The investment costs and energy performance evaluation in social housing renovation. A decision support system that approaches Directive 2010/31/EU.

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Abstract

The European Council, during the March 2007 meeting, focused on the need of improving energy efficiency in the European Union and asked for a prompt response to the priorities defined in the "Action plan for energy efficiency". The Plan identified the important energy saving potential in building costs and especially in residential building. This way, it is possible to gather that there is still a great unrealized economically convenient potential for energy savings in buildings. Nevertheless, it is really important that this operation follows a correct cost-benefit analysis, based on a method conforming to the new Directive 2010/31/EU. In fact, this Directive states that the measures to improve further the energy performance of buildings should take into account cost-effectiveness. This research is a preliminary approach for the methodological application of the EU Directive, with the intent of giving a model for the member States during the implementation process. In particular, the model approaches issues connected to the "major renovation" of existing multi-family residential buildings owned and managed by the State. Starting from the building energy needs, the model evaluates the effects of a building element renovation, pointing at energy savings and socio-economic costs during the intervention life-cycle. The acceptable maximum cost of the renovation intervention is analyzed considering the range of validity of the cost optimal curve for the minimum energy requirement. The report is completed by a selection of case studies taken from the Italian social housing context in order to validate the methodology studied.

Keywords - Decision support system, economic life cycle, retrofit, social housing

Paper type - Research paper

Introduction

The European Council, during the March 2007 meeting, focused on the need of improving energy efficiency in the European Union to achieve the objective of reducing by 20% the Union's energy consumption by 2020 and asked for a prompt response to the priorities defined in the "Action plan for energy efficiency". The Plan identified the significant potential for cost-effective energy savings in the buildings sector. In fact, buildings account for 40% of total energy consumption in the Union and housing sector is one of the major contributors. Since the sector is expanding, it represents a great unrealised potential for energy savings. About that, during last May 2010, Directive 31/2010/EU on energy performance of buildings was issued and recast the 2002 version [1]. The Directive underlines the need to define measures for improving further the energy performance of buildings, using a new set of minimum requirements for the energy performance of buildings and building elements calculated through a new assessment methodology. The calculation method should be developed taking into account climatic and local conditions as well as indoor climate environment and cost-effectiveness. Moreover, it should be based not only on the season in which heating is required, but should cover the annual energy performance of building. The new requirements should also be set to achieving the cost-optimal balance between the investments involved and the energy costs saved throughout the life cycle of the building or the building element. To confirm this assumption, two recent European-wide studies [2], [3] show that 75-85% of the technical savings potential for 2020 is comprised of cost-effective options.
By the end of June 2011, the European Commission should lay down a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements, for different kinds of interventions.
The main purpose of this paper is to give a preliminary support to the framework for the definition of the cost-optimal minimum requirements for building elements during major renovations of existing buildings. Since the public sector should lead the way in the field of energy performance of buildings, an application of the purposed method to Italian social housing case study should be taken into consideration.

The methodological approach

The Directive 2002/91/EU describes how the energy performance of buildings should be evaluated and required the Member States to find a maximum energy consumption level based on a standard use of the building without taking into account costs issues. Now the new 2010 Directive requests the Member States to set minimum energy performance requirements for buildings taking into consideration cost-optimal levels, that shall be calculated according to a comparative methodology.
The comparative methodology framework shall be established in accordance with Article 5 and especially with Annex III. It shall differentiate between new and existing buildings and between different categories of buildings. Article 5 contains the full legal text while Annex III gives a sketch for developing a comparative methodology framework to identify cost-optimal levels of energy performance requirements for buildings and building elements.
For further understand the methodological approach, it's necessary to preliminarily refer to some

definitions taken from the Directive, such as "major renovation", “building element” and “cost-optimal level” as well as the calculation steps identified in the Annex III.

The Directive identifies ‘Major renovation’ as the renovation of a building where:

a. *the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated; or*
b. *more than 25 % of the surface of the building envelope undergoes renovation;*

Member States may choose to define a ‘major renovation’ either in terms of a percentage of the surface of the building envelope or in terms of the value of the building. If a Member State decides to define a major renovation in terms of the value of the building, values such as the actuarial value, or the current value based on the cost of reconstruction, excluding the value of the land upon which the building is situated, could be used.

