*

YEARLY INCREASE OF THE ENERGY PRICE	SCENARIOS	
	Without incentives	With incentives
0%	CF-SC1	CF-CT1
0.5%	CF-SC2	CF-CT2
1%	CF-SC3	CF-CT3

without incentives (CF-SC1, CF-SC2, and CF-SC3), particularly, becomes negative for a discount rate equal or larger than 2.5%, (which is the discount rate adopted for achieving the profitability). The NPV curves of the scenarios with the incentives (CF-CT1, CF-CT2, and CF-CT3), instead, are mainly in the positive quadrant and assure a good profitability of the actions.

The increase in the energy price (from the hypothesis 1 to 3), both with or without incentives, contributes to modifying the form and the position of the curves because it makes the money savings increasing, but with a decreasing appreciation at year 0 when the discount rate increases.

Obviously, since every action has an own "temporal and monetary form", there will be multiple curves of NPV with different elasticity compared to the discount rate and different positions and translations in the positive and negative quadrants of the graph.

The effectiveness of the incentives to achieve the profitability of the energy retrofit actions can be understood from the comparison between the Figures 4 and 5.

In Figure 4 the NPVs of all actions are represented for the scenario CF-SC2. Under the similar conditions to this scenario (with financing, without incentives, hypothesis 2-energy cost), the NPVs of almost all actions have a strongly negative value, and only a few of them overcome the least conditions of the financial convenience. Figure 5 shows the NPVs for the scenario CF-CT2, which only differs from the previous one for the presence of the incentives. In this scenario, the addition of the incentives to the cash flows overturns the results of some actions, but the poor financial performance of some actions remains the same, e.g. KR3-CI (Building envelope insulation), BT3-SI and SA4-SI (Replacement/Integration of Window Frames).

The analysis of the NPV and the Payback Period notices that from the scenario without incentives (CF-SC2) to the one with incentives (CF-CT2), three cases may occur (Table 7):

- actions that maintain a negative NPV and the Payback Period higher than 25 years (dark grey);
- actions for which the previous negative NPV becomes positive in the scenario with incentive and the Payback Period is between 16 and 25 years (light grey);
- actions that always have a positive NPV and a Payback Period lower than 16 years, showing a high profitability (white).

The disaggregation of the NPVs for type of actions (Figure 6) makes clear that the incentives allow doubling the percentage of actions of "Replacement/Integration of Window Frames" (SI) and "Installation of Screens Solariums" (SS), which goes respectively from 23.1% to 46.1% and from 44.4% to 88.9%. The effectiveness of the incentives is greater for the "Building envelope

Table 6 - *Cash flows of six scenarios with financing, Action TP4-SI (Replacement/Integration of Window Frames)*

