Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 133 (2017) 392–400

Energy Procedia

www.elsevier.com/locate/procedia

Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area, 12-13 May 2017, Matera, Italy

Historical buildings retrofit: the city hall of the city of Motta di Livenza (TV)

Alessandro Righi[a] *, Tiziano Dalla Mora[a], Fabio Peron[a], Piercarlo Romagnoni[a]

[a]*Department of Design and Planning in Complex Environments, University IUAV of Venice, IT*

Abstract

Issues related to energy saving, environmental sustainability and safety in case of seismic events are more and more the focus of attention of public opinion and the various actors of the construction sector. The Italian housing stock needs a strong energy adjustment, functional and seismic. The majority of buildings dating back to before the entry into force of the laws on energy saving of 1976 and first of the orders on the seismic design of 2003. The intervention on private buildings is favored by various financial systems and various facilities but to intervention on the public housing stock it is not easy. Most of the public buildings are identified as historical and therefore listed by the Superintendence of Cultural Heritage. Historical constraints, facades and fine decorations and inhomogeneity of the construction techniques and materials used make it very difficult to intervene in these buildings. The article will analyze a case study: the city hall of the municipality of Motta di Livenza (TV). This historic building, listed by the Super-intendent, has been subject to an energy audit that defines what are the best measures of energy efficiency and their economic sustainability. The search result will define which are the most cost-effective interventions to associate with the project of seismic improvement already underway. The case study is a real example of finding a balance between the need for seismic and energy intervention, constraints placed by the Superintendent, the data constraints by decorations and valuable items cannot be modified and the need for improvement of interior comfort.

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area

Keywords: Type your keywords here, separated by semicolons ;

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: alessandro.righi@iuav.it

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area
10.1016/j.egypro.2017.09.368

Issues related to energy saving, environmental sustainability and safety in case of seismic events are more and more the focus of attention of public opinion and the various stakeholders of the construction sector. The Italian housing stock needs a strong energy adjustment, functional and seismic. The European Community [1] has set the objectives of greenhouse gas emissions in the coming years, and in Italy to make it more interesting to intervene on private assets various tax breaks and incentives are been proposed in order to make buildings more energy efficient but also more secure, given the recent seismic events have demonstrated the inadequacy of the Italian building stock (in Molise in 2002, L'Aquila in 2009, Emilia in 2012). The majority of residential buildings [2] dating back to before the entry into force of the laws on energy saving of 1976 and first of the orders on the seismic de-sign of 2003. The intervention on private buildings is favoured by various financial incentives but the intervention on the public housing stock it is not easy: most of the public buildings are inadequate today, both in terms of energy and functional and above all seismic as built before the 70's; moreover many public buildings are identified as historical and therefore listed by the Superintendence of Cultural Heritage. In these cases, proposals for interventions in newer buildings energy intervention requirements and seismic standards are not achievable. Historical constraints, facades and fine decorations and inhomogeneity of the construction techniques and materials make very difficult to intervene in these buildings. The recipe must wrap it case by case basis and is not so obvious that we can intervene in a linear and complete fashion.

2. METHODOLOGY FOR ENERGY AUDIT

The methodology for the energy audit used in the building is composed of three parts: the analysis of the energy performance in the current situation, the analysis of energy performance ensured by the interventions and the economic evaluation of each intervention. The first analysis foresees a deepened inspection that detects all geometrical and performance characteristics of the existing building-system. Therefore, it is analyzed the geometry of the building, the orientation, the proximity to other buildings, the characteristics and thickness of the wall and floor, the type of doors and windows and the features of the heating and cooling plant. All the found characteristics are synthesized in a mathematic model showing the energy performance in the building. This model is calibrated with historical data of energy consumption obtained by bills. This model allows to verify how much each intervention influence the energy performance of the building. The interventions that could increase the energy performance are both in architectural envelope and system. The building could be give better improving the insulation of walls, floors, roof and the substitution of windows. The improvements in the plant performance could be obtained substituting the generator, insulating the distribution tube and improving the plant regulation. A great step to reducing electrical consumption in the buildings is to intervene on the efficiency of internal lighting and installing renewable energy source, moreover for not-residential building where electrical consumption is higher. The convenience of the intervention of energy performance improvement is evaluated based on a less time to save money in the bills that will cover the cost of the intervention. In the last years, the European State Members has incentivized the private sphere to achieve some interventions of building restoration offering economic facilitation and incentives. In Italy, over the economic facilitation dedicated to private, incentives to public administration are available, concerning both the intervention about the architectural building, but also the requalification of the system.