A ‘building element’ is a technical building system or an element of the building envelope.

‘Cost-optimal level’ means the energy performance level which leads to the lowest cost during the estimated economic life cycle, where:

a. *the lowest cost is determined taking into account energy-related investment costs, maintenance and operating costs (including energy costs and savings, the category of building concerned, earnings from energy produced), where applicable, and disposal costs, where applicable; and*
b. *the estimated economic life cycle is determined by each Member State. It refers to the remaining estimated economic life cycle of a building where energy performance requirements are set for the building as a whole, or to the estimated economic life cycle of a building element where energy performance requirements are set for building elements.*

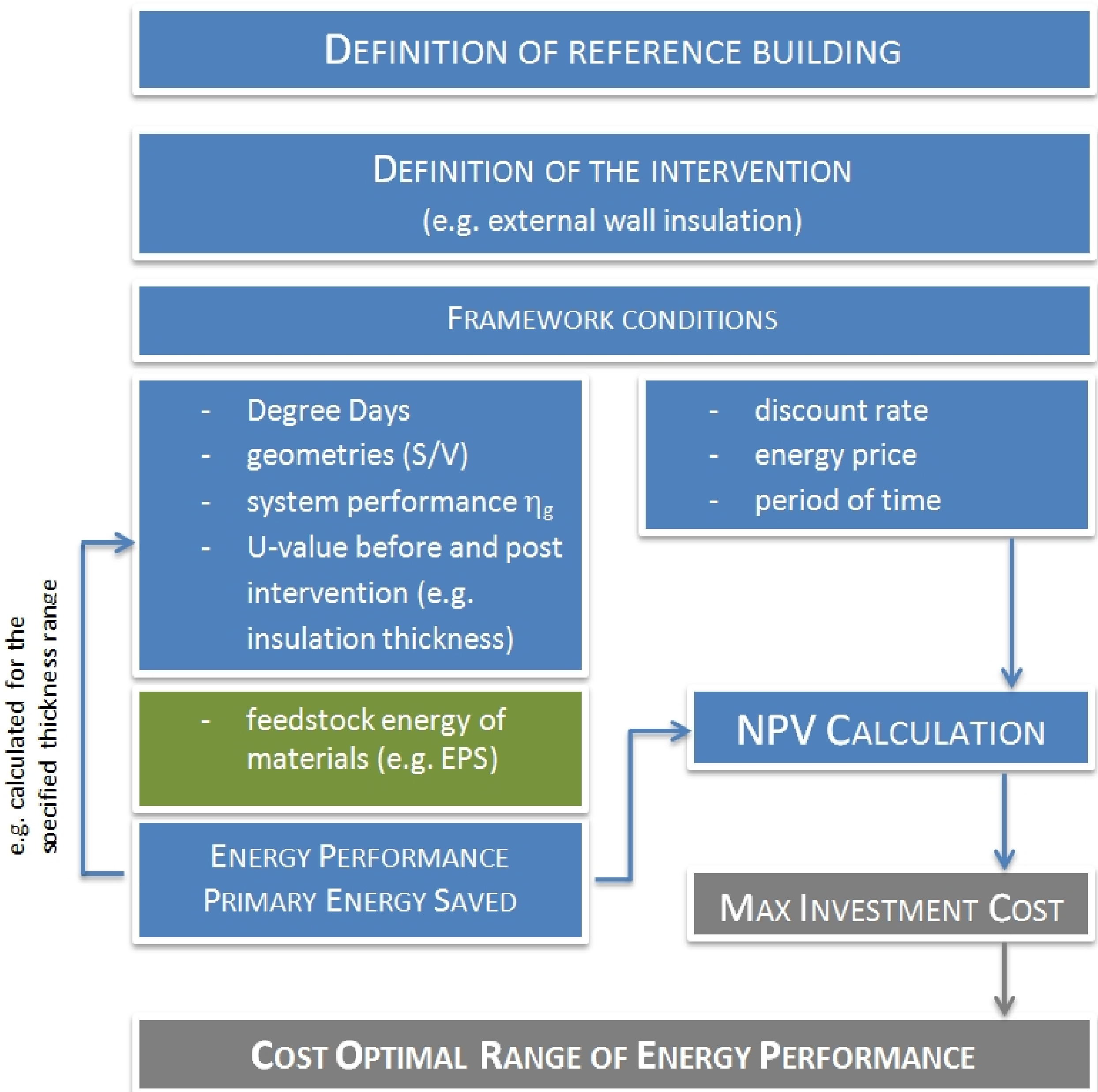
The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic life cycle is positive.

