Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Energy and Buildings xxx (2007) xxx–xxx
ENERGY and BUILDINGS
www.elsevier.com/locate/enbuild

Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation

Lamberto Tronchin *, Kristian Fabbri

DIENCA-CIARM, University of Bologna, Viale Risorgimento 2, I-40136 Bologna, Italy

Received 17 July 2007; received in revised form 3 October 2007; accepted 9 October 2007

Abstract

The European Community introduced the energy certificate of buildings to reduce the energy consumption in buildings and emanated some standards in order to publicize the energy buildings certificate procedure. Consequently, to calculate energy performance of buildings (EPB), many numerical codes have been developed, which take into account several parameters in static or dynamic conditions.

In this article three different models for EPB software calculations have been analysed and compared, in order to quantify their gap with the real energy consumptions. The study has been conducted considering a single-family house in Italy, and focused the differences among numerical codes and real consumption in relation with flexible architectural solutions, that are widely utilised especially in rural areas in Mediterranean countries.

Keywords: Energy performance of buildings; Software simulation; Energy certificate; Energy consumption; Operating and calculated energy ratings

1. Introduction

The evaluation of energy performance of buildings (EPB) depends on several factors, which are related with local climate contest.

In northern Europe the climate is cold during the most part of the year and the evaluation of EPB depends on energy heating dispersions. In those countries the project of buildings' technical solutions requires to strongly insulate the wrapped and the frames, and to capture the solar energy throughout frames and wall-accumulation (solar passive solution—''*Trombe* wall'').

In southern countries, where climate is hot and dry, the buildings' technical solutions requires to subtract overheating by means of wind-passive ventilation, cooling plants and taking advantages of thermal inertia of wall.

Nevertheless, in the Mediterranean area the climate is not too cold or too hot to justify neither of the aforementioned approaches of the buildings technical solutions. In these countries it is necessary to use flexible solutions, which could change depending on climate conditions. As a result, the historical architecture typology and rural buildings in these countries have some flexible architectural elements such as porch, court, patio, frame with shutter, and so on.

The building construction technologies developed during XX century does not take into account the energy behaviour. Only recent standards, as EN 832 [1], which follows an approach developed in northern countries, have introduced the obligation of winter insulation. The same approach has been used in Mediterranean area countries with reduces size of insulation.

The constructive technologies after 1950 have reduced the thermal inertia of the buildings wrapped and structure and reduced the wall thickness. The heating plants supply the heating of buildings and the wall insulation, which are not resolved with insulation materials.

After the energy crisis in 1973 and climate change policies during 1980 the EU have produced a series of standards until the EN 832.

In the same period the society had an economy increase. This economic growth created a modification of the comfort indoor perception and satisfaction. People need comfort indoor during all year: in winter and in summer season. These factors have contributed to diffusion of cooling plants and split systems in residential and other buildings.

* Corresponding author. Tel.: +39 051 2093281; fax: +39 051 2093296.
E-mail address: tronchin@ciarm.ing.unibo.it (L. Tronchin).

0378-7788/$ – see front matter
doi:10.1016/j.enbuild.2007.10.012

All this factors cause the increase of energy consumption in buildings sector, especially in the Mediterranean area country where the energy is expended during winter to heating and during summer to cooling.

The European Community estimates that more than 40% of EU energy consumption depends on buildings. The EU legislation and normative have emanated the 91/2002/Directive ''Energy Performance of Buildings Directive'' (EPBD) [2], to reduce this consumption. The technical normative linked with EPBD are being developing by C.E.N. and they are called CEN-Umbrella [3].

The EPBD introduces the obligation of energy certification of buildings, and in EPBD Annex it includes all energy consumption in buildings. The approach is similar than the energy label used in household-electric sector with a graduated energy performance scale (A excellent performance, G bad performance).

The CEN-Umbrella includes a revision of EN 832 and EN 13790 and the introduction of an overall energy evaluation, i.e.

- energy need and energy used during winter and summer for heating, cooling and ventilation;
- domestic hot water production (DHW);
- electrical energy.

2. The importance of building energy mode simulation

In this context the software and models of EPB calculation are more important to evaluate the EPB and they could contribute to find the best solution to increase energy efficiency.

The calculation model should guarantee the ''globality'' and the uniformity of energy performance evaluation: ''globality'' in reference to overall energy consumptions, and uniformity respect to different countries and local climate conditions.

The simulation should guarantee, for new and existing buildings, the correspondence between calculated and real energy consumptions by bills. In case of matching between real and calculated energy, the building' user could control the building energy efficiency.

The buildings energy certificate is similar than household-electric certification. Nevertheless, in buildings the verification between real and calculated energy consumption has more variable factors, which make complex the evaluation. These variables depend on the building geometry and materials, the local climate and seasonal variation, the habit of users, the DHW consumption, the lighting use, and so on. All these variables are not comparable and standardizable.

3. Application at detached house building (one family)

In this paper two different models of simulation are used. Both models have been compared with the real energy consumption by bills. The results would not be representative of all buildings but just for this case.

Fig. 1. The case study: view of the single-family house in the local context.

The simulation has been carried out on a detached house building (one family), in the Mediterranean area, in centre of Italy [Fig. 1]. The buildings have one ground floor and basement, four people compose the family, and the energy bills are referred to three previous years.

The buildings have a concrete structure and the wall in bricklayer with insulation inside; the frames are in PVC with double glass. This building has been selected since it is separated to other buildings.

4. The calculation models of simulation: standards reference and software

The calculation models here used are:

- Method A: evaluation to *effective* energy consumption by energy bills of three previous years. The evaluation is based on the CEN-Umbrella prEN 15603 clause 7 [4];
- Method B: evaluation based on the CEN-Umbrella: prEN 15217, prEN 13790 [5], and prEN 15316-x standards [Figs. 2–4];
- Method C: evaluation based on the EN 832 (actually in force) and the Italian law recommendations [6].