2.1. Geometric survey and mathematical model

The energy performance in the building depends on a lot of factors: the geometry, orientation, urban context, use of building and type of use. But it depends also on performance of the building and plant. It must be measured all these characteristics examining in depth the characteristics and thickness of the wall and floor, the type of doors and windows and the features of the heating and cooling plant. The inspections must observe every geometrical and performance features of the existing building-plant apparatus. All these information are synthesized in a mathematic model able to simulate the energy attitude in dynamic "capacity". Thank the use of the specific software is possible to analyze the energy performance compliance the applicable normative. For this operation, it is used EnergyPlus with the used of Design Builder as a graphic interface for making the energy simulation. To increase the goodness of the results in the mathematic model, it is equilibrated with the historic data of real consumption studied in energy bills. After building and equilibrating the mathematic model, it is possible to evaluate directly with the relatives precision which interventions are more incisive and convenient varying simply the starting mathematic model.

2.2.Interventions and cost optimal

Measures of interventions improving energy performances of buildings could be affect the envelope and also the systems. Interventions could be selected according to the characteristics of the buildings and the optimized measure is evaluated in terms of reduction of energy consumptions and global cost with reference in 30 years.

Various interventions on envelope could be considered. The insulation of walls with inside or outside application depends on the type of building. In the historic buildings it is usually not allowed to intervene on the outside due to the presence of decors or materials in view. Sometimes it is possible not intervene even inside so it must be intervene with very high performance ant to much expensive materials to reduce the thick-ness of intervention. The insulation of coverage is widespread but it depends on the type of situation. Often intervention could be applied on outside insulating the roof, but the much more performant intervention, although not always possible, consists on the insulation of the last slab closest to the heated space, often resulting in the attic. The re-placement of windows and doors is very important especially if real situation presents metallic and/or single glazing frames. The substitution of windows and doors is not al-ways possible especially in historic buildings. The historic value of the frames does not allow to replace them and then often it is possible to restore them and replace the single glazing with double glazing. Often it is not allowed to place a triple glazing as too thick than thinner frame of historical windows. An intervention on the system component in an historic building is quite complicated, because of the plants are often very ancient, the tubes sometimes are under very delicate floors and the presence of decorations does not allow a proper heat distribution net. The most simple interventions concerns the generator replacement. The replacement of old lighting with energy efficient lighting is very important and cost-efficient. The change to new types of lighting especially for the uses non-residential represent a tricky phase as it could result in an increase and a change of the position of the lamps. Furthermore the use of renewable sources such as photovoltaic is very convenient especially on non-residential buildings where power consumption is much higher. The installation of these technologies, however, is very delicate and in the case of historic building it requires a very careful integration and visual impact.

The evaluation of these kind of interventions could be simulated and evaluated using the previously described mathematical model. The assessment is based on the comparison of energy consumption and costs of the building at the current situation with a list of measures of interventions. The optimal will be the package that allows to further reduce the energy consumption at a less global cost.

2.2.1 The Energy Performance Assessment

The energy performance is fully described by the indicators EPtot performance, expressed as the building global primary energy demand (EP,gl) divided by the conditioned area. The global primary energy refers to all the EPBD energy services (heating, cooling, DHW, ventilation, lighting) and it is calculated according to the standard ISO/DIS 52000-1:2015[3]. The calculation concerns first of all the energy need for heating and cooling by means of the quasi-steady state numerical model of the Italian technical specification UNI/TS 11300-1, which implements the international standard EN ISO 13790:2008 [4]. As well, the delivered energy is calculated by means of the Italian technical specification UNI/TS 11300 series [5], which implements the European standards EN 15316 series [6] and EN 15243:2007 [7]. The energy demand for lighting is calculated by means of the EN 15193:2007 standard [8].