The sketch suggested in Annex III requires each Member State to:

a. define reference buildings that are representative in terms of functionality and climate conditions. The reference buildings need to cover residential and non residential buildings (e.g. offices), both from new and existing;
b. define energy efficiency measures to be assessed for the reference building. These can be measures for building as a whole, for building elements, or for a combination of buildings elements;
c. assess the final and primary energy need of these reference buildings. The calculation must be done in accordance with relevant European standards;
d. calculate the costs of the energy efficiency measures during the expected economic life cycle of the reference buildings. Investment costs, maintenance and operating costs, earnings from energy produced and disposal costs (if applicable) need to be taken into consideration.

Calculation steps

Conforming to the sketch of Annex III, the proposed methodology requires the knowledge of few variables (input data) and it can be represented graphically using the following flow-chart:



Definition of reference building

Buildings have an impact on long-term energy consumption. Given the long renovation cycle for existing buildings, new, and existing buildings that are subject to major renovation, should therefore meet minimum energy performance requirements adapted to the local climate.
Major renovations of existing buildings, regardless of their size, provide an opportunity to take cost-effective measures to enhance energy performance. For reasons of cost-effectiveness, it should be possible to limit the minimum energy performance requirements to the renovated parts that are most relevant for the energy performance of the building.

Building stock used is as follow:

- same building typology;
- same wall layers;
- no insulation in external walls, floors or roof;
- same heating system;
- same construction years (1968-1975);
- subject to "major renovation intervention" by applying an external wall insulation layer to the whole external surface.

Energy performance

The calculation of the energy performance after the refurbishment intervention is made by using a simplified methodology developed by the Energy and Environment National Agency (ENEA).
The methodology can be summed up as follows:

$\Delta Qh = \Delta U * \Delta T * S$

$\Delta Qa = DD * 24 * f * R * \Delta U * S/1000$ [kWh]

$Qpr = \Delta Qa / \eta g$

ΔQh = energy for heating [W]
Qa = energy …. [W]
Qpr = primary energy saved
f = correction factor for average indoor temperature (for intermittent heating) [-]
R = correction factor for non heated [-]
S = area of intervention [sqm]
ΔU = predicted U-value post intervention [W/sqm K]
ηg = global efficiency of heating system

The calculation of energy performance of the building elements is made using the EN 6946:2008.
Energy saving is obtained as the primary energy demand before the intervention, minus the energy demand after the refurbishment, plus the feedstock energy of the construction materials used.

Economic assessment

The proposed model simulates the change in the cost of the intervention to achieve a specified energy performance.

Input data

- discount rate;
- period of time;
- average unit price of the energy vector;
- estimated long term energy price development.

The model gives an economic assessment of the proposed intervention by calculating the Net Present Value (NPV), if this is equal to or greater than zero, then the proposal can be considered cost-effective over the life cycle considered. When the NPV returns exactly zero, we are dealing with minimum level performance under which it is not suitable the initial investment.
The choice between various interventions with positive values of NPV, can be done separately evaluating the factors involved. For example, one can choose to focus on the energy saved during life cycle, or give priority to the investment cost.

At this time, we need to make some considerations about estimated discount rate, annual increment of energy price and building element life cycle.
As mentioned before, discount rate and the annual increment of energy price are two exogenous input data for the calculation. So, they not depend from the practitioners but from the indexes that are annually updated from Public Authorities.
In consideration of that, the Italian Institute of Statistics revealed that the average inflation rate for the 2010 is equal to 2,3 %.
Since the aims of this paper are to define a methodological approach that conform EU Directive and apply it to a set of social housing' case studies, it's reasonable to assume this average value as the reference for the two variables mentioned above.
In fact, on the long period it's always difficult setting appropriate values. This why we cannot make future previsions without considering a minimum level of uncertainty.
Thus, refer to average values could be a correct approach.
In particular, we assume that the discount rate for a long period investment on a Public property can correspond to the social rate of time preference and its value thus match the average annual inflation rate.
According to previous assumption, in relation to estimated long term energy price development, we can set a minimal annual growth that match the average inflation rate.
The Directive states that "*the estimated economic life cycle of a building or building element should be determined by Member States, taking into account current practices and experience in defining typical economic life cycles.*"
From a methodological point of view, a common definition of life cycle of a single intervention is the key in his economic assessment. This aspect is very delicate and, obviously, it depends on a range of causes, such as:

- For every kind of intervention, the variability of technological construction typology;
- Based on local tradition, the variability of construction systems.