4.1. Method A

The first method is based on the real energy consumption by bills (gas and electricity). The average values of gas and electricity consumption, reported in bills, are converted in primary energy by means of a primary energy factor related to different energy carriers. The CEN standard prEN 15603 clause 7, ''Measured Energy Ratings'', which evaluates the average of energy value of bills during a period of 3 years, has been used for this simulation.

4.2. Method B

The second method here utilised follows the CEN standard: prEN 13790, prEN 15603 and related normative regarding plant systems. The simulation has been carried out by means of the

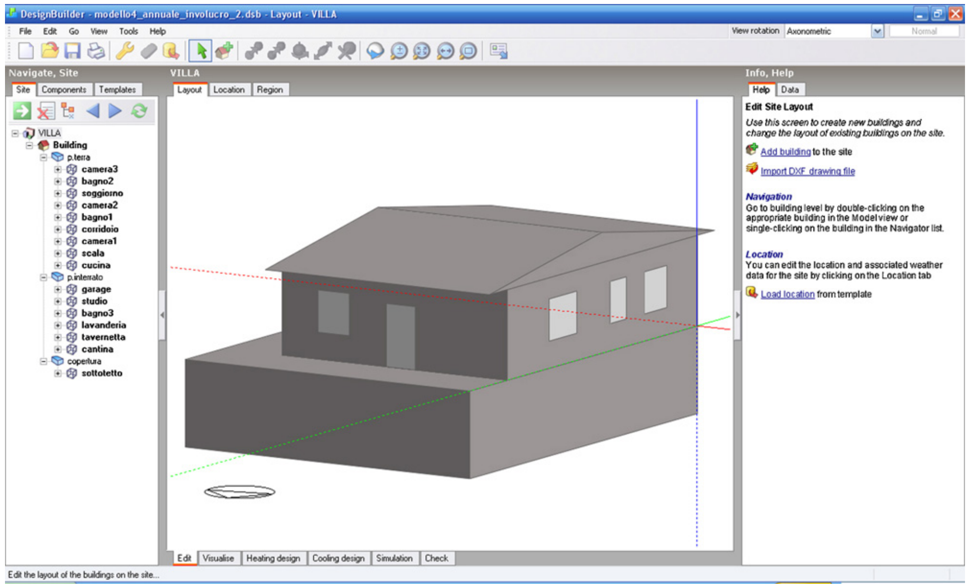

Fig. 2. DesignBuilder simulation.

software ‘‘DesignBuilder’’[7]. It is based on the software EnergyPlus, implemented with a 3D interface and meteorological database.

DesignBuilder represents useful software, because of his user-friendly interface, meteorological database, and sophisticated model to evaluate energy supply for internal and solar energy supply. This software allows the dynamic evaluation of heating and cooling consumption during all seasons, including DHW and other energy consumption. It also allows knowing the average temperature indoor and surface temperature during all the year.

DesignBuilder does not perfectly correspond with ‘‘CEN-Umbrella working progress’’; with reference to CEN standard, it needs updates regarding combustible coefficients and factors and the renewable energy sources.

4.3. Method C

The third method is referred to the UNI EN 832 standard, prEN 13790 and the ‘‘CTI Recommendation R03/3’’ (CTI Italian Thermo-technical Committee is the Italian normative organism about energy and plant with CEN mirror group). The R03/3 represents a simplified evaluation of energy performance of buildings. This method has been developed in order to simplify the evaluation allowing an acceptable confidence interval. Therefore, it does not have a dynamic simulation and the data-input are simplified.

This method has been implemented into the software called ‘‘BestClass’’ [8]. It is used by Province of Milan and developed by Milan Polytechnic. This software estimates the energy consumption during winter season for heating and DHW.

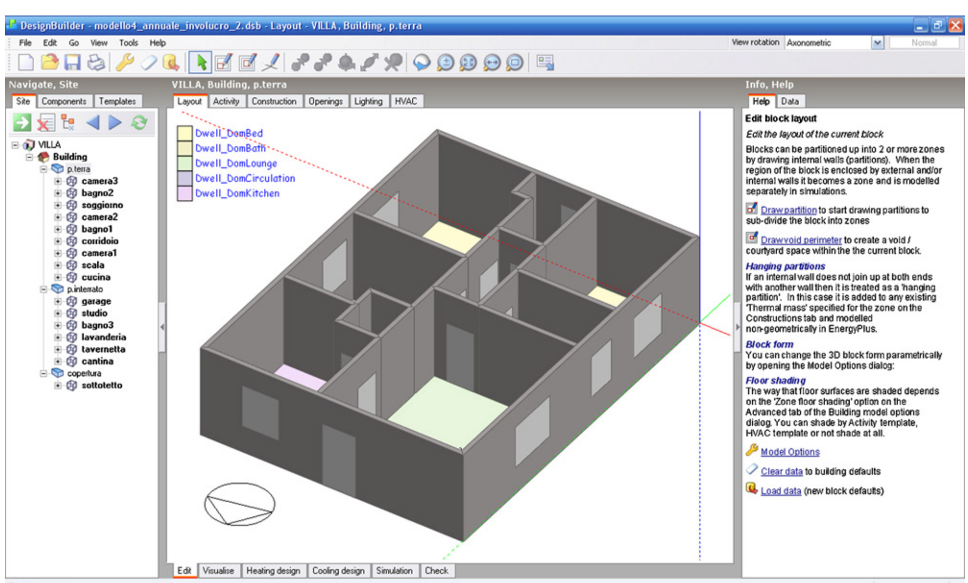

Fig. 3. DesignBuilder simulation: ground-floor.