2.2.2. The global cost calculation

The Commission Delegated Regulation No. 244/2012 [9] requires the evaluation of the cost optimal level at a financial and at a macroeconomic level. In the first case the methodology based the calculation on the overall costs, considering the initial in-vestment, the sum of the annual costs for each year (energy, maintenance, operation and any additional costs), the extraordinary replacement of systems and components, the final value, and the costs of disposal, as appropriate. All costs are actualized to the starting year. In the macroeconomic approach, the costs corresponding to the CO2 emissions are also considered. In this study the financial perspective calculation is applied, considering also national subsidies. The financing framework methodology is based on the net present value (global costs, GC) calculation, carried out according to standard EN 15459:2007 [10], which provides a method for considering the economic aspects related to the application of heating systems and other technical systems and envelope components that affect the energy consumption of the building.

2.2.3. The Cost Optimal Approach

The study adopted a cost optimal methodology to calculate the optimal levels of minimum energy performance requirements.

The energy cost optimization procedure evaluates different energy efficiency measures, each one with a different number of options that identify a level of thermal insulation , described by specific costs and by relevant performance parameters, such as the thermal transmittance according to benchmarks on Conto Termico 2.0 regulation (DM 16/02/16) [11][12]. Among all the considered packages of intervention, the optimization process allows to identify the measure characterized by the lowest global cost within the calculation period.

2.3. Incentive

In recent years European countries have encouraged the private sector to improve the energy efficiency of their properties by offering tax breaks or incentives. In Italy various kind of incentives have been created including the tax advantages of 50% and 65% and the Conto Termico 2.0. The tax breaks allow to have in 10 annual instalments repayment up to 50% and up to 65% of the intervention made thanks to a discount on fees. These incentives are available for both private individuals and companies but cannot be used by public authorities. The statement Thermal now at version 2.0 is an incentive directed to the Public Administration and in part also to private.

Table I - Typology of interventions with incentives for private and public sector according to Conto Termico 2.0

Typology of interventions with incentives for admitted entity		
Art. 4.1 a)	Insulation of opaque vertical closures	**Public Administration**
	Insulation of the upper horizontal opaque closures	
	Insulation of the lower horizontal opaque closures	
Art. 4.1 b)	Replacement of transparent closures and simultaneous installation of thermostatic valves	
Art. 4.1 c)	Installation of heat generator condensing	
Art. 4.1 d)	Installation of screening systems and / or fixed shading, also integrated, or mobile	
	Installation of automatic mechanisms of regulation and control of the shields	
Art. 4.1 e)	Transformation of existing buildings into "nearly zero energy buildings nZEB"	
Art. 4.1 f)	Replacement of lighting fixtures including lamps for indoor lighting and outdoor appliances - Installation of highly efficient or LED lamps	
Art. 4.1 g)	Installation of building automation technologies	
Art. 4.2 a)	Replacement of existing heat generators with heat pumps	**Private and Public Administration**
Art. 4.2 b)	Replacement of existing heat generators with biomass generators	
Art. 4.2 c)	Thermal solar installation and solar cooling	
Art. 4.2 d)	Installation of water heaters with heat pump	
Art. 4.2 e) / f)	Replacement of existing plants with winter heating hybrid heat pump	

This incentive is compatible with many types of intervention is building envelope that the system efficiency. The contributions are not given simply so a percentage of total expenditure, as with tax deductions, but according to the particular formulas and figures in any case does not exceed a limit unit cost. Any intervention must also submit to the particular minimum requirements that indicate the minimum services to be guaranteed to deliver the contribution. There are also rewarding or compensation that take into account both the geographical location of the intervention is combined on the envelope and the system. In detail the actions admitted to contribute are listed in Table I.

3. APPLICATION OF RETROFITTING: CASE STUDY

The analysed case study is the municipal building of Motta di Livenza (TV) in the northeast of Italy. It's an historic building is and was built before 1800. The building is collocated downtown in central square and it was applied plenty of interventions be-tween 1700 and 1980 that modified and amplified the structure unifying more buildings that were initially independent. This building presents two main meaning: in reference to its public function it's identified as a strategic example with the intent of a seismic safe-ty evaluation, but also it is listed by heritage superintendence due to its historic and testimonial value. The building consisted in four floors: the ground floor is occupied by economic activity and a great entrance hall to the building, the first and second floor occupied by to public office and the third floor designated for archive and under roof (Table II).

