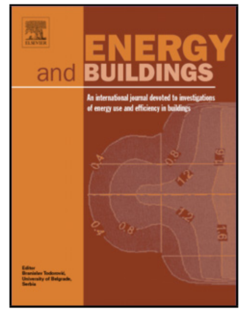
Accepted Manuscript



Title: A PARAMETRIC METHOD TO ASSESS THE ENERGY PERFORMANCE OF THE SOCIAL HOUSING STOCK AND SIMULATE SUITABLE RETROFIT SCENARIOS: AN ITALIAN CASE STUDY

Author: Vittorino Belpoliti Giacomo Bizzarri

PII: S0378-7788(15)00209-1
DOI: http://dx.doi.org/doi:10.1016/j.enbuild.2015.03.017
Reference: ENB 5750

To appear in: *ENB*

Received date: 27-9-2014
Revised date: 19-2-2015
Accepted date: 6-3-2015

Please cite this article as: V. Belpoliti, G. Bizzarri, A PARAMETRIC METHOD TO ASSESS THE ENERGY PERFORMANCE OF THE SOCIAL HOUSING STOCK AND SIMULATE SUITABLE RETROFIT SCENARIOS: AN ITALIAN CASE STUDY, *Energy and Buildings* (2015), http://dx.doi.org/10.1016/j.enbuild.2015.03.017

A PARAMETRIC METHOD TO ASSESS THE ENERGY PERFORMANCE OF THE SOCIAL HOUSING STOCK AND SIMULATE SUITABLE RETROFIT SCENARIOS: AN ITALIAN CASE STUDY

Vittorino Belpoliti[a] , Giacomo Bizzarri[a]

[a] Research Centre Architettura Energia, Department of Architecture, University of Ferrara
via Della Ghiara 36, 44121, Ferrara, Italy
vittorino.belpoliti@unife.it - giacomo.bizzarri@unife.it

CORRESPONDING AUTHOR:

Vittorino Belpoliti, arch. Ph.D.

Research Centre Architettura>Energia
Department of Architecture - University of Ferrara
M.Sc. Architecture - Ph.D. in Energy Technologies

e-mail: vittorino.belpoliti@unife.it

address: via Della Ghiara 36, 44121, Italy

telephone: +39 0532 293604

mobile: +39 4098360

ABSTRACT

A deep three-years survey of the existing social housing stock in Emilia Romagna, Italy, has been completed helping to accomplish a full acknowledgement of more than 70 buildings in terms of both their envelopes and heating system characteristics. Analysing the outcome data, a simplified parametric calculation protocol has been created to operate a preliminary audit and energy retrofit simulation on the entire social housing stock of the Region.

The results of the study, initial data about the energy state-of-the-art of the building cluster and feasible retrofit solutions, are useful to identify where to focus for a further and more accurate energy diagnosis.

This paper represents a synthesis of a three-years research work, demonstrating the potential of the parametric assessment method in terms of evaluating environmental and energy benefits, deriving from scheduled retrofit actions, to assist technicians in endeavouring interventions priority.

KEYWORDS Energy retrofit; energy efficiency; social housing; CO_2 emissions; energy assessment methods; parametric analysis; bottom-up.

1 INTRODUCTION

Nowadays, energy is among the principal factors of the social and economic development of our society, dealing with important issues of present times, such as politics and the environment.

The access to an efficient infrastructure system and the distribution of quality services for the end users is the key action in order to pursue a competitive development of the territory. The intense research and technological development, strongly endorsed by public-private partnerships, allows for the access to new resources and new forms of energy, promotes the diffusion of high efficiency and low environmental impact plants and systems, and sets the base for the growth of new enterprises and job activities.

The buildings energy performance improvement, especially regarding the public dwellings, is among the actions that should be pursued to reach the Kyoto and Copenhagen goals.

Such consideration is hereby developed in relation to the social housing stock managed by ACER (Social Housing Agency of the Region Emilia Romagna, Italy), assumed as case studies for the three-years research study, summarized in this paper.

2 ROLE OF THE SOCIAL HOUSING IN THE ENERGY CONSUMPTION OF THE REGION EMILIA ROMAGNA, ITALY

In the Region Emilia Romagna (Italy), the residential building sector is responsible for 19.5% (31.6% industry, 48% transportation, 17,1% agriculture, 3,1% services) of the total energy demand (source: ENEA [1, 2]). Within this sector, the energy consumption is divided as follows: 70% for heating system (in relation to social-housing it is mostly heating and it seldom concerns cooling), 10% DHW production, 14% electrical lighting and appliances, and 6% for kitchen use. Such energy consumption could be dramatically reduced introducing Building Codes addressed to energy efficient design for new construction and energy retrofit measures for the existing stock. In this scenario, the necessity of defining effective energy policies for the social housing becomes essential to effectively reduce Carbon emission in atmosphere.

Due to the difficulty in pursuing a complete energy assessment of the entire residential sector of the Region Emilia Romagna, but overall because it would be nearly impossible to schedule broad energy-retrofit strategies with a private ownership, the study has focused on the social housing stock, entirely managed by public (or semi-public) subjects. A detailed survey, assisted by the district social housing agencies (each Province/District of the Region Emilia Romagna has its own agency), and combined with the indication issued by ISTAT [3] allowed to quantify the social housing properties owned or managed by ACER at Regional level, accounting for 58,395 dwelling units.

The study moves from the broad literature regarding rating methodology to assess energy performances in residential buildings, with particular focus on the statistical approaches [4, 5, 6, 7], and applies it to the delimited case study of the social housing of the Region Emilia Romagna. Furthermore, the research proposes suitable actions to improve it. The reduction of the buildings energy demand and carbon emission was pursued through the application of three subsequent energy retrofit packages: primary retrofit of the heating system; refurbishment actions to increase the energy performance of the building envelope (in order to meet the minimum energy level, in accordance to the Regional Regulation 156/2008 [8]); best practice scenario, combination of the two above (especially improving the envelope to a further level, with the aim of achieving high energy performances).