According to Directive regulations, an Italian report, made by ENEA [4], allows to define the estimated life cycle of walls insulation systems. The report states that the life cycle mainly depends on the duration of the insulation layer and therefore, it's reasonable to assume a period of 20 years as a life cycle for this kind of intervention.

Environmental Costs (externalities)

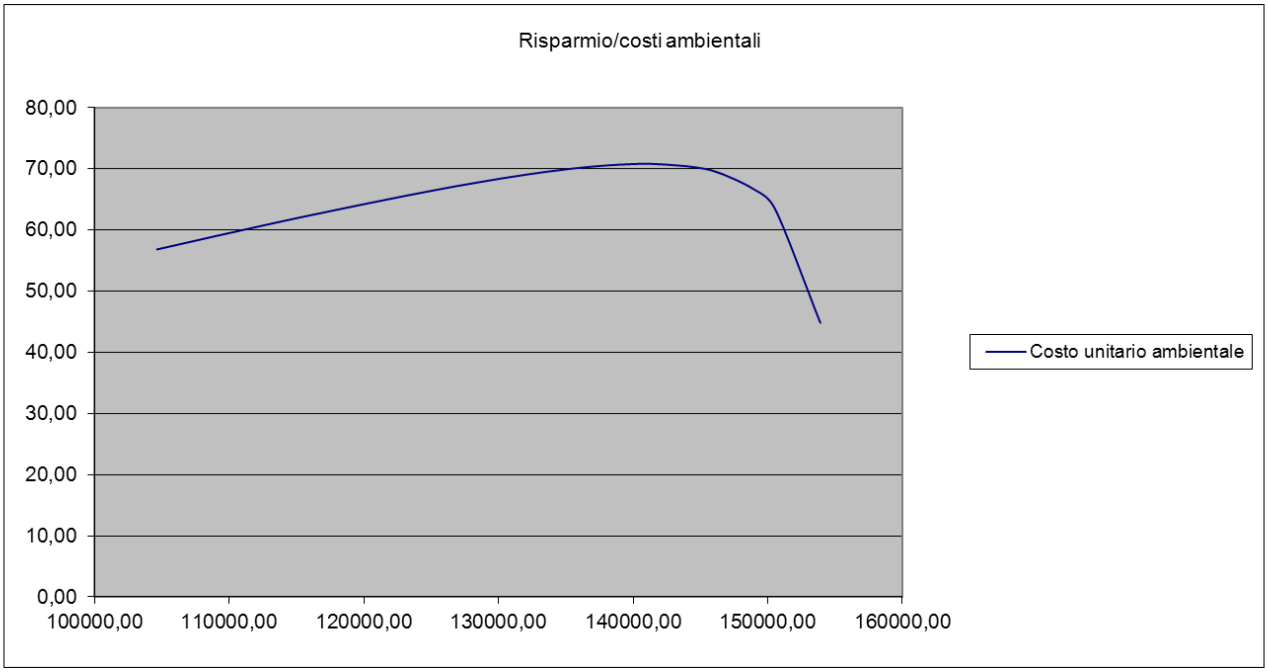
For a better assessment it is necessary to take into account the energy stock of the materials.
It was decided to count all the feedstock energy in the first year of the intervention, because its weight is equivalent to an initial investment and should not be distributed on its life-cycle.

Application to case studies

The sample buildings were analyzed by the method proposed by the project TABULA, asset rating with standard user. Despite common elements, the buildings considered are different in size and number of floors.
We've considered an intervention common to all buildings with the same material and same finish, a layer of EPS and exterior plaster as finish. For each thickness of insulation you can find usually on trade and for some characteristics values, were calculated the energy performance, assessed as primary energy savings of the intervention and its maximum cost.