	With financing		Annual increasing of energy cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	...	Year 15	Year 16	...	Year 24	Year 25
a	Cost of the action (€)	-69,646.0													
b	Energy savings (kWh)			6,745.0	6,745.0	6,745.0	6,745.0	6,745.0	6,745.0	...	6,745.0	6,745.0	...	6,745.0	6,745.0
c	Cost of energy source - hypothesis 1 (€)		0.0%	0.080	0.080	0.080	0.080	0.080	0.080	...	0.080	0.080	...	0.080	0.080
d	Cost of energy source - hypothesis 2 (€)		0.5%	0.080	0.080	0.081	0.081	0.082	0.082	...	0.086	0.086	...	0.090	0.090
e	Cost of energy source - hypothesis 3 (€)		1.0%	0.080	0.081	0.082	0.082	0.083	0.084	...	0.092	0.093	...	0.101	0.102
f	Monetary savings - hypothesis 1 (€) (*b*c*)		0.0%	539.6	539.6	539.6	539.6	539.6	539.6	...	539.6	539.6	...	539.6	539.6
g	Monetary savings - hypothesis 2 (€) (*b*d*)		0.5%	539.6	542.3	545.0	547.7	550.5	553.2	...	578.6	581.5	...	605.2	608.2
h	Monetary savings - hypothesis 3 (€) (*b*e*)		1.0%	539.6	545.0	550.4	555.0	561.5	567.1	...	620.3	626.5	...	678.4	685.1
i	CDP's financing			-5,258.8	-5,258.8	-5,258.8	-5,258.8	-5,258.8	-5,258.8	...	-5,258.8		...		
l	Flow scenario CF-SC1 (€) (*f-i*)		0.0%	-4,719.2	-4,719.2	-4,719.2	-4,719.2	-4,719.2	-4,719.2	...	-4,719.2	539.6	...	539.6	539.6
m	Flow scenario CF-SC2 (€) (*g-i*)		0.5%	-4,719.2	-4,716.5	-4,713.8	-4,711.1	-4,708.3	-4,705.6	...	-4,680.2	581.5	...	605.2	608.2
n	Flow scenario CF-SC3 (€) (*h-i*)		1.0%	-4,719.2	-4,713.8	-4,708.4	-4,702.9	-4,697.3	-4,691.7	...	-4,638.5	626.5	...	678.4	685.1
o	Payments of the incentive Conto Termico 2.0 (€)			5,571.7	5,571.7	5,571.7	5,571.7	5,571.7		...					
p	Flow scenario CF-CT1 (€) (*f-i+o*)		0.0%	852.5	852.5	852.5	852.5	852.5	-4,719.2	...	-4,719.2	539.6	...	539.6	539.6
q	Flow scenario CF-CT2 (€) (*g-i+o*)		0.5%	852.5	855.2	857.9	860.6	863.3	-4,705.6	...	-4,680.2	581.5	...	605.2	608.2
r	Flow scenario CF-CT3 (€) (*h-i+o*)		1.0%	852.5	857.9	863.3	868.8	874.4	-4,691.7	...	-4,638.5	626.5	...	678.4	685.1

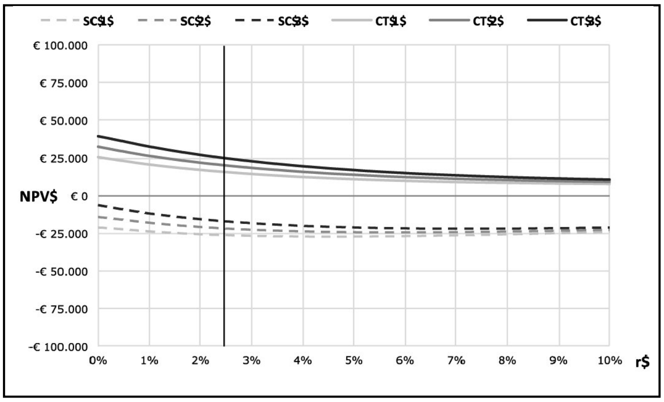

Figure 3 - *NPV (axe y) of the six scenarios (Action RC2-CI)*

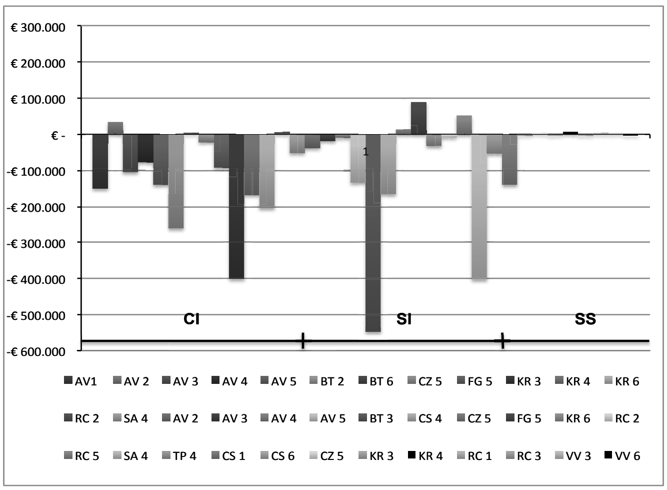

Figure 4 - *NPV (axe y) of the 36 actions (axe x) without incentives (Scenario CF-SC2) per type of action (CI, SI e SS)*