Hence, the research is limited to the analysis of the retrofit actions that allow for an optimization of the sole buildings demand of thermal energy for winter heating. No intervention has been accounted regarding the demand of electricity, supposing it is conventionally provided by the National grid, which is characterized by standard efficiency (data by literature). The reason for such limitation is also to be found in the recommendation of the National legislation, currently requiring the sole calculation of winter energy consumption as a mean to define the global energy performance of a residential building. Moreover, the present study concerns the existing building cluster, and more precisely it focuses only on edifices built before the approval of the Regional Regulation on buildings energy efficiency (endorsement of Regional Regulation 156/2008), assumed as the threshold for a consistent improvement in energy efficiencies for new constructions.

3 OBJECTIVES OF THE STUDY AND METHODOLOGIES

The main objective of the study is to accomplish a preliminary energy performance audit of the social housing stock of the Region Emilia Romagna, and test on it several energy retrofit actions, in order target which situations (individual buildings, housing complexes, or large urban clusters) show the best result in terms of cost/benefit ratio. This procedure will help Social-Housing Agencies identifying where to pursue more accurate analysis, helping them optimizing time and economic recourses.

Such objective can be achieved thanks to a newly elaborated energy audit parametric protocol: surveying only few data, it is capable of providing energy performance results for each building belonging to the social housing stock. The protocol also associates to the energy outcomes three energy retrofit actions, to test their effect on the buildings.

The elaboration of the new energy audit protocol, targeted on the social housing of the Region Emilia Romagna, was based on a bottom-up methodology:

- Identification of enough case studies (different from each other for dimensions, typology, morphology, and technological features) to describe the whole Regional social housing stock (70 buildings have been selected for such purpose);
- Energy analysis of the above 70 case studies, using several calculation methods;
- Identification, thanks to the above analysis, of the characteristics/factors/parameters that mostly influence the social housing energy performance. Therefore, identification of the factors that influence it the least, and can be turned into constant values;

- Elaboration of the new protocol by simplification of the calculation method UNI TS 11300, parts 1 and 2 [9], accounting for the above-mentioned factors;

In the following phase of the research, the result of the bottom-up approach have been extended to the broader Regional stock through a statistical approach:

- Assembly of data set of the whole Region taken from the Regional ACER database;
- Application of the elaborated calculation protocol to the extended Regional social housing stock.

4 SELECTION OF CASE STUDIES AND ENERGY ANALYSIS USING DIFFERENT CALCULATION METHODS

As mentioned before, to pursue a bottom-up approach, few case studies need to be selected and deeply analysed. 70 buildings, chosen for their differences in date of construction, dimensions, shape, technology, heating system, and number of dwelling units, have been selected among the social housing stock managed by ACER Reggio Emilia and ACER Ferrara (Figure 1).

A full energy diagnosis has been tracked for each case study. To accurately highlight the typological and technological issues that mostly influence the energy performance in social housing, different calculation methods have been used, from a more approximated to a more detailed one:

- Comparisons method, associating the case studies to previously analysed buildings;
- So-called “real” energy consumption (data collection from previous energy bills);
- Mean steady-state analytical calculation;
- Dynamic-state analytical calculation.

The result-shift between the methods is not the central focus of this paper, however it is relevant to stress what more accurate studies have highlighted [10]: significant differences could be found in the outcomes of the different calculation methodologies; up to 30% shift between results obtained with dynamic-state calculation and steady-state one, which is the methodology currently recommended by the Italian legislation for buildings energy certification. Corresponding studies [11] have also demonstrated how such stringent assessment methods, originally made for a specific geographical/climatic situation, show evident critical issues in applying to other scenarios. Given the above considerations, no energy assessment tool can today be considered suitable for all situations. The presented research starts from these uncertainties to justify the elaboration of a novel energy analysis method. Such calculation protocol would explicitly be a more approximated analysis instrument, and it would only be applicable to a targeted building cluster: the social housing of the Region Emilia Romagna. The necessary approximation in the calculation method has been achieved by excluding certain common-parameters, *i.e.* typological factors (similar in social housing) or climatic characteristics (homogeneous for the geographical Region), which allowed turning calculation variables into constant. The resulting parametric energy evaluation protocol aims to become a preliminary tool for technicians to run first-level urban analysis, in order to target specific clusters that require further examination (by using more complex and detailed systems, *i.e.* dynamic-state calculation method).

For the National and Regional legislation (Legislative Decree 192/2005 and following modifications [12], Regional Regulation 156/2008 and following modifications) the reference value of a building energy performance is the EP_{gl}, the "global Energy Performance index" expressed in kWh/m^2 year; it is achievable through a mean steady-state calculation contained in the norms UNI TS 11300 and displayed in the Energy Performance Certificate (EPC). Such methodology has been identified as benchmark for the necessary simplification carried on through the research.

This introduction sets the boundary conditions for the bottom-up analysis framework: from particular to general, the deep and detailed investigation on the 70 case-studies has helped identifying critical issues and common parameters, which were required to simplify the analytical calculation and to elaborate the parametric protocol.

APPROXIMATE POSITION OF FIGURE 1

5 IDENTIFICATION OF BASIC FACTORS AND CLASSIFICATION OF THE BUILDINGS

The accurate multi-analysis carried on the 70 case studies have highlighted few characteristics that have been recognized as peculiar to the building's energy performance, and therefore cannot be discarded while simplifying the calculation. Typological and technological factors where found being responsible for energy lacks. Research projects concerning this topic (IEE project TABULA [13] and related studies [14, 15]) have pointed out three main groups of characteristics that influence buildings energy performance: climatic conditions, typological and technological factors.

Given the intentionally preliminary nature of the study, more approximations where required.

Due to the common location of each surveyed building or apartment of the social housing stock (in Emilia Romagna, the majority of them are located within the urban area of the cities), the climatic conditions have been considered a constant value in the analysis.