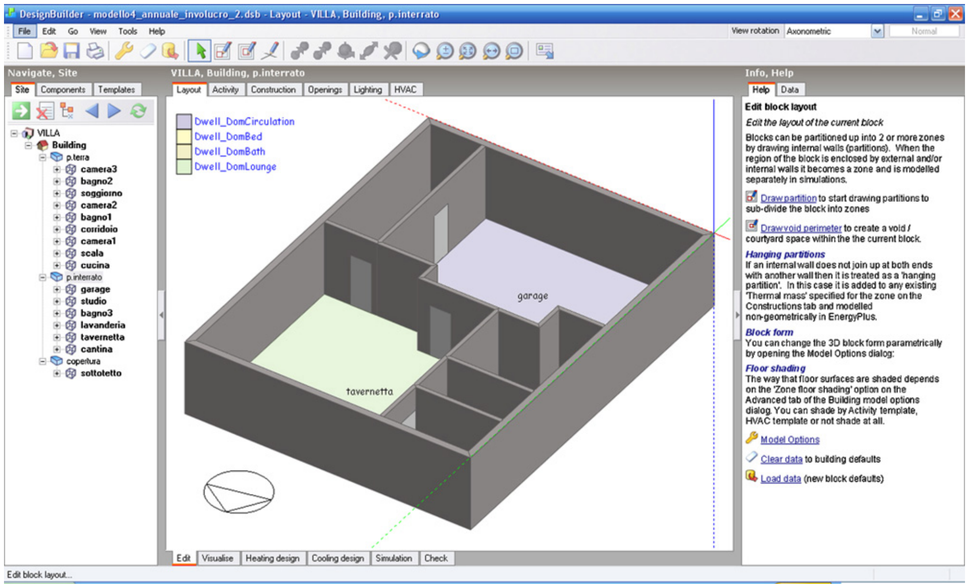

Fig. 4. DesignBuilder simulation: basement.

BestClass offers a simplified interface and comparison between different technical solutions.

Nevertheless this software does evaluate only heating during winter season, and DHW for all the year. Moreover, the plant parameters are standardized and finally the software does not include electric consumptions.

The confidence intervals are experimentally determined by comparison between the results of this method with dynamic numerical methods having the same input data, as requested in UNI EN ISO 832 Annex K. The confidence intervals are considered verified when the errors are not greater than 15%.

5. Description of calculations model for each method

5.1. Method A: prEN 15603 standard

In order to evaluate the primary energy, the CEN standard prEn 15603 introduces the formula:

$$E_{\mathrm{p}} = \sum_j E_{\mathrm{del}_j} f\,p_j - \sum_j E_{\mathrm{exp}_j} f\,p_j \quad (1)$$

with E_{del} the delivered energy, E_{exp} the exported energy, and fp_j the primary energy factor for the delivered (or exported) energy carrier j.

To evaluate the primary energy it is necessary to know three previous years for each energy carrier: methane gas and electrical energy. Starting from (1) the real consumption of energy primary reference can be obtained. This result represents the reference value to compare with other calculation methods.

5.2. Method B: "DesignBuilder"

DesignBuilder is perhaps the most comprehensive user interface for EnergyPlus dynamic thermal simulation engine. DesignBuilder Software Ltd. (DBS) is a commercial software development and research Company started in 1999. DesignBuilder was released in December 2005.

The DesignBuilder knowledge base is organized into different categories: model importing CAD; template components; material database; natural ventilation model, etc. The simulation code of calculation is based on software EnergyPlus.

5.2.1. EnergyPlus

EnergyPlus is a building energy simulation program for modelling building heating, cooling, lighting, ventilating, and other energy flows. It is based on the most popular features and capabilities of BLAST and DOE-2. It includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems. It has an ANSI/ASHRAE 140 2004 validation [9].

EnergyPlus is a stand-alone simulation program without a 'user friendly' graphical interface, and it is an open-source software.

The method B is the most detailed simulation method with dynamic parameters and they include all energy supply and energy dispersion. DesignBuilder joints the software Energyplus calculation model and the EPBD European standards.

5.2.2. European standards

The software uses a formula, which derives from the European Standards, for thermal energy. For heating the formula is

$$Q_{\mathrm{H,nd}} = Q_{\mathrm{L,H}} - \eta_{\mathrm{g,H}}\ Q_{\mathrm{G,H}} \quad (2)$$

with $Q_{\mathrm{H,nd}}$ the building energy need for heating (MJ), $Q_{\mathrm{L,H}}$ the total heat transfer for heating mode, $Q_{\mathrm{G,H}}$ the total heat sources

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012

for heating mode, and $\eta_{G,H}$ the dimensionless gain utilisation factor.

For cooling the formula becomes

$$Q_{C,nd} = Q_{G,C} - \eta_{l,C}\ Q_{L,C} \quad (3)$$

with $Q_{C,nd}$ the building energy need for cooling (MJ), $Q_{L,C}$ the total heat transfer for cooling mode, $Q_{G,C}$ the total heat sources for cooling mode and $\eta_{L,C}$ the dimensionless gain use factor.

In Eqs. (2) and (3) the letters H and C are referred respectively to heating mode and cooling mode. The total heat transfer for each mode, in both cases, is expressed by

$$Q_L = Q_{tr} + Q_{ve} \quad (4)$$

with Q_{tr} the heat transfer by transmission, depending on transmittance value for each wrapped components and Q_{ve} the total heat transfer by ventilation.

In analogy with (4), the total heat sources for each mode, in both cases, is expressed by

$$Q_G = Q_{int} + Q_{sol} \quad (5)$$

with Q_{int} the sum of internal heat source over the given period and Q_{sol} the sum of solar sources over the given period (depending on climate and meteorological data).