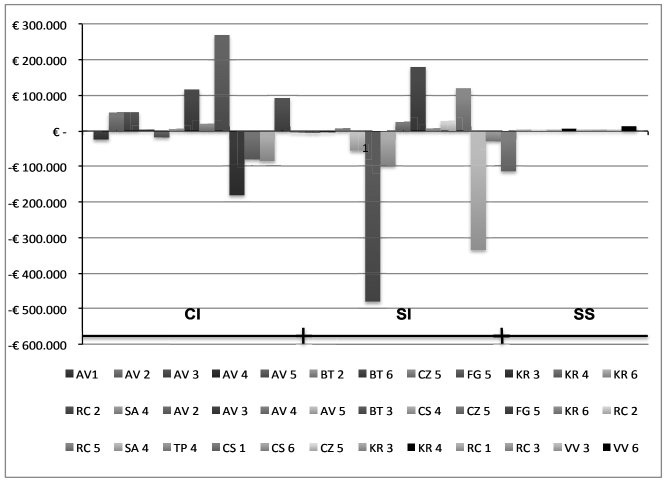

Figure 5 - *NPV (axe y) of the 36 actions (axe x) without incentives (Scenario CF-CT2) per type of action (CI, SI e SS)*

Insulation" (CI) reaching the convenience in 57.1% actions, while they were just 21.4% without incentives. Altogether around a quarter of the actions is convenient without incentives and increasing up to 61% thanks to the Conto Termico 2.0.

3.4 Risk analysis: results

In risk analysis model the following variables were used:

- *the interest rate*. The interest rate for the calculation of the mortgage varies between a positive and a negative scenario, identifying a minimum rate of 1.60% and a maximum of about 2.1%, however falling within the proposed range suggested by Cassa Depositi e Prestiti;
- *the discount rate*. As for the discount rates, these were used to obtain the time alignment of the cash flows of revenues and expenses during the period of analysis. The discount rate range goes from 2.5% (positive

Table 7 - *NPV and Payback Period of the 36 actions. Scenarios CF-SC2 and CF-CT2*

	Building code	Without incentives		With incentives	
		NPV (r = 2.5%) €	Payback Period *years*	NPV (r = 2.5%) €	Payback Period *years*
Building envelope insulation - CI	AV1	-150,818	> 25	-24,024	> 25
	AV 2	33,846	0	51,976	0
	AV 3	-104,811	> 25	52,920	19
	AV 4	-77,276	> 25	3,621	24
	AV 5	-140,331	> 25	-17,173	> 25
	BT 2	-260,615	> 25	4,960	24
	BT 6	3,674	23	116,954	16
	CZ 5	-21,692	> 25	20,154	19
	FG 5	-92,790	25	269,812	19
	KR 3	-400,657	> 25	-180,186	> 25
	KR 4	-168,133	> 25	-79,714	> 25
	KR 6	-204,542	> 25	-84,249	> 25
	RC 2	5,929	22	92,960	0
	SA 4	-51,748	> 25	-4,219	24
Replacement/integration of window frames - SI	AV 2	-38,043	> 25	-5,409	> 25
	AV 3	-18,223	> 25	-456	24
	AV 4	-9,103	> 25	7,214	18
	AV 5	-134,396	> 25	-55,349	> 25
	BT 3	-547,561	> 25	-479,574	> 25
	CS 4	-165,907	> 25	-97,919	> 25
	CZ 5	13,236	16	25,593	0
	FG 5	89,763	19	180,413	16
	KR 6	-32,590	> 25	6,800	22
	RC 2	-8,063	25	27,980	17
	RC 5	52,025	19	120,013	0
	SA 4	-402,130	> 25	-334,142	> 25
	TP 4	-53,284	> 25	-28,031	> 25
Installation of sunshade systems - SS	CS 1	-140,242	> 25	-113,047	> 25
	CS 6	-541	> 25	302	20
	CZ 5	385	0	614	0
	KR 3	-700	> 25	303	21
	KR 4	6,110	0	6,872	0
	RC 1	-1,093	25	3,204	17
	RC 3	136	17	284	0
	VV 3	324	20	1,059	0
	VV 6	-1,770	24	13,389	16