Table II - Municipal building in Motta di Livenza characteristics

Site	**Motta di Livenza (TV)**
Altitude	15 m a.s.l.
Heating degree days	2347 HDD
Climate zone	E
Net Conditioned Building Area	905,14 m^2
Dispersion Surface	1102,02 m^2
Total Volume	3892,09 m^3
Compactness ratio (S/V)	0,28 m^2/m^3

The building was built with external walls modified in the past but never insulated, the roof slab is composed by not insulated solid concrete, the internal floor is differently composed (strong concrete or wooden with beams in the different typologies of material: wood, steel, concrete) and the retaining walls are not insulated. The windows are historic and present wooden frame with insulated glazing, except some windows with single glaze (Table III).

Table III - Characteristics of selected parameters in the existent building

Element	**Description**	**Thermal Transmittance**
Wall	Brickwall with parget. No insulation.	U = 1.336 $W/m^2 K$
Window	Double-glazed windows with wooden frame with thermal bridge.	U = 2.715 $W/m^2 K$
	Single-glazed windows with wooden frame with thermal bridge.	U = 5.801$W/m^2 K$
Ground floor	Cast concrete on gravel basement with pavement. No insulation.	U = 2.022 $W/m^2 K$
Attic floor	Wooden floor with screed and pavement. No insulation.	U = 0.201 $W/m^2 K$
Roof (flat)	Concrete slab with bituminous membrane. No insulation.	U = 1.501 $W/m^2 K$
Roof pitched	Not insulated wooden roof.	U = 0.684 $W/m^2 K$

The internal lighting is composed with neon lamps or with single lamps. The heat-ing system is assembled by two outdated boilers working with natural gas, not insulated piping in view, zone regulation and fan coils emission in the main area and radiators in the office zones. The summer conditioning is currently provided by the single spits for some areas. Both the systems, heating and conditioning, present faults giving discomfort for the workers and occupants. The building doesn't present any renewable energy source. The town's administration effectuated an energy audit to evaluate the possible implementations in order to improve comfort and also to evaluate the more convenient package of measures of intervention for reduction the energy consumptions.

3.1. Energy Audit And Cost Optimal

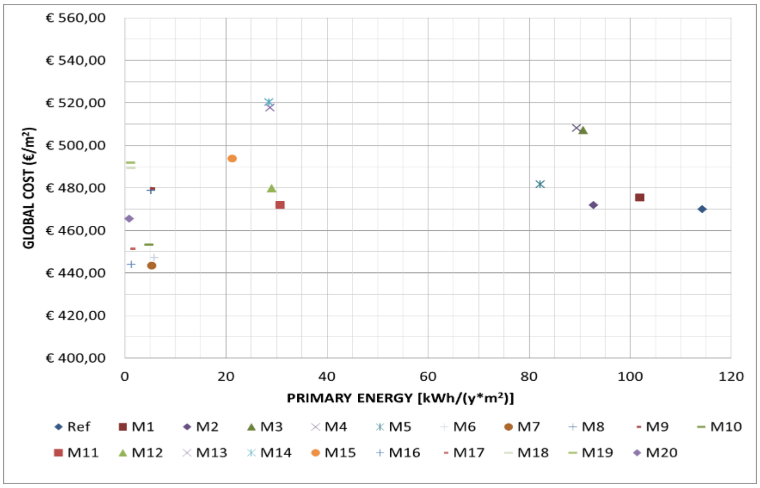
An energy audit has evaluated the energy attitude of the municipal building in Motta di Livenza (TV). Once the information about the geometry of the building and the thermic characteristics of the components is collected through inspections and analysis, a mathematic model of the building's plant was developed. The next step consisted to calibrate the model with real consumption of the energy bills. The last step consisted of simulating the energy performance obtained by different energy improvement interventions. The packages of simulated interventions are described according to the mini-mal requirement Conto Termico 2.0 regulation for each technical components (Table IV).

Table IV - Definition of intervention on the building; the measures consider the replacing of existent heat generator with a condensing boiler (a) and an high efficiency air-water heat pump (b).