The internal heat source over the given period (Q_{int}) is obtained by stochastic method and it is not comparable with the real consumption. This value includes all energy supply inside building: cooking use, plant system, lighting, electrical plant, household appliance, etc.

$$Q_{int} = \sum_k \Phi_{int,k} + \sum_l (1 - b_l)\Phi_{int,u,l} \quad (6)$$

with Φint,k (W) the hourly heat flow rate from internal heat source k (occupancy, domestic appliance, artificial light, computers, etc. in real case or provided by norm tables), $\Phi_{int,u,l}$ the hourly heat flow rate from internal heat source l in the adjacent unconditioned space in W and b_l (W) the reduction factor for the adjacent unconditioned space with internal source l (ISO 13789).

The heat energy dispersion and heat energy supply are calculated in relation with outside temperature variations and with insulation radiation during all year based on local meteorological data.

To evaluate the DHW consumption calculation the software uses a formula like

$$Q_{h,w} = V_w\, \rho\, C\, n\, (t_w - t_0) \quad (7)$$

with V the volume of DHW consumed, ρ the water density, C the water specific heat (4186 J/kg K), n the number of day of period, t_w the temperature of water out, and t_0 the temperature of water in.

The input data for energy use standard (DHW, lighting, energy for cooking, electrical consumption, natural ventilation) represents perhaps one of the more critical points of this calculation model. The input data and the database, being not referred to the real user's behaviour, are extremely variable, and not the same as reported in Italian normative. DHW consumption depends on several factors: use destination, number of users, number of end users (tab, washer, etc.). Internal energy gain (or supply) obtained from computers, electrical domestic appliance, electrical and gas cooking use, etc., are all standardized to the W/m^2 parameter. The values of natural ventilation factors differ from those reported in Italian normative. Moreover, they depend on users habit. The electrical lighting consumption (i.e. energy gain) are standardized and based on W/m^2 parameter; it would have preferred to standardize it in relation of kind of lamps.

5.3. Method C: software best class

The method C is based on Italian Law [10] and CTI recommendation [6]. The Polytechnic of Milan implemented it in the software BestClass, which is a simplified method developed for the application of energy certification by local municipality to introduce an energy labelling in the Province of Milan.

This method considers the primary energy need for heating and energy to DHW, and includes thermal and electrical energy.

For energy need of heating the calculation formula is

$$Q_H = Q_L + Q_G \quad (8)$$

with Q_G the energy supply calculated with formula

$$Q_G = Q_{int} + Q_{sol} \quad (9)$$

with Q_{int} the energy internal gain, Q_{sol} the energy solar gain in relation with a local standard insulation value and the windows area and Q_L the heat dispersion is calculated with formula

$$Q_L = H(\theta_i - \theta_e)t \quad (10)$$

with θ_i the inside temperature, θ_e the outside temperature, fixed by normative for each month during winter regime, t the period (winter regime), and H the heat transfer coefficients reported on surface area (W/K) calculated with formula

$$H = H_T + H_V \quad (11)$$

with H_T the transmission heat transfer coefficients calculated with prEN 13789, and H_V the ventilation heat transfer coefficient calculated with the formula

$$H_V = \dot{V}\rho_a c_a \quad (12)$$

with $\rho_a c_a$ the heat capacity of air (0.34 W h/m^3 K) and $\dot{V}$ the volume flow (m^3/h) calculated with the formula

$$\dot{V} = Vn \quad (13)$$

with n the number of air changes for hours fixed by normative. The energy need for DHW is calculated with the formula [6].

The total primary energy is the sum of energy heating need and energy DHW need:

$$Q = Q_h + Q_{hw} \quad (14)$$

Q is expressed in relation with the characteristics and performance of heating plant system.

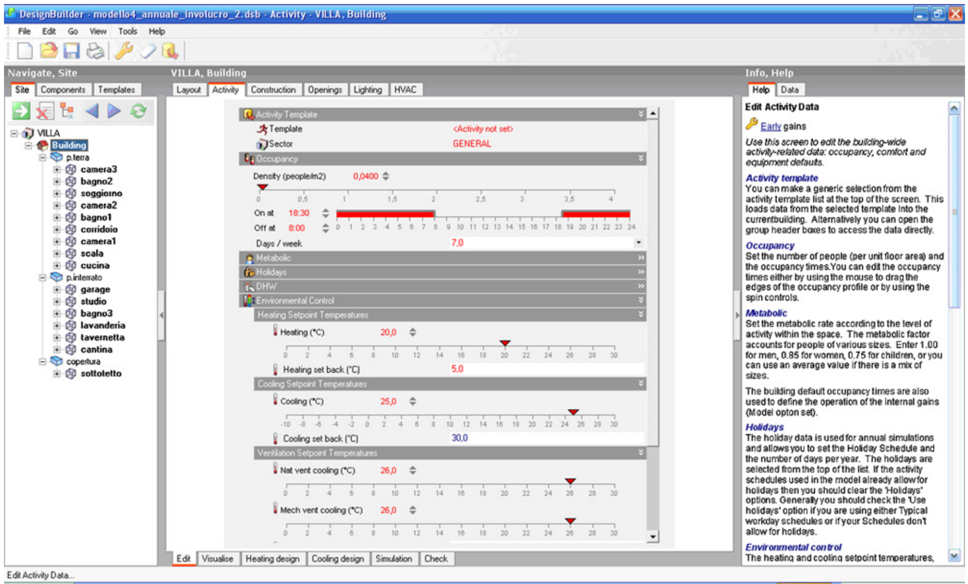

Fig. 5. DesignBuilder general input data.

6. The adopted simplification

In order to properly evaluate energy performance of the building, the walls and frames transmittance of building structures has been estimated with analogy with other similar buildings of the same period. Moreover, a ''standard'' plant equipment, which could be utilised in southern Europe climate, was considered: the plant a boiler with radiators terminals for heating; traditional electric and lighting plant; standard equipment of household-electric (washing machine, refrigerator, TV computer, etc.); two split system for conditioning [Figs. 5 and 6, DesignBuilder input data; Figs. 7 and 8, BestClass input data].