The deep survey on the Regional social housing stock has highlighted the typological similarities at apartment level: buildings might change significantly in dimensions and number of units, but individual apartments are very similar in relation to energy expenses, usually having only one or two walls exposed outside (and therefore causing thermal loss due to transmission through the envelope); it has been estimated that the area of the envelope responsible for thermal loss, is proportional to the apartment floor net area (averagely about 70 m^2).

Basic technological factors (construction technology and heating system type) where found being the age of the building (which relates to development in construction and insulation level), and the age and type of the heating system (connected to potential decrease in the devices' efficiency). More specifically, they have been outlined and described as follows:

- Heating system typology (central system, individual system, district heating): different heating systems are characterized by different appliances, such as distribution sub-system (vertical or horizontal main piping system) and emission sub-system (radiators, fan-coils or other devices), and therefore can have different thermal efficiencies;
- Construction year: before or after 1991. In 1991 the Italian Government approved the National Law 10/1991 [16], among the first prescribing a minimum energy performance level for new constructions; therefore, year 1991 has been assumed the threshold for more efficient constructions. It has been observed that older buildings are characterized by higher transmittance U-values of both opaque and transparent components of the envelope. Moreover, 1991 also means obsolete heating systems components, such as the distribution sub-system (system's pipes), which could be depicted by low efficiency.

It is recalled that the present study only applies to constructions built before 2008, endorsement year of the Regional Regulation 156/2008 (it is the application of the National Legislative Decree 192/2005, itself the Italian endorsement of the Directive 2002/91/EC [17]). Between 1991 and 2008, no other legislation have influenced the building energy efficiency, so there was no need to identify any intermediate threshold-year, preventing the study from becoming unnecessarily complex.

• Year of substitution or major refurbishment of the heating system: before or after 1995, considering the life of a boiler about 20 years long (elapsed that time, the device thermal efficiency would decrease and its replacement would be required).

Through the combination of the three basic factors, 10 building categories can be generated. The categories derive form the 70 case studies, but any other building belonging to the Regional social housing stock can lead back to one of them. Similar studies [18] have highlighted how such classification according to relevant characteristics is required in dealing with large numbers of buildings.

Table 1 shows the description of the 10 categories and the number of units per Regional Districts belonging to each of them: total data have been collected accessing the Regional ACER database, while the classification according to *year of construction, heating-system type* and *installation* has been calculated for Reggio Emilia then parameterized to the remaining Districts; the quantification of the exact number of units connected to each local district-heating by 2008 for each Province was allowed by the deep on-field survey for Reggio Emilia, and thanks to personal communications for the other Districts [19-26].

APPROXIMATE POSITION OF TABLE 1

6 REGIONAL BASELINE SCENARIO: THE PARAMETRIC CALCULATION PROTOCOL

As comprehensible, thanks to the description above, the classification and the following energy analysis had to tolerate a certain degree of approximation, because of the difficulty to precisely evaluate a numerous building stock characterized by high heterogeneity of building units.

Given the above research boundaries and tolerance, ACER Reggio Emilia [27] has played a fundamental and pioneering role in the elaboration of a simplified calculation protocol that bases the energy assessment on a statistical method, a successful experience previously tested on even larger urban clusters [28]. This tool, coherent to the National and Regional legislation regarding buildings energy efficiency, guaranteed the technological and energy assessment of several case studies, and the creation of a database to collect all the surveyed information. Such record has been useful to operate a transposition of the results to the entire Regional social housing building stock, and further on, it helped evaluating the energy performance improvement, CO_2 emission reductions and the cost and payback time related to three different retrofit simulations.

The parametric protocol bases its energy calculation (for both state-of-the-art and retrofit scenarios) on the UNI TS 11300 regulation body, simplified accounting for the basic factors described in paragraph 5, as the outcome of the bottom-up analysis. Correlated researches [6, 29] have demonstrated pros and cons of bottom-up statistical techniques to model energy consumption of large building clusters, pointing out the importance of stating the results error gap in compare to a reference value [30], in this case, the one shown in the EPC. Running the 70 cases studies through the parametric protocol, it could be observed a EP_{gl} shift ranging from -10% to +30% in compare to the EPC value. Such error gap has to be taken into account carefully. However, given the research limitation, the parametric protocol can provide a useful outcome for a preliminary analysis. The aim of elaborating a parametric calculation protocol was to ease the energy audit activity carried by the technicians of the Regional Social Housing Agency, and to provide them with a preliminary result of targeted energy retrofit actions. The protocol calculates the energy performance (EP_{gl}) of a building by surveying a restricted amount of data. A technician could easily bring the system along while going through a regular building survey, also accomplishing an energy audit.

6.1 Energy performance

The EP_{gl} virtually produced for each surveyed construction do not consist of a precise value, since it is generated as a parameterisation from a multitude of case studies; however, averaged to the results of other buildings belonging to the same category, it provides a preliminary evaluation of the Regional energy level. Table 2 shows the baseline energy performance resulting from the parameterization process, as well as the energy classification according to the national legislation.

APPROXIMATE POSITION OF TABLE 2

Moreover, these results can be used to define refurbishment guidelines to increase the buildings energy performance. For the buildings belonging to one specific category, it is suggest a targeted retrofit action: as an example, the retrofit of group A.1.1 (building construction year before 1991; heating system installed before 1995) will consider the application of an insulating coating on the envelope and the replacement of the heating system. Paragraph 7 describes the energy retrofit guidelines followed by the present study.

6.2 Carbon emission profile

To parametrically calculate the Regional Carbon emission profile, referring to a previous study [31] a further sub-classification was elaborated according to fuel-kind employed by the different energy end-users. Due to the difficulty in collecting such information for each District of the Region, data where only gathered for Reggio Emilia (Energy Plan of the Municipality of Reggio Emilia [32]), then parameterized to the remaining Districts. Four groups of thermal energy end-users characterize the social housing:

Group NG: natural-gas boilers end-users represent 92.5% of the entire share, spread among all the categories of table 1, excluding C.1 and C.2 (district-heating); Group LPG: Liquid Petroleum Gas boiler end-users, accounting for 1.0%, (entirely found in category A.1.1); Group DO: Diesel Oil boiler end-users, accounting for 1.5%, (entirely found in category A.1.1); Group DH: district-heating end-users for the residual 5% (the entire categories C.1 and C.2).