Results

From the analysis we obtain the relationship, in graphic form, which describes the type of curve optimal level of cost as a function of energy performance.
The study led to the definition of a curve defined by a unique equation. The important thing is that this curve, as shown on the application case studies, does not change, but is only translated in the Cartesian plane, according to a vector that depends on the cost of primary energy saved, and then the investment cost. This makes the curve actually usable.
It is important to emphasize the role of Member States in defining the limits of validity of the curve. We propose a threshold level that coincides with the current legislation on the element building U-value. The upper limit stands at a point where the gap between curve type and “environmental” curve is not too broad. This point match with the maximum of the curve below that represent the relationship between savings and “environmental” costs.



Discussion and conclusions

Applying this methodology, each Member State assess the input data and calculate the results. The methodology and local data will then allow to identify cost-optimal level of minimum energy performance requirements for building elements renovation, and can compare the results of this calculation with the minimum energy performance requirements that are currently in effect.
The method used leads to the definition of a new unit of measure of the energy performance because more consistent with the concept of cost-optimal curve, in fact a single index would not be able to define type curves.
In addition to that we think in terms of environment, considering the energy of the feedstock materials. Knowing a mean energy for the EPS [5], we calculate a new curve in our opinion more realistic in terms of cost-effectiveness in describing the life-cycle.

References

[1] Directive 2002/91/EU on energy performance of buildings.
[2] Fraunhofer-Institute for Systems and Innovation Research (Fraunhofer ISI) and partners, (2009). Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries. Final Report for the European Commission Directorate-General Energy and Transport.
[3] Ecofys, (2009), Sectoral Emission Reduction Potentiasls and Economic Costs for Climate Change (SERPEC-CC) Summary report.
[4] ENEA, (2008), ERS-Energy ReStyling of residential buildings and offices.
[5] Taborelli S., Furno E., (2008), EPS: Environmental impacts and life cycle. Report from the research project, Italian EPS Association

Annex I - Extract from case studies and tool for calculation

Cavallari Murat - Viale dei mughetti 30-34 - Stato di fatto | Manica

V $[m^3]$	S/V $[m^{-1}]$	Af $[m^2]$	Numero Appartamenti	Piani f.t.
4147	0,524	164,69	20	4

Strutture opache

Tipologia	U W/m^2K
Muratura esterna	1,41
Muratura su vano scala	1,14
Solaio su interrato	1,28
Solaio su sottotetto	1,28

Strutture trasparenti

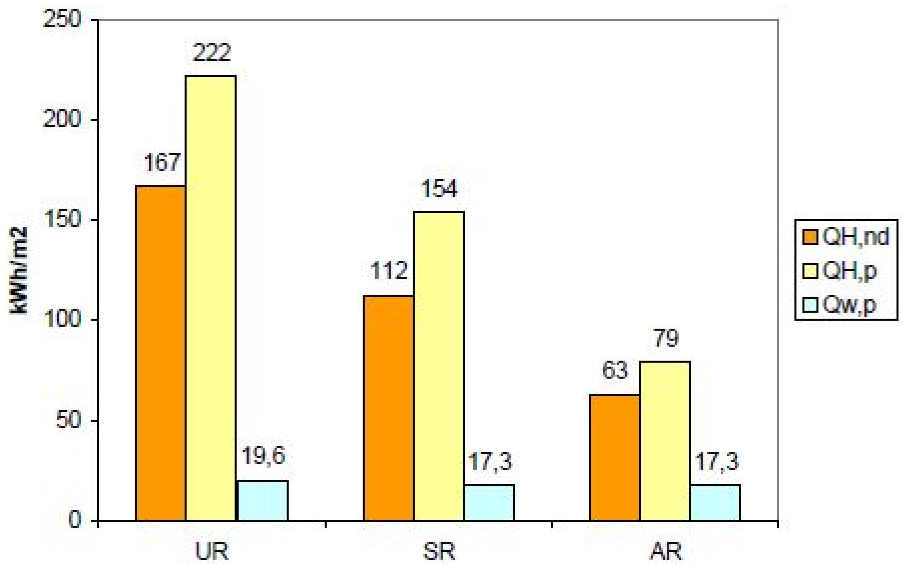
Tipologia	U W/m^2K
Vetro singolo	5,71
Telaio in legno	2,70
Dimensioni	
Finestra 110x210	4,435
Finestra 60x120	4,374
Finestra 110x120	4,298