7. Results of simulations and comments

The results of simulations obtained with the three methods described above are reported in the following figures. They are divided into two seasonal periods: year and winter (October–April).

In Figs. 9 and 10 the result of simulation with methods A, B and C, are reported. They are divided in two periods: annual and winter regime.

Comparing method A (real consumption) and B (dynamic) the interval of confidence during annual period was found to be 8.9%, in favour to method A (see Fig. 11). Besides, during winter regime the interval of confidence is only 0.7% in favour to method A (i.e. near real consumptions).

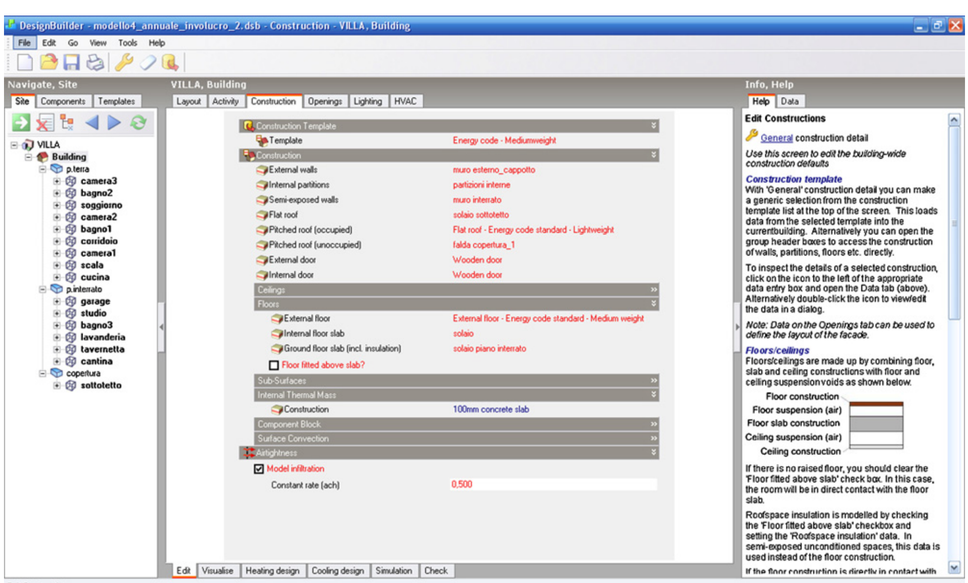

Fig. 6. DesignBuilder wrapped input data.

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012

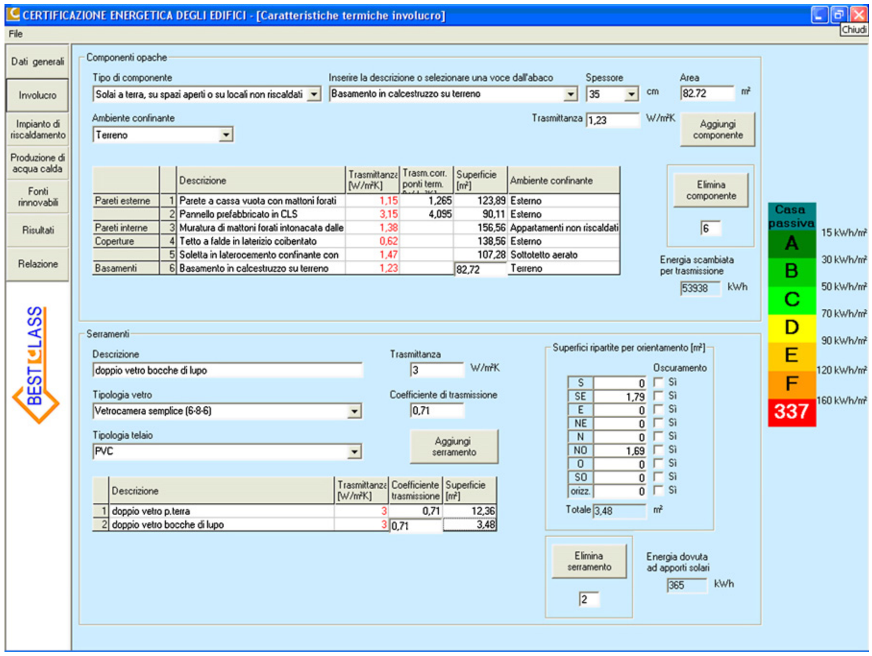

Fig. 7. BestClass wrapped input data.

Comparing method B, which includes all dynamic parameters, with real consumption, more similar results were found, with an acceptable interval of confidence smaller than 10%. This value is related to the difference between real consumption and the software data standardization (DHW consumption, light consumption, etc.).

Comparing method A and method C, the interval of confidence during annual period is 36.9%, in favour to method A, whereas during winter regime the interval of confidence is 27.9% in favour to method B. In both cases the interval of confidence is greater than 10% and therefore it is not fully acceptable. The gap is not related with the calculation model (static or dynamic model) but rather it depends on the input data. Moreover, the difference should be based on the calculation algorithm of method C, which does not include, in its output, electrical consumption (lighting and others) and energy consumption during summer regime, but only energy for heating and DHW.

Comparing method B with method C, the following results have been obtained: during annual period the gap is 25.7% in favour of method B; during winter period the gap is 28.5% in favour of method C.