Measure of intervention	**Measure (a)**	**Measure (b)**
Insulation on roof (U=0,20 W/m^{2}K)	M1	M11
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K)	M2	M12
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + substitutions of external windows (U=1,50 W/m^{2}K)	M3	M13
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + substitutions of windows (U=1,50 W/m^{2}K) + basement insulation (U=0,25 W/m^{2}K)	M4	M14
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + substitutions of external windows (U=1,50 W/m^{2}K) + insulation of basement (U=0,25 W/m^{2}K) + substitution of lighting with led	M5	M15
Insulation on roof (U=0,20 W/m^{2}K) + photovoltaic system	M6	M16
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + photovoltaic system	M7	M17
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + substitutions of external windows (U=1,50 W/m^{2}K) + photovoltaic system	M8	M18
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + substitutions of external windows (U=1,50 W/m^{2}K) + insulation of basement (U=0,25 W/m^{2}K) + photovoltaic system	M9	M19
Insulation on roof (U=0,20 W/m^{2}K) + insulation on walls (inside U=0,23 W/m^{2}K) + substitutions of external windows (U=1,50 W/m^{2}K) + insulation of basement (U=0,25 W/m^{2}K) + substitution of lighting with led + PV system	M10	M20

All the interventions are proposed according to incentives in Conto Termico 2.0 previously described. The comparison between energy performances and economic evaluation of singular intervention, allows to choose the best intervention at minor cost. The analyses is developed with and without application of incentives.

Figure 1- Output for interventions without incentive



The state of art has an annual heating needs equal to 114,26 kWh/m2y and a yearly cost of maintenance equal to 458,14 euro/m2. The analysis allows to individuate easily the best energy improvement's intervention. Without considering the incentives, the best ratio between intervention's cost and energy performance of the intervention, in comparison with the current situation (Reference), is shown in the intervention M16 that includes the insulation of roof, the installation of photovoltaic panels and the substitution of existing heating boiler with an electrical heat pump air-water. The global cost decreases to 451,13 €/m2 in relation with a great reduction of consumption, 1,26 kWh/m2y. The second best intervention without counting the incentives is the M6. This intervention includes the insulation of roof, the installation of photovoltaic panels and the substitution of existing heating boiler with a condensing boiler working with natural gas. The global cost decreases to 458,17 €/m2 in relation with a great reduction of consumption 5,83 kWh/m2y. Calculating also the incentives, the intervention more convenient doesn't change, remaining M16. The global cost decreases equal to 443,81 €/m2 with a consumption reduction equal to 1,26 kWh/m2y.

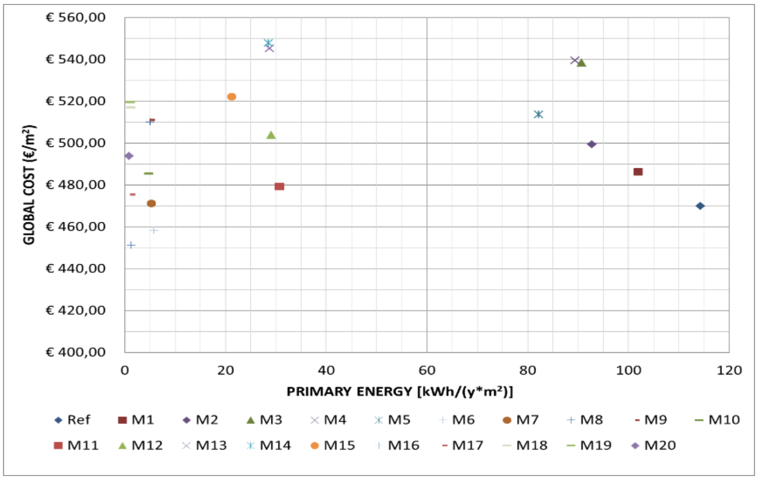


Figure 2 - Output for interventions without incentive

3.2. Structural (re)design and energy audit

During the development of the energy audit, the building has been the subject of seismic intervention. The project, still currently under way, had aims the improvement of the static and seismic performances. This very invasive intervention has consolidated the foundations with infiltration of special resins into the ground, consolidating the first and second floor with beams in xlam and rods in addition to consolidating the cover with the replacement of some wood pieces and reworking the roof. Due to the poor sealing of the walls it was also necessary to intervene on the consolidation of the carriers of masonry plugging with a cage of reinforcing fibers and structural plaster for the entire height of the building. This action caused the removal of all existing systems even if not originally planned: heating system, cooling system, electrical system and computer sys-tem.