Impianto

Generatore		
Teleriscaldamento	1,00	$\eta_{h,gn}$
Distribuzione		
Colonne montanti	0,91	$\eta_{h,d}$
Produzione ACS		
Generatore di calore indipendente	0,84	$\eta_{w,s}$
Distribuzione	0,88	$\eta_{w,d}$

Comportamento energetico

Manica



	UR	SR	AR
	kWh/m^2	kWh/m^2	kWh/m^2
$Q_{H,nd}$	167	112	63
$Q_{H,p}$	222	154	79
$Q_{w,p}$	19,6	17,3	17,3

UR Stato di fatto
SR Riqualificazione base
AR Riqualificazione avanzata

Cavallari-Murat - Manica

Anno	0	1	2	3	4	5	6	7	8	9	10
Intevento su strutture opache verticali											
Costo intervento [€]	-66.410,54										
Risparmio economico energia primaria [€/anno]		-55.324,17	9.106,20	9.288,33	9.474,10	9.663,58	9.856,85	10.053,99	10.255,07	10.460,17	10.669,37
Flusso di cassa [€]	-66.410,54	-55.324,17	9.106,20	9.288,33	9.474,10	9.663,58	9.856,85	10.053,99	10.255,07	10.460,17	10.669,37
Tasso di sconto [-]	0,053										
Coefficiente attualizzazione [-]	1,00	0,95	0,90	0,86	0,81	0,77	0,73	0,70	0,66	0,63	0,60
Flusso di cassa attualizzato [€]	-66.410,54	-52.539,57	8.212,60	7.955,23	7.705,92	7.464,42	7.230,49	7.003,90	6.784,40	6.571,78	6.365,83
Valore Attuale Netto [€]	0,00										
Tasso di Rendimento Interno [-]	5,3%										
Flusso di cassa cumulativo [€]	-66.410,54	-121.734,71	-112.628,51	-103.340,18	-93.866,08	-84.202,51	-74.345,66	-64.291,67	-54.036,61	-43.576,44	-32.907,07
VAN cumulativo [€]	-66.410,54	-118.950,12	-110.737,52	-102.782,29	-95.076,37	-87.611,95	-80.381,46	-73.377,57	-66.593,17	-60.021,38	-53.655,55
Risparmio energia primaria [kWh/anno]	1.970.388,57	-953.709,14	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88
Vettore energetico											
Combustibile	Metano										
PCI [MJ/mc]	31,65										
Fattore conversione en. termica/en. primaria	1										
Costo standard combustibile [€/mc]	0,5										
Costo combustibile [€/kWh]	0,0569										
Incremento annuo costo combustibile [-]	0,020										
Costo combustibile incrementato [€/kWh]		0,0580	0,0592	0,0604	0,0616	0,0628	0,0640	0,0653	0,0666	0,0680	0,0693