Each group has been further sub-divided according to the *heating system substitution or major refurbishment year* parameter, since older systems can perform worse than newly installed ones. Finally, thermal efficiency values have been attributed to each sub-group by averaging the ones of the 70 case studies (Tab. 3).

APPROXIMATE POSITION OF TABLE 3

The following paragraphs describe how crossing data of the building energy performances (Tab. 2) and of the heating system efficiencies (Tab. 3) the CO_2 emissions-related energy balance has been evaluated.

Given this energy balance, the related emission scenario has been determined in reference to the forecast of CO_2 emissions published by UNFCCC, by the Directive 2004-156-EC [33], by the database of APAT, the national data-transmission centre for atmosphere, climate and emissions [34], and by the literature reference [35]. The conversion factors are shown in table 4.

APPROXIMATE POSITION OF TABLE 4

6.2.1 Group NG: natural gas end-users

This group accounts for the most of the share. Since building construction year and heating system installation year ranges significantly, it has been necessary to provide a simplified approach.

As defined above, group NG has been further divided in NG.1, for which it has been assumed the installation of a heating system before 1995, and therefore characterized by an average thermal efficiency of 85%; group NG.2 is defined by units with a more recent heating device (after 1995), characterized by an average thermal efficiency of 88% (Tab. 3).

Assuming a 70 m^2 average unit, the total amount of apartments belonging to Group NG.1 = 38,499, the average EP_{gl} for the groups NG.1 and NG.2 (Tab. 3), and the related emission factor (Tab. 4), the baseline emissions scenario has been evaluated equal to 161,870,970 kg CO_2/year.

The same calculation has been carried on for the 15,528 units of group NG.2: the CO_2 emissions result is equal to 48,13,590 kg CO_2/year.

The total amount of yearly CO_2 emissions for group NG is 210,001,560 kg CO_2/year.

6.2.2 Group LPG: Liquid Petroleum Gas end-users

This group is relatively marginal and entirely contained in category A.1.1 (Tab. 1). Its heating systems are characterized by an average thermal efficiency of 82% (Tab. 3).

Given the 70 m^2 average unit, the total amount of apartments belonging to Group LPG = 554, the characteristic average EP_{gl} (Tab. 3) and the emission factors (Tab. 4), the baseline CO_2 emissions scenario has been evaluated equal to 2,617,650 kg CO_2/year.

6.2.3 Group DO: Diesel Oil end-users

The calculation for this group is similar to the previous one. The group's heating systems are characterized by an average thermal efficiency of 80% (Tab. 3).

Given the 70 m^2 average unit, the total amount of apartments belonging to Group LPG = 873, the characteristic average EP_{gl} (Tab. 3) and the emission factors (Tab. 4), the baseline CO_2 emissions scenario has been evaluated equal to 4,916,244 kg CO_2/year.

6.2.4 Group DH: district heating end-users

The evaluation of the carbon emission factor for group DH has been particularly complex due to the heterogeneous technologies producing thermal energy for the different district heating nets. Two large operators produce thermal energy through district heating for social housing in the Region: Gruppo Iren – Iren Emilia [36], operating for the provinces of Piacenza, Parma, and Reggio Emilia; and Gruppo Hera [37], active in Modena, Bologna, Ferrara, Forlì-Cesena, and Ravenna. As recalled in table 1, not all provinces have social housing connected to the district.

To this regard, carbon emission for the heterogeneous group DH has been calculated for Reggio Emilia, according to the data posted online by Iren [38] and thanks to previous studies that outlined the composition of the local district heating system [32, 39], and for the other provinces (Modena, Bologna, Ferrara, Forlì-Cesena, and Ravenna) by cross-referencing the detailed information posted online by Hera [37, 40].

In Reggio Emilia, the district heating system is fed by three CHP plants and three natural gas-fired thermal plants. Hence, each power plant is identified by its own technological characteristics (*i.e.* different efficiencies, size, emissions, possibility of combined heat and power).

Therefore it has been defined a procedure capable of a comprehensive evaluation of the energy balance and the net emission scenario.

In this case, three main references have been considered for this scope: three personal communications from Enìa [41], the local thermal energy provider, a study on the environmental impact of the new combined cycle plant [42], and a report on the activities of Enìa [43] for the years 2007-2010.

The main difficulty in evaluating the GHG emissions of the district heating system has been balancing the diverse forms of primary energy that produce thermal energy in this heterogeneous scenario.

Given the complexity of the calculation this paper only reports the results, referring to previous studies (Bizzarri G. [39]) for further details on the analytic procedure.

Table 5 shows all the CO_2 emission factors for the interested districts.

The total baseline CO_2 emissions for Group DH has been estimated by multiplying the number of units per each district (Tab. 1) by 70 m^2 (average unit net area), by the the related EP_{gl} (Tab. 2), and by the emission factor (Tab. 5). The result is around 6,322,881 kg CO_2/year.

<u>APPROXIMATE POSITION OF TABLE 5</u>

6.2.5 global CO_2 emission baseline scenario

Finally, the global emission scenario related to the social-housing of the Italian Region Emilia Romagna, characterized by an heterogeneous energy performance index (EP_{gl}), ranging from 300 to 150 kWh/m^2 year (Table 2), has been estimated around 223,858,335 kg CO_2/year.

7 ENERGY RETROFIT STRATEGIES

At last, energy retrofit actions have been simulated on the Regional social housing stock.

The operations to improve energy efficiency of the buildings have been grouped in three levels.