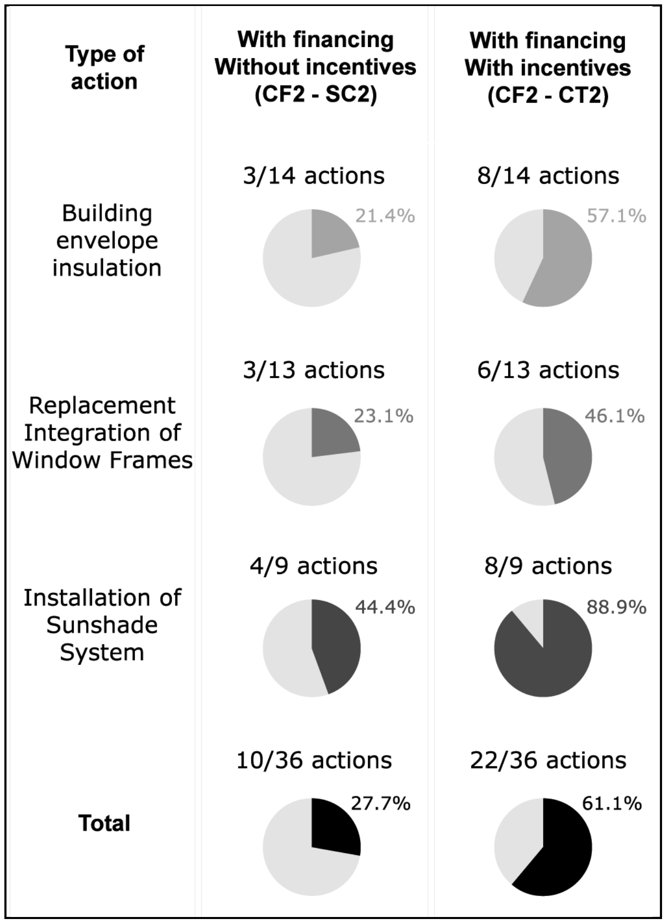

Figure 6 - *Percentage of those actions that achieve the financial profitability for NPV (r = 2.5%)*

scenario) and 4% (negative scenario), assuming an average rate for a public player and referring to yields of Btp;

- *the cost of energy*. As far as the cost of energy concern, we have assumed an increasing trend of prices, considering historical trends at the national level, within a range of + 0.5% and +1% per annum.

Regarding the exogenous input variables of the model, their assumptions are shown in Table 6, and their values have been derived from the analysis of the market. The normal probability distributions have been selected for the interest and discount rates, indicating, in addition to the mean and the standard deviation, minimum and maximum value adopted after market signals. As for the interest rate, these values have been suggested by the indications of Cassa Depositi e Prestiti, while the value of the discount rate is provided by the variability of yields of government securities (Btp).

Subjectivity (French, Gabrielli, 2005) in the choice of probability distributions of variables plays a significant role in the simulation. In this case, they are resulting from the behavior of the stakeholders in the market.

The distribution of the values of the cost of energy has a shape of a triangular distribution, assigning possible variations between a minimum of 0% (price unchanged over time) up to a maximum increase of 1% per annum.

All variables were correlated with the other: in particular, a positive correlation has been imposed (+0.7) among financial variables, namely the interest rate and the discount rate. The variable relating to energy costs has a positive correlation with the other two of +0.5.

The simulations have been performed for all scenarios, except for those whose NPV is strongly negative, and where, therefore, the risk analysis would not have had any impact.

The results obtained with the simulation for the scenario CZ5 (building envelope insulation) are reported in figure 7.

The NPV achieved by Monte Carlo simulation (17,819€) does not differ much from the value obtained by the deterministic approach (15,751€with a discount rate of 2.3% and zero growth assumptions for energy costs), but it provides additional information about the uncertainty of the results. The asymmetry of the distribution (0.12) indicates a symmetrical distribution with a tail, which extends towards the most positive values: in this case, the distribution (and hence the output, the NPV) is moderately inclined to the right. The average and median values are almost identical showing that there is a high chance that the expected value is less than that calculated by analyzing traditional cost-revenues; the standard deviation is equal to 1,518€ The minimum expected value of the investment is a NPV of 12,819€, in the case of rather negative values of the input variables, namely the rate of interest and the discount rate, as well as a prediction of stable prices concerning the cost of energy. The maximum value of the frequency distribution is 23,851€ About the sensitivity of the variables, the cost of energy turns out to be the one with the greatest impact. The sensitivity of the model to the input variables is measured through the graph "tornado": the tornado diagram graphically represents the "hierarchy" of impacts that have occurred in the model. The variable illustrated at the top in the chart (Fig. 8), the cost of energy, is the one that has the greatest impact on the result (NPV), while the other two variables (the rates) have lower but very similar effects. The higher is the energy cost and, therefore, the subsequent savings, the more the net present value increases: the effect is positive in the model. On the contrary, the growth in the discount rate or interest, the investment attractiveness is reduced and the NPV with it.