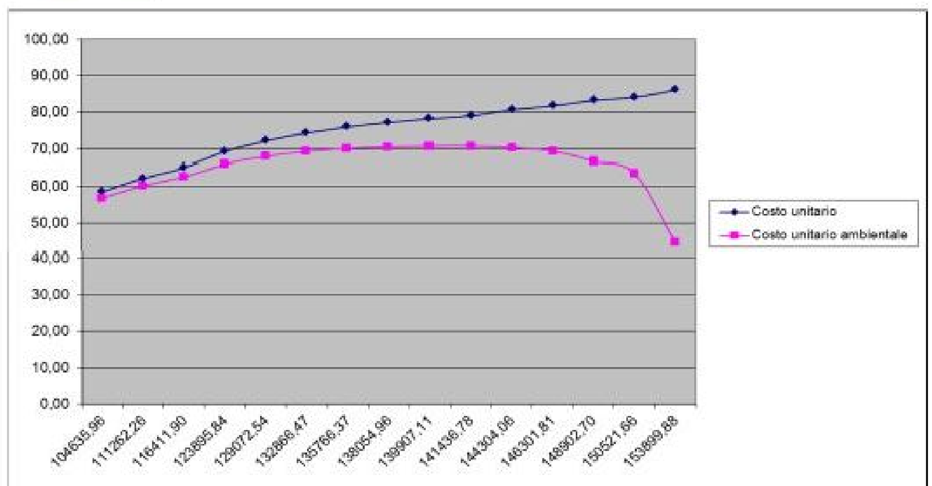
Anno	11	12	13	14	15	16	17	18	19	20
Risparmio economico energia primaria [€/anno]	10.882,76	11.100,41	11.322,42	11.548,87	11.779,85	12.015,44	12.255,75	12.500,87	12.750,89	13.005,90
Flusso di cassa [€]	10.882,76	11.100,41	11.322,42	11.548,87	11.779,85	12.015,44	12.255,75	12.500,87	12.750,89	13.005,90
Coefficiente attualizzazione [-]	0,57	0,54	0,51	0,49	0,46	0,44	0,42	0,39	0,37	0,36
Flusso di cassa attualizzato [€]	6.166,33	5.973,08	5.785,89	5.604,57	5.428,93	5.258,79	5.093,99	4.934,34	4.779,71	4.629,92
Flusso di cassa cumulativo [€]	-22.024,31	-10.923,90	398,52	11.947,39	23.727,24	35.742,68	47.998,44	60.499,30	73.250,19	86.256,09
VAN cumulativo [€]	-47.489,22	-41.516,13	-35.730,24	-30.125,67	-24.696,74	-19.437,95	-14.343,97	-9.409,62	-4.629,92	0,00
Risparmio energia primaria [kWh/anno]	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88	153.899,88
Costo combustibile incrementato [€/kWh]	0,0707	0,0721	0,0736	0,0750	0,0765	0,0781	0,0796	0,0812	0,0829	0,0845

Dati relativi all'edificio e all'intervento	
Numero piani	4
Gradi Giorno di riferimento [-]	2.617
Superficie netta riscaldata [mq]	1.382,33
Volume riscaldato [mc]	4.147,00
Rapporto S/V	0,524
Superficie esterna disperdente totale [mq]	2.173,03
Superficie esterna disperdente di intervento [mq]	1.481,86
Percentuale di superficie interessata [-]	0,68
Rendimento medio globale stagionale [-]	0,75
Trasmittanza elemento opaco esistente [W/mq K]	1,410
Trasmittanza elemento opaco post-intervento [W/mq K]	0,032
Risparmio energia primaria [kWh/anno]	153899,88

Sp	U	Risp	K Unit	K Amb
0,04	0,47	104635,96	58,47	56,82
0,05	0,41	111262,26	62,17	60,11
0,06	0,37	116411,90	65,05	62,57
0,08	0,30	123895,84	69,23	65,93
0,10	0,25	129072,54	72,12	68,00
0,12	0,22	132866,47	74,24	69,30
0,14	0,19	135766,37	75,86	70,10
0,16	0,17	138054,96	77,14	70,55
0,18	0,16	139907,11	78,17	70,76
0,20	0,14	141436,78	79,03	70,79
0,25	0,12	144304,06	80,63	70,34
0,30	0,10	146301,81	81,75	69,39
0,40	0,08	148902,70	83,20	66,73
0,50	0,06	150521,66	84,10	63,52
1,00	0,03	153899,88	85,99	44,82

Situazione ante intervento	
Indice di prestazione energetica ante intervento Epi [kWh/mq anno]	222,00
Fabbisogno energia primaria per climatizzazione invernale [kWh/anno]	306.878,00

Situazione post intervento	
Indice di prestazione energetica post intervento Epi [kWh/mq anno]	110,67
Fabbisogno energia primaria per climatizzazione invernale [kWh/anno]	152.978,12



Prestazione strato materiale isolante	
Lambda	0,033
Spessore	1,00
Rsi	0,13
Rse	0,04
Rt	30,473
U	0,033
Densita [kg/mc]	28,00

Performance ambientale	
Energia di stock EPS [MJ/kg]	96,10
Energia di stock strato isolante [kWh/mq]	747,44
Energia di stock limite teorico [kWh/mq]	2.077,12
Energia di stock limite reale [kWh/mq]	0,00

Costo unitario dell'intervento [€/mq]	44,82
Costo ambientale dello strato isolante [€/mq]	8,24
Costo ambientale totale dell'intervento [€]	12203,57