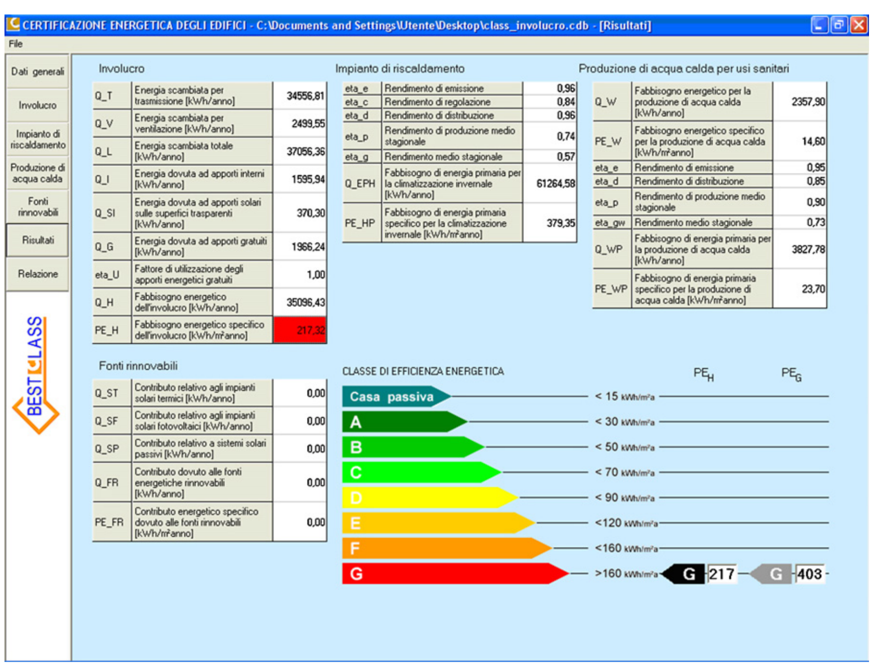

Fig. 8. BestClass results.

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012

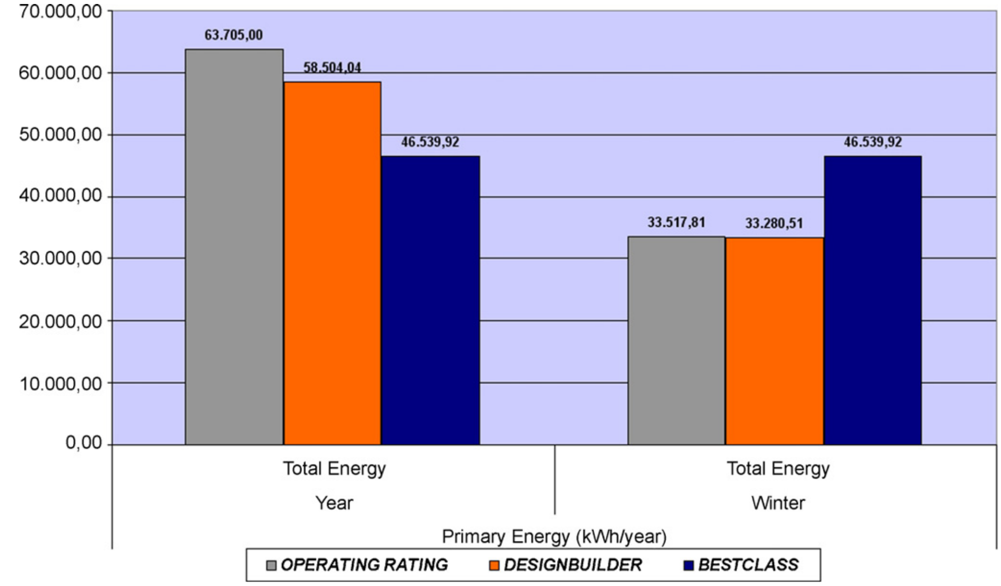

Fig. 9. Method comparison primary energy.

This difference is related to the characteristics of method C that could be considered a "hybrid model". This model evaluates the energy consumption to heating during winter regime (conventional and not real period respect real climate conditions) and evaluates the energy consumption to DHW during all year.

Comparing method A with method B and C during winter period (October-April), a greater confidence interval was found for method C (>60%).

As already pointed out, these differences and gaps in method C are caused by the "hybrid" structure of BestClass (EN 832), which is methodologically correct and corresponding to the normative. It estimates only heating needed during winter season and DHW consumption during all year, accordingly with EN 832. The result obtained with method C is therefore not comparable with those obtained with methods A and B. In order to compare methods B or C it became necessary to evaluate energy saving with retrofit project.

8. Possible energy saving improvements

Starting from existing buildings, retrofit has been simulated in three different cases of building factors.

8.1. Case A: wrapper retrofit

In this situation, the wrappers have been enhanced in the following way: external wrapped insulation without thermal

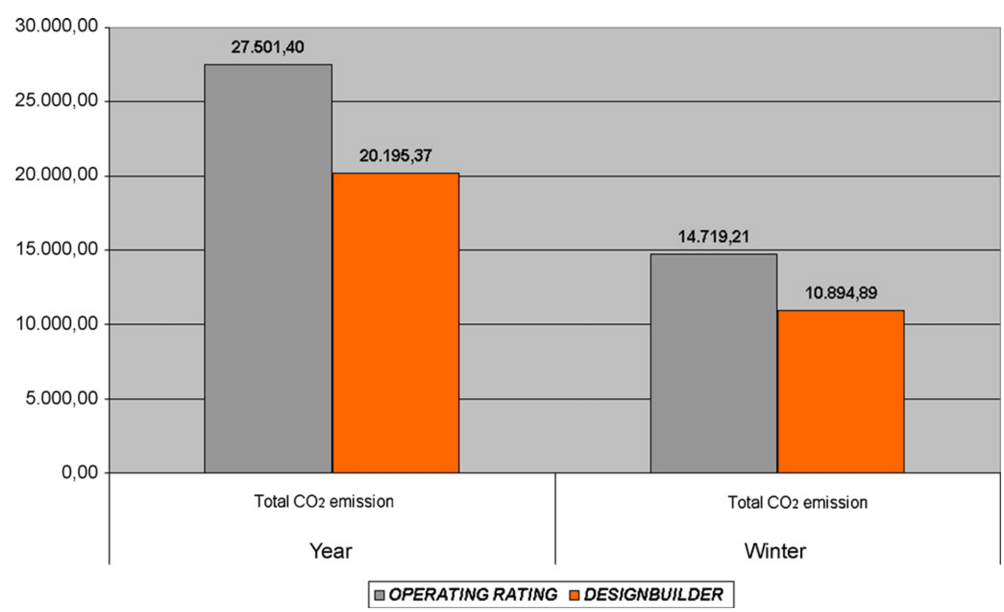

Fig. 10. Method comparison CO_2 emission.