Primary actions concern what is minimally required to refurbish an average building: heating system refurbishment, replacement of single-pane windows with double-pane ones. The decision of not employing more efficient measures (such as triple-pane windows, for instance) is mainly economical: "social" housing still means low-rent dwelling units. Moreover, it is estimated that the first level of retrofit requires an initial investment that coincides with the current budget of the Regional Social Housing Agency (ACER).

Secondary actions mainly concern the energy retrofit of the building envelope, especially regarding the improvement of its insulation capacity; in this case two increasing steps of insulation levels have been evaluated: considering buildings of different age, the oldest require more insulation (construction built before 1991 did not fulfil the requirements of the National Law 10/1991, which prescribed a minimum insulation level for new constructions), while more recent ones are characterized by a more efficient technology, with a little insulation material within the envelope layers.

The study reaches preliminary results, approximating to only two degrees of insulation (8 cm- or 16 cm-thick insulating panels), and a single material (XPS, extruded expanded polystyrene). Further research will focus on other insulation products and variation of thickness.

The Best Class scenario (third step) combines the most performing among primary and secondary actions.

The three levels of retrofit actions are described in table 6, showing details about the specific performance improvement.

APPROXIMATE POSITION OF TABLE 6

The preliminary payback period of the retrofit scenarios for each category has been evaluated matching the following calculated data:

- Starting investment cost related to the efficiency improvement measures;
- Annual energy saving, calculated as subtraction of pre- and post-retrofit energy cost;

Regional building material price lists and personal communications from local producers have been used to pursue the economic analysis. For the study, no National incentive concerning energy efficiency improvement has been considered.

7.1 Scenario 1: primary actions

Scenario 1 assumes the sole application of primary actions, including the refurbishment of the heating system and the substitution of the single-pane windows. It does not assure the achievement of the minimum energy performance required by the Regulation 156/2008 of the Region Emilia Romagna, but it represents an affordable option for ACER.

Assuming the amount of building as per the classification of table 1, primary actions grant a new average EP_{gl} of 164 kWh/m^2 year, improved of about 39.5% from the state-of-the-art situation. As a consequence, Carbon emissions could decrease to 135,434,300 kg CO_2/year. The initial economic investment on each building requiring the refurbishment can be considered sustainable, and its payback period is averagely about 8 years (Tab. 7), considering current charges for thermal and electrical energy for domestic use (source: AEEG [44, 45].

APPROXIMATE POSITION OF TABLE 7

7.2 Scenario 2: secondary actions

The secondary retrofit scenario involves the refurbishment of the building envelope, particularly focusing on increasing its insulating performance. The classification elaborated as a result of the data collected by the Social Housing Agencies, in regard to year of construction (Tab. 1), has been used to define the suitable insulation panel for each building: 8 cm or 16 cm thickness.

The objective of the secondary actions was to define an intermediate energy retrofit step, between the primary and the Best Class scenario, in order the whole Regional social housing stock to meet the Local energy codes requirements.

Finally, the new scenario reduces the energy consumption of 48.7%, showing a new average EP_{gl} of 138 kWh/m^2 year. Consequently, the estimation of the new CO_2 emissions is 114,839,330 kg/year, and the pay-back period of the investment averagely 17 years, a period which denotes economic unsustainability without the access to specific Governmental financial aids (Tab. 8).

APPROXIMATE POSITION OF TABLE 8

7.3 Scenario 3: Best Practice. Maximization of the energy performance

The last Scenario simulates the application of the most performing of both the primary and secondary actions. The operation allows reducing the EP_{gl} to an average 70 kWh/m^2 year, as a consequence of a 73.6% reduction of the energy consumption as well as of the Carbon emissions in atmosphere (decreasing to 59,098,600 kg CO_2/year.).

However, the lack of a consistent financial-aid policy in the Country does not allow ACER, as well as other public administrator, investing on these high-performance measures. In fact, payback period for scenario 3 has been calculated around 21 years (Tab. 9).

It can be concluded that the last scenario is not very far (regarding money investment) from the second one. This makes it evident how the first scenario becomes fundamental for ACER's affordability.

APPROXIMATE POSITION OF TABLE 9

8 CONCLUSIONS

This paper represents the final report of a three-years research project, elaborated in cooperation with the Social Housing Agency of the Region Emilia Romagna and ACER Reggio Emilia, aiming at exploring the benefits of a massive intervention to increase the energy performance of the whole Regional social housing cluster.

A deep state-of-the-art evaluation of the existing building stock and the collection of data related to the Regional social housing has been accomplished.

After the elaboration of a parametric method to ease the processing of such a large amount of data, the energy balances and the carbon emission profiles have been computed.

Once delineated the baseline scenario, three increasing levels of energy improvement have been simulated.

It can be concluded that the minimum energy retrofit scenario can be considered the only affordable by the Regional Social Housing Agency: the retrofit typology, which consists of replacing the heating system and the single-pane windows with double-pane ones, is characterized by a sustainable cost/benefits ratio, ensuring a 39.5% reduction of energy consumption and CO_2 emissions, against a 8 years economic pay-back period.

The achieved results have been possible thanks to the parametric protocol, which has helped speeding up the calculations. The elaborated calculation method, lately turned into a simple application running on mobile devices, does not substitute the existing ones, but it serves the primary assessment of building clusters, identifying where to pursue more accurate analysis, therefore helping the Social-Housing Agency in optimizing the work of its technicians, steering energy retrofit interventions effectiveness.

ACKNOWLEDGEMENTS

ACER Reggio Emilia has financed the research and made available its housing stock, archive and previously surveyed data.

REFERENCES

[1] ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development). Available online: http://old.enea.it/com/ingl/ (accessed on 9 February 2015).

[2] Catoni P. G, Iorio G. (2011). ENEA. Statistiche energetiche regionali 1988-2008. Emilia-Romagna.

[3] ISTAT. Available online: http://www.istat.it (accessed on 26 July 2013).

[4] Ballarini I., Corrado V. (2009) Application of energy rating methods to the existing building stock: Analysis of some residential buildings in Turin. Energy and Buildings, 41, 790-800.