A similar simulation concerns the RC1-SS case study regarding the installation of solar screens (Figure 9). As in the previous example, the analyses confirm the robustness of the Discounted cash flow analysis, showing a symmetric distribution, where the mean and median have the same value and the mean value is 2,936€ The result obtained with the Discounted cash flow analysis was 2,719€ but was obtained using a discount rate of 2.5%, while in the Monte Carlo simulation of this rate reflects the minimum discount rate threshold. As the simulation encloses the growth assumptions of the energy cost, which turns out to be the variable of greatest impact on the feasibility of the investment, the average NPV of Monte Carlo analysis is slightly higher than the one found with the Discounted cash flow analysis, which, in turn, does not internalize growth in energy prices.

The minimum value resulting from the simulations results to be 2,353€, the maximum is 3,595€

4. CONCLUSIONS

The economic and financial analysis made it possible to evaluate the feasibility of some energy retrofit actions in a sample of buildings, promoted by a public player. Regarding 3 different types of action (Building envelope insulation, Replacement/integration of window frames and Installation of sunshade systems), 24 buildings located in the 4 Italian Regions Convergence Objective were selected for the analysis. Through the Discounted cash flow analysis, it was possible to study some indicators of financial performance of the actions and analyze the overall effectiveness of the incentives now existing in Italy (Conto Termico 2.0).

In a first phase, after constructing the database by selecting and rearranging the data from the Audit outcomes of the first and second level and the assumptions of retrofits, all actions were analyzed through a Discounted cash flow analysis, where the outflows are represented by the investment cost of each action. This cost represents the mortgage repayment, assuming that the public sector borrows 100% of the initial cost and that must be granted by Cassa Depositi e Prestiti. Revenues are, in fact, the savings achievable with energy retrofits, to which must be added the incomes of the incentives. Each action was analyzed from the Net Present Value and the Payback Period points of view.

Table 8 - *Input variables of the models*

Input	*Distribuzione*	*Mean*	*SD*	*Min*	*Max*	*Correlation*
Interest rate	Normal	1.84%	0.18%	1.6%	2.10%	Discount rate/Energy price
Discount rate	Normal	3.30%	0.30%	2.50%	4.00%	Interest rate/Energy price
Energy price	Triangular	0.50%	-	0.00%	1.00%	Discount rate/Interest rate