This new layout of the building shows how the M16 is still more convenient be-cause the general intervention on the cover has already been provided by the structural intervention and therefore the insulation of the cover and the installation of a photovoltaic system in tiles is not much more invasive and more expensive than the already planned structural (re)design. As regards the installations, in addition to the new more efficient proposed type of generator, the structural intervention also provides for the complete overhaul of the entire isolated distribution, compatible for both heating and cooling, more efficient and correctly dimensioned fan coils, and a new control system.

The existing situation presented problems of poor efficiency of the distribution due to old not isolated pipes but also inefficiencies with part of adjustment and emission due to old and under-sized fan. This intervention, not originally planned by the energy audit, will increase the energy performance of the building. As regards the other analyzed interventions, in addition to being cost effective, it would be difficult to propose and feasible: the insulation of the walls in a historic building is not possible on the outside of the façade due to decoration presence, also inside because of the discovery of some frescoes are listed by the Superintendence. The replacement of windows is very difficult by the presence of antique frames: only the substitution of a single glass and the renovation of the original frame are allowed. The insulation of basement is very difficult: historical floors often cannot be removed and the problematic structural condition of the foundations of this type of buildings is overshadowing this need.

The energy efficiency project of the Municipality of Motta di Livenza (TV) consists of the following measures: insulation of the roof, the installation of a photovoltaic system to tiles compatible with the demands of the Superintendent, revamping the distribution block, adjustment and emission by means of fan coils with adjustment on the machine in addition to the replacement of obsolete boilers with high-efficiency heat pumps. In addition to this series of interventions the town council has also opted for the replacement of all indoor lighting with LED lamps.

4. CONCLUSIONS

The research provides a methodology of analysis for the identification of the best facilitated interventions of energy efficiency of buildings. The article shows how this method is effective even in cases of historical buildings and monuments. In this type of buildings the fact prepackaged intervention recipes cannot be taken into account be-cause there are many variables that influence in addition to the energy performance al-so the static behavior of the structure and the historicity of the decorations. It is shown that the proposed interventions, even if not completely integrated into structural (re)design ongoing, responded in each case to the optimal point. The integration of these interventions makes it even more convenient these non-invasive interventions. In the historical buildings in fact the energy efficiency cannot be based on invasive intervetions, as in other types of buildings, unless there is an integration with other types of treatment such as that static or historical value. The methodology is therefore also applicable to historic buildings and consequently to all other types of building. The methodology of analysis allows to compare very detailed analysis in a highly intuitive simplified mode. It's also possible to improve this analysis with other types of energy-saving intervention analyzed both in single form that in compound form.

ACKNOLEDGEMENTS

The authors would like to thank the Municipal Administration of Motta di Livenza (TV) for the availability of documents and data about the building.

REFERENCES

[1] European Parliament, Directive 2012/27/UE of The European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and2006/32/EC, Official Journal of the European Union 55, 2012, 1–56.
[2] Statistiche Istat. Censimento popolazione istat. 2016. Available at: http://dati-censimentopopolazione.istat.it/index.aspx. Accessed January, 2017
[3] International Organization for Standardization (ISO). ISO/DIS 52000-1:2015. Energy performance of buildings - Overarching EPB assessment - Part 1: General framework and procedures.
[4] European Committee for Standardization (CEN). EN ISO 13790:2008. Energy performance of buildings - Calculation of energy use for space heating and cooling; 2008.
[5] Italian Organisation for Stardardisation (UNI). UNI/TS 11300 (series). Energy performance of buildings; 2010-2016.
[6] European Committee for Standardization (CEN). EN 15316 (series). Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies; 2007-2011.
[7] European Committee for Standardization (CEN). EN 15243:2007. Ventilation for buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems; 2007.
[8] European Committee for Standardization (CEN). EN 15193:2007. Energy performance of buildings - Energy requirements for lighting; 2007.
[9] European Union. Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council. Official Journal of the European Union, 21 March 2012.
[10] European Committee for Standardization (CEN). EN 15459:2007. Energy performance of buildings - Economic evaluation procedure for energy systems in buildings; 2007.
[11] Decreto Interministeriale 16 febbraio 2016. (2016, gennaio). Aggiornamento Conto Termico. http://www.gazzettaufficiale.it/eli/id/2016/03/02/16A01548/sg
[12] http://www.gse.it/it/Conto%20Termico/Conto%20Termico%202.0/Pagine/default.aspx