[5] Fracastoro G.V., Serraino M. (2011) A methodology for assessing the energy performance of large scale building stocks and possible applications. Energy and Buildings, 43, 844–852.

[6] Kavgic M., Mavrogianni A., Mumovic D., Summerfield A., Stevanovic Z., Djurovic-Petrovic M. (2010) A review of bottom-up building stock models for energy consumption in the residential sector. Building and Environment, 45, 1683-1697.

[7] Reilly D., Duffy A., Conlon M., Willis D. (2013) Development and implementation of a simplified residential energy asset rating model. Energy and Buildings, 65, 159-166.

[8] Emilia Romagna Legislative Assembly Deliberation: D.A.L. 156/2008, Modify by DGR 1362/2011 and DGR 1366/2011Atto di Indirizzo e Coordinamento Sui Requisiti di Rendimento Energetico e Sulle Procedure di Certificazione Energetica Degli Edifici. Available online: http://demetra.regione.emilia-romagna.it/al/monitor.php?urn=er:assemblealegislativa:delibera: 2008;156 (accessed on 9 February 2015).

[9] Standard UNI TS 11300 parte 1 Energy Performance of Buildings - Part 1 Calculation of Energy Use for Space Heating and Cooling; UNI TS 11300 Parte 2 Energy Performance of Buildings - Part 2 Calculation of Energy Primary and Energy Performance for Heating Plant and Domestic Hot Water Production. Available online: http://11300.cti2000.it/ (accessed on 9 February 2015).

[10] Tronchin L., Fabbri K. (2010). A Round Robin Test for Buildings Energy Performance in Italy. Energy and Buildings. 42, 1862-1877.

[11] Schiano-Phan R., Ford B., Gillott M., Rodrigues L. T. (2008). The Passivhaus standard in the UK: Is it desirable? Is it achievable? Proceedings of PLEA 2008 – 25th Conference on Passive and Low Energy Architecture, Dublin, 22nd to 24th October 2008.

[12] Legislative decree 19 august 2005, n. 192. Enhancement of the Directive 2002/91/CE related to the energy performance of buildings. Available online: http://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2005;192 (accessed on 9 February 2015).

[13] IEE founded project TABULA “Typology Approach for Building Stock Energy Assessment” (2009-2012). Available online: http://episcope.eu/iee-project/tabula/ (accessed on 9 February 2015).

[14] Ballarini I., Corgnati S.P., Corrado V., Talà N. (2011) Improving energy modelling of large building stock through the development of archetype buildings. Proceeding of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association, Sydney, 14-15 November, pp. 2874-2880.

[15] Dascalaki E.G., Droutsa K.G., Balaras C.A., Kontoyiannidis S. (2011) Building typologies as a tool for assessing the energy performance of residential buildings - A case study for the Hellenic building stock. Energy and Buildings, 43, 3400-3409.

[16] National law 9 January 1991, n. 10. Rules for the accomplishment of the National Energy Plan in relation to the rational use of energy, energy saving and improvement of renewable energy sources. Available online: http://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1991-01-09;10!vig= (accessed on 9 February 2015).

[17] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. Available online: http://www.dfpni.gov.uk/eu_directive-3.pdf (accessed on 9 February 2015).

[18] Zimmermann M., Althaus H. J., Haas A. (2005). Benchmarks for sustainable construction. A contribution to develop a standard. Energy and Buildings, 37, 1147-1157.

[19] ACER Piacenza, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 8 February 2015.

[20] ACER Parma, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 8 February 2015.

[21] ACER Modena, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 8 February 2015.

[22] ACER Ferrara, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 8 February 2015.

[23] ACER Forlì-Cesena, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 8 February 2015.

[24] ACER Ravenna, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 9 February 2015.

[25] ACER Rimini, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 9 February 2015.

[26] ACER Bologna, Precise number of managed units connected to the local district-heating system by 2008. Personal Communications, 13 February 2015.

[27] ACER Reggio Emilia. Social Housing Agency of the Region Emilia Romagna, Italy – chapter of Reggio Emilia. Available online: http://www.acer.re.it (accessed on 9 February 2015).

[28] Chen S., Li N., Guan J., Xie Y., Sun F., Ni J. (2008). A statistical method to investigate national energy consumption in the residential building sector of China. Energy and Buildings, 40, 654-665.

[29] Swan L.G., Ugursal V.I. (2009) Modeling of end-use energy consumption in the residential sector: a review of modeling techniques. Renewable and Sustainable Energy Reviews, 13, 1819–1835.

[30] Fabbri K. (2013) Planning a Regional Energy System in Association with the Creation of Energy Performance Certificates (EPCs), Statistical Analysis and Energy Efficiency Measures: An Italian Case Study. Buildings, 3, 545-569.

[31] Bizzarri G., Belpoliti V., Pratissoli A., Pastore P., Bottarelli M. (2008). Potential in GHG emissions abatement through an effective energy policy: the Reggio Emilia case. Proceedings of the international conference WIT 2008, WIT Press, Skiathos.

[32] Bizzarri G. (2009), Piano Energetico Comune di Reggio Emilia. Reggio Emilia, first ed., Consulta C.P.3 Editor, Reggio Emilia.

[33] Directive 2004-156-CE 1 January 2005, Attachment A, Emission Factors for Greenhouse Gas National Inventories UNFCCC.

[34] APAT, National Telematic Centre for Athmosphere, Climate, and Emissions. Available online: http://www.inventaria.sinanet.apat.it/macrosettori.php (accessed on 9 February 2015).

[35] Battisti R. (2001). Evaluation of national climate change policies in EU member states - Country report on Italy, Ecofys.

[36] Gurppo Iren – Iren Emilia. Available online: http://www.irenemilia.it (accessed on 9 February 2015).

[37] Gruppo Hera. Available online: http://www.gruppohera.it (accessed on 9 February 2015).