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012

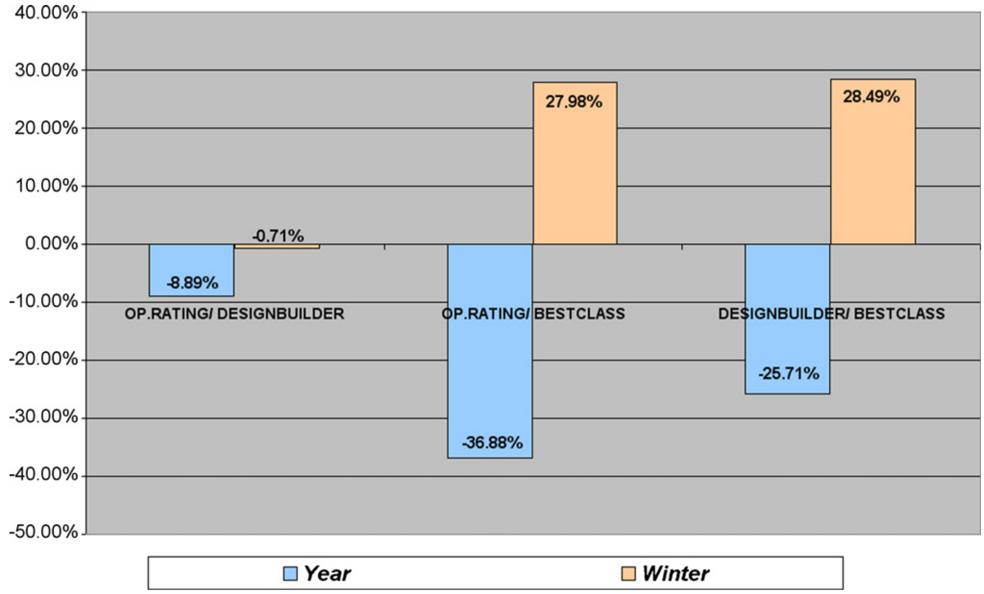

Fig. 11. Method comparison interval confidence.

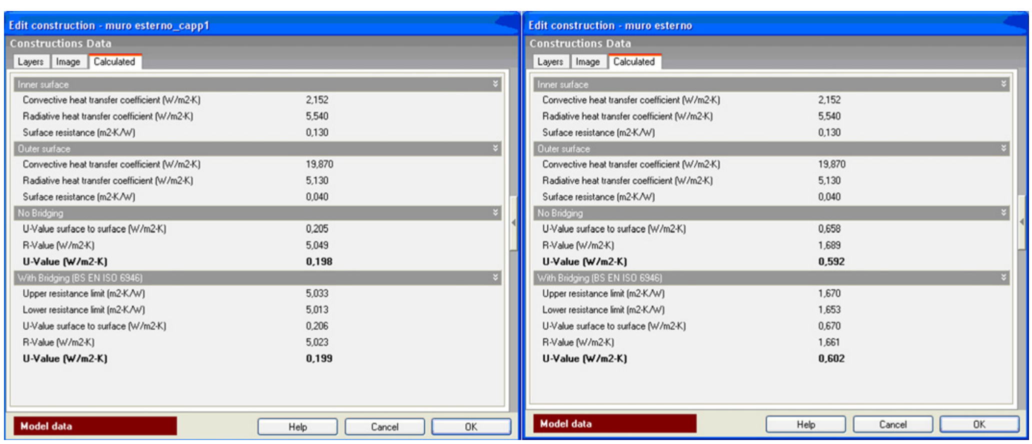

Fig. 12. Wrapped solution: thermal transmittance before and after improvement.

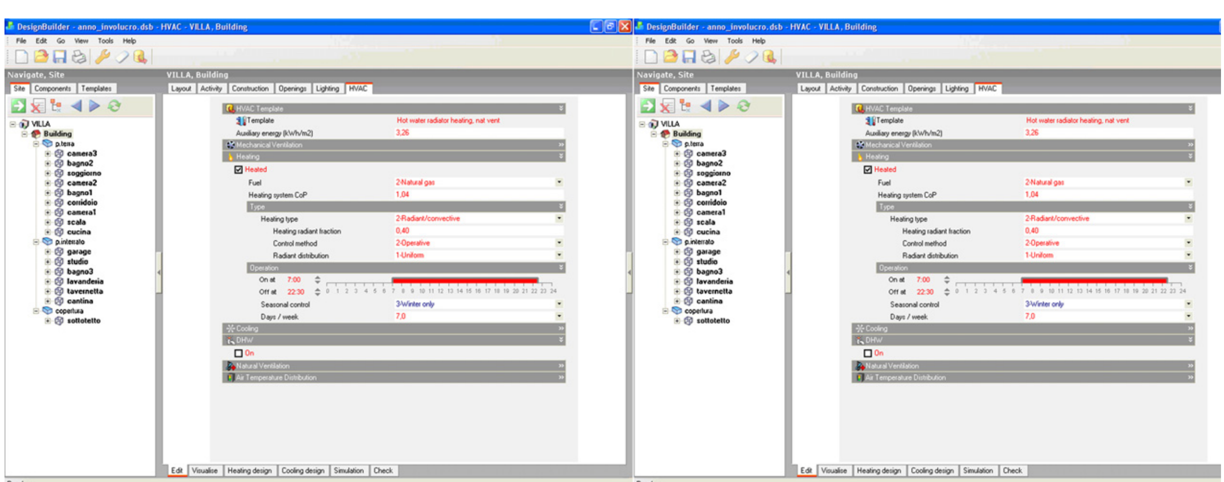

Fig. 13. Plan system solution: before and after improvement.