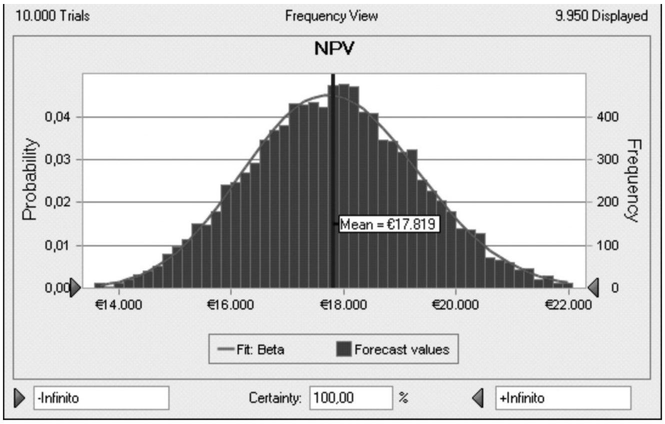

Figure 7 - *Simulation on case CZ5-CI (building envelope insulation)*

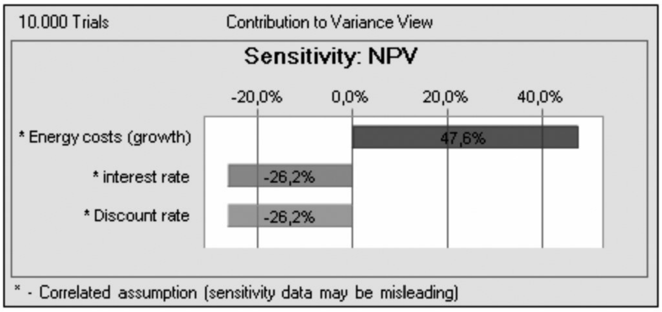

Figure 8 - *Simulation on case CZ5-CI (Building envelope insulation)- Tornado*

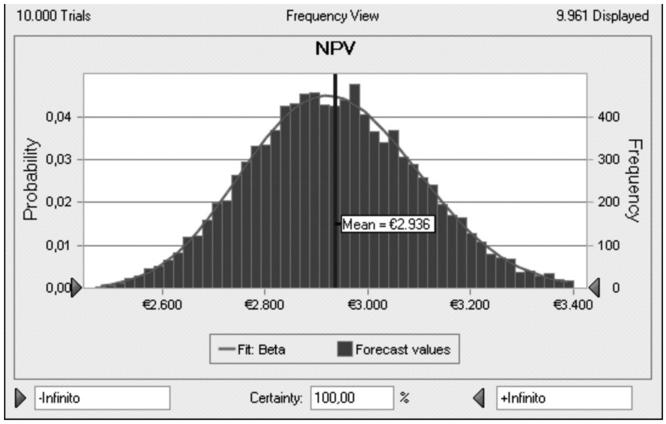

Figure 9 - *Simulation on case RC1-SS (Installation of sunshade systems)*

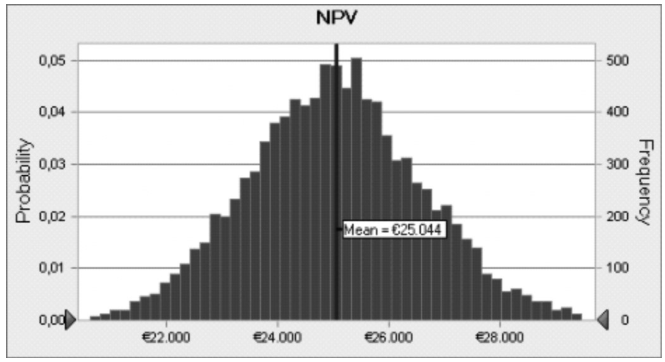

Figure 10 - *Simulation on RC2-SI (Replacement/Integration of window frames)*

As shown in the tables, it should be noted that there are some case studies:

- The actions that are never feasible, where the NPV is negative, with or without incentives, and the Payback Period is greater than the term of analysis, fixed in 25 years.
- The actions where the NPV is negative without incentives, and positive for the hypotheses with incentives.
- The actions that show a positive NPV and a short Payback Period (lower than 16 years), both with and without incentives, indicating a substantial economic advantage to implement the actions.

The results obtained were analyzed employing a risk analysis, through the Monte Carlo approach. The different simulations have allowed assessing the robustness of the results and the model's sensitivity to certain variables. In particular, interest and discount rates, and energy prices (in terms of growth) were taken as random variables in the model, and a probability distribution was defined to set up a Monte Carlo simulation.

None of the results reflects non-feasibility situations: the minor changes imposed on input variables, as indicated by the credit, financial and energy markets, have never generated negative NPV. The distributions generated by the simulation have mostly confirmed the results obtained with the Discounted cash flow analysis, indicating a slight probability of positive results, especially in the presence of an increase in the cost of energy, which is very plausible considering the current energy policies. A combination of adverse conditions (high interest rates, high discount rate and limited growth in energy costs) significantly reduces the expected return, halving, in some cases, the net present value of the project. But in the current scenario, the cost of money close to zero, the yield of Btp (which was taken as the base of the discount rate) and a very low energy cost growth lead to the hypothesis that our results will be placed on the right side of the probability distributions, thus with high NPV and short Payback Period.

The aim of the research was to propose a methodology to guide the decision-making of public sector to select the retrofit actions to be submitted to other analysis of a feasibility analysis and incorporate other aspects such as environmental, administrative, procedural, social, sustainability. Future steps of the research will also investigate these non-economic issues.

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