[38] Iren Ambiente. Available online: http://www.irenambiente.it/attivita.php?id=138 (accessed on 9 February 2015).

[39] Bizzarri G. (2011). Local energy policies for Kyoto goals: Ecoabita protocol a key action to reduce energy consumption in residential sector. Energy and Buildings, 43, 2394–2403.

[40] Gruppo Hera. Carta della qualità del servizio teleriscaldamento. Un'opportunità per l'uso razionale dell'energia. (2011). Available online:

http://www.gruppohera.it/binary/hr_clienti/casa_teleriscaldamento_servizio/CARTA_DEI_SERVIZI_TLR_2012.1328190073.pdf (accessed on 9 February 2015).

[41] Enìa S.p.A., Thermal energy provided to end-users in the reference years 2007-2010. Personal Communications, 15 May 2007, 30 August 2007, 4 June 2010.

[42] Iren, "Sustainability Report" Project Group, Barilli M., Durante D., Gaudi M., Grillo M., Pellegrini L., Scarrone M. C., Tucci F. (2004). Report on the environmental and energy impact of the new 55MWe turbogas plant in the Municipality of Reggio Emilia. Ideal Comunicazione, Torino.

[43] Enìa. Perspective for the district heating net in Reggio Emilia (2006).

[44] AEEG Authority for Electrical Energy and Gas. Available online: http://www.autorita.energia.it/it/index.htm (accessed on 9 February 2015).

[45] AEEG Authority for Electrical Energy and Gas. (2010). Annual report on the state of the services and the activities. Rome.

HIGHLIGHTS

- We survey the whole social housing stock of the Province of Reggio Emilia, Italy
- We analyse the energy performance of 70 buildings with different characteristics
- We simulate energy retrofit scenarios on the 70 case studies
- We extract data from the above results and build an energy assessment protocol
- We apply the parametric protocol onto the whole Regional social housing heritage

Figure 1 Pictures showing the 70 buildings selected, among the social housing stock of ACER Reggio Emilia and Ferrara, for the bottom-up analysis.

BUILDING CATEGORIES				UNITS PER DISTRICT OF THE REGION EMILIA ROMAGNA									TOTAL UNITS PER CATEGORY	%
CODE	HEATING SYSTEM	YEAR OF CONSTRUCTION	HEATING SYSTEM INSTALLATION OR MAJOR REFURBISHMENT	PIACENZA	PARMA	REGGIO EMILIA	MODENA	BOLOGNA	FERRARA	RAVENNA	FORLi CESENA	RIMINI		
A.1.1	Central	Before 1991	Before 1995	706	1404	920	1527	3833	1497	1040	980	515	**12422**	**21,3**
A.1.2	Central	Before 1991	After 1995	295	586	384	637	1600	625	434	409	215	**5185**	**8,9**
A.2.1	Central	After 1991	Before 1995	45	90	59	98	246	96	67	63	33	**797**	**1,4**
A.2.2	Central	After 1991	After 1995	19	38	25	42	104	41	28	27	14	**338**	**0,6**
B.1.1	Individual	Before 1991	Before 1995	1427	2836	1859	3086	7745	3025	2101	1980	1042	**25101**	**43,0**
B.1.2	Individual	Before 1991	After 1995	535	1063	697	1157	2904	1134	788	742	391	**9411**	**16,1**
B.2.1	Individual	After 1991	Before 1995	91	182	119	198	496	194	134	127	67	**1607**	**2,8**
B.2.2	Individual	After 1991	After 1995	34	67	44	73	183	72	50	47	25	**594**	**1,0**
C.1	District heating	Before 1991		0	0	526	154	1957	54	45	25	0	**2762**	**4,7**
C.2	District heating	After 1991		0	0	34	10	127	4	3	2	0	**179**	**0,3**
TOTAL UNITS PER DISTRICT				3152	6266	4667	6982	19194	6742	4689	4402	2301	**58395**	**100**

Table 1 Total Regional social housing units managed by each District and shared in the 10 categories: the division accounts for the three basic factors.

BUILDING CATEGORIES	AVERAGE BASELINE EP_{gl}	STATE-OF-THE-ART ENERGY CLASS
	kWh/m² year	in accordance to Regulation 156/08, Region Emilia Romagna
A.1.1	300	Class F - G
A.1.2	220	Class E - G
A.2.1	190	Class E
A.2.2	150	Class D - E
B.1.1	300	Class F - G
B.1.2	220	Class E - G
B.2.1	190	Class E
B.2.2	150	Class D - E
C.1	200	Class E - F
C.2	150	Class D - E

Table 2 State-of-the-art building energy performance; the table shows the estimated values of EP_{gl} and the related Energy Class for each category.

FUEL GROUP / BUILDING CATEGORIES	NG Natural Gas: NG.1 boiler installed before 1995	NG Natural Gas: NG.2 boiler installed after 1995	LPG Liquid Petroleum Gas	DO Diesel Oil	DH District heating	TOTALS	BASELINE EP_{gl} * [kWh/m^2 year]
A.1.1	10995		554	873		12422	300
A.1.2		5185				5185	220
A.2.1	797					797	190
A.2.2		338				338	150
B.1.1	25101					25101	300
B.1.2		9411				9411	220
B.2.1	1607					1607	190
B.2.2		594				594	150
C.1					2762	2762	200
C.2					179	179	150
TOTAL UNITS per fuel group	38499	15528	554	873	2941	58395	
Units Percentage per fuel group	65,9	26,6	1,0	1,5	5,0	100	
System-related thermal efficiency	85	88	82	80	various		
AVERAGE EP_{gl} wighted on units number per category [kWh/m^2 year]	293	216	300	300	various**		

* according to table 2

** due to the difference in carbon emission factor of each district heating, the calculation ha assumed EP_{gl} as per table 2

Table 3. Fuel group-related EP_{gl} by matching building categories and fuel-type employed by end-users.

	CO_2 emission factor [kg/MWh]	Oxidation / conversion factor	Net calorific value
			kWh/sm^3
Natural gas	205	0,995	9811,00
			GJ/t
Liquid petroleum gas	225	0,990	46,15
Diesel oil	268	0,990	42,62

Table 4 Fuel CO_2 emission factors and net calorific value.

DISTRICTS	Yearly CO_2 emissions [Mg]	Thermal energy provided yearly to end-users [GWh]	CO_2 emission factor [kg/MWh]
Reggio Emilia	69.080	248	113,0
Bologna	56.531	333	169,8
Ferrara	6.948	188	37,0
Forlì-Cesena	14.624	38	384,8
Modena	4.796	38	126,2
Ravenna	863	5	172,6
Totale	83.762	602	139,1

Table 5 District heating thermal energy production and CO_2 emission factor per Province.

Actions	Levels			Improvement to energy performance	Reference calculation value [refernce measurement unit]
	Primary actions	Secondary actions	Best Class actions		
Replacement of old heating system with high-efficient boiler	√			Improvement to Production Sub-system efficiency	η = 0,95 [%]
Replacement of old heating system with condensation boiler			√	Improvement to Production Sub-system efficiency	η = 1,07 [%]
Installation of thermostatic valves	√		√	Improvement to Emission Sub-system efficiency	η = 0,97 [%]
Reflective panels on radiators backside	√				
Refurbishment of radiators (cleaning procedure and components replacemtent)	√				
Replacement of old or non-functioning radiators	√		√		
Installation of the heat-accounting system	√		√	Reduction of fuel consumption due to increased awareness of end-users	/
Substitution of single-pane windows with double-pane ones	√		√	Improvement to windows U-value (to reach the minimum standard for Regional Regulation 156/08)	U = 2,2 [W/m^2K]
Roof insulation with 8 cm of XPS		√		Improvement to roof U-value (to reach the minimum standard for Regional Regulation 156/08)	U = 0,30 [W/m^2K]
or **Roof insulation with 16 cm of XPS**		√	√	Improvement to roof U-value (to reach higher levels of energy efficiency)	U = 0,16 [W/m^2K]
Walls insulation with 8 cm of XPS		√		Improvement to walls U-value (to reach the minimum standard for Regional Regulation 156/08)	U = 0,34 [W/m^2K]
or **Walls insulation with 16 cm of XPS**		√	√	Improvement to walls U-value (to reach higher levels of energy efficiency)	U = 0,18 [W/m^2K]

Table 6 Detailed checklist of energy retrofit levels: selection of targeted action for three different retrofit scenarios; technological building components improvement and reference calculation value for each action.

SCENARIO 1: PRIMARY ACTIONS				
BUILDING CATEGORIES	**AVERAGE ENERGY CONSUMPTION REDUCTION**	**AVERAGE PAYBACK TIME**	**SCENARIO 1 AVERAGE EP_{gl}**	**SCENARIO 1 ENERGY CLASS**
	%	Years	kWh/m² year	in accordance to Regulation 156/08, Region Emilia Romagna, Italy
A.1.1	40	8	250 - 130	Class E - F
A.1.2	34	8	< 150	Class D - F
A.2.1	35	6,5	< 130	Class D
A.2.2	27	7	< 110	Class C
B.1.1	43	8	240 - 120	Class E - F
B.1.2	34	8	< 150	Class D - F
B.2.1	35	6,5	< 130	Class D
B.2.2	33	7	< 100	Class C
C.1	20	6,5	< 170	Class D - E
C.2	13	5	< 130	Class C - D

Table 7 Energy retrofit actions and energy balance for Scenario 1: the table shows reduced energy consumption and CO_2 emissions in compare to baseline scenario; new EP_{gl} values and related pay-back time have been calculated.

SCENARIO 2: SECENDARY ACTIONS				
BUILDING CATEGORIES	**AVERAGE ENERGY CONSUMPTION REDUCTION**	**AVERAGE PAY-BACK TIME**	**SCENARIO 2 AVERAGE EP_{gl}**	**SCENARIO 2 ENERGY CLASS**
	%	Years	kWh/m² year	in accordance to Regulation 156/08, Region Emilia Romagna, Italy
A.1.1	50	18	200 - 100	Class C - D
A.1.2	50	18	< 110	Class C - D
A.2.1	30	11	< 140	Class B - C
A.2.2	30	11	< 100	Class B
B.1.1	50	18	200 - 100	Class C - D
B.1.2	50	18	< 110	Class C - D
B.2.1	30	11	< 140	Class B - C
B.2.2	30	11	< 100	Class B
C.1	50	18	< 100	Class B - C
C.2	30	11	< 100	Class B

Table 8 Energy retrofit actions and energy balance for Scenario 2: the table shows further reduction of energy consumption and CO_2 emissions in compare to baseline scenario; new EP_{gl} values and related pay-back time have been calculated.

SCENARIO 3: BEST PRACTICE				
BUILDING CATEGORIES	**AVERAGE ENERGY CONSUMPTION REDUCTION**	**AVERAGE PAY-BACK TIME**	**SCENARIO 3 AVERAGE EP_{gl}**	**SCENARIO 3 ENERGY CLASS**
	%	Years	kWh/m^2 year	in accordance to Regulation 156/08, Region Emilia Romagna, Italy
A.1.1	76	23	90 - 50	Class B - C
A.1.2	70	23	< 70	Class B
A.2.1	65	15	< 70	Class A - B
A.2.2	60	15	< 60	Class A
B.1.1	76	22	90 - 50	Class B - C
B.1.2	70	21	< 70	Class B
B.2.1	65	15	< 70	Class A - B
B.2.2	60	14	< 60	Class A
C.1	71	22	< 60	Class A - B
C.2	67	14	< 50	Class A

Table 9 Energy retrofit actions and energy balance for Scenario 3: the table shows high reduction of energy consumption and CO_2 emissions in compare to baseline scenario; new EP_{gl} values and related pay-back time have been calculated.

Figure 1 (B-W)