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012

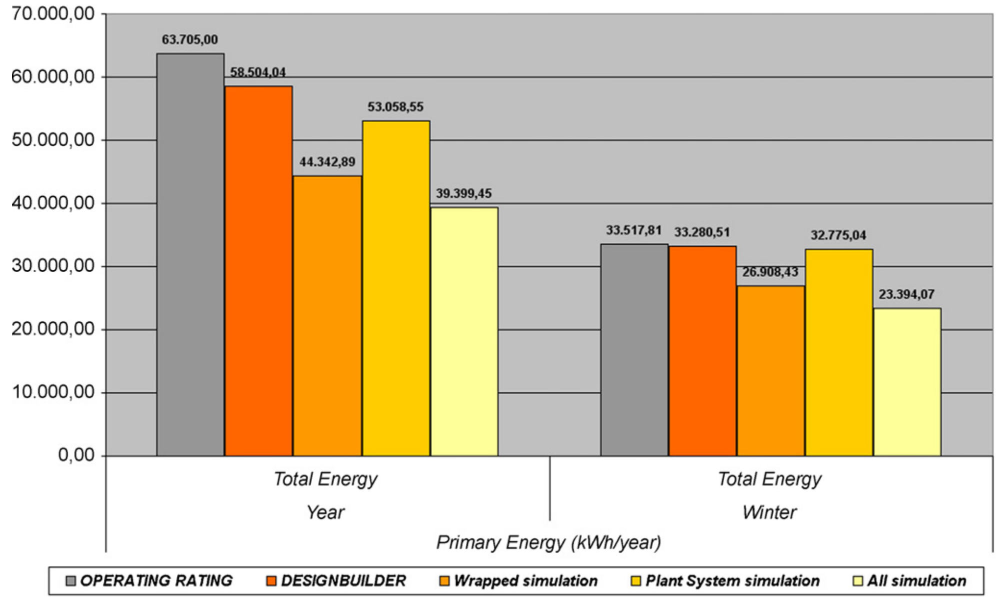

Fig. 14. Improvement comparison: primary energy (DesignBuilder).

bridge (6 cm of insulation with conductivity $\lambda = 0.004$ (W/m^2 K) [Fig. 12]; roof insulation (6 cm of insulation); substitution of window glazing with high thermal performance double-glazing.

8.2. Case B: heating plant retrofit

In this situation heating plant has been improved.

Boiler substitution with one having better coefficient of performance ($\eta = 1.04$ instead of $\eta = 0.89$) [Fig. 13]; adding heat pump for DHW; substitution of the light bulb with high-energy performance high bulb; only for method C: using of solar panel for DHW.

8.3. Case C: both solution A and B

Case C—In this situation, both solutions proposed in case A and B (wrapped and plant) have been applied: it would enhance energy performance with a lower cost solution (analysing cost/benefit ratio) with comparison to single cases A and B.

9. Result of energy saving improvement simulation

The result of simulation with method B (dynamic) are reported in Fig. 14 and 5 [Fig. 15]. A better energy saving was obtained with case A insulation (about 16% decrease) respect to

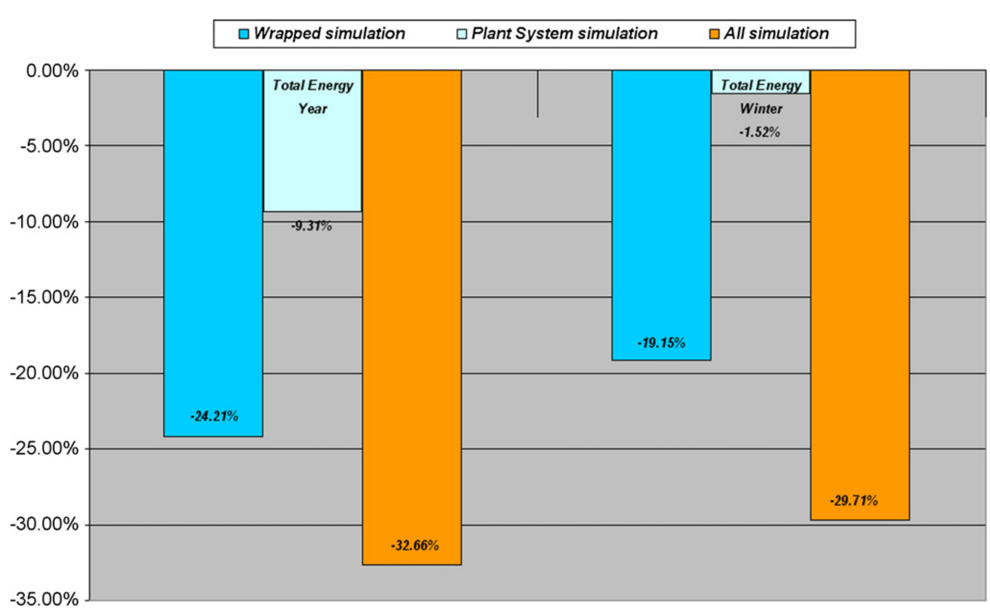

Fig. 15. Improvement comparison: energy saving percentage (DesignBuilder).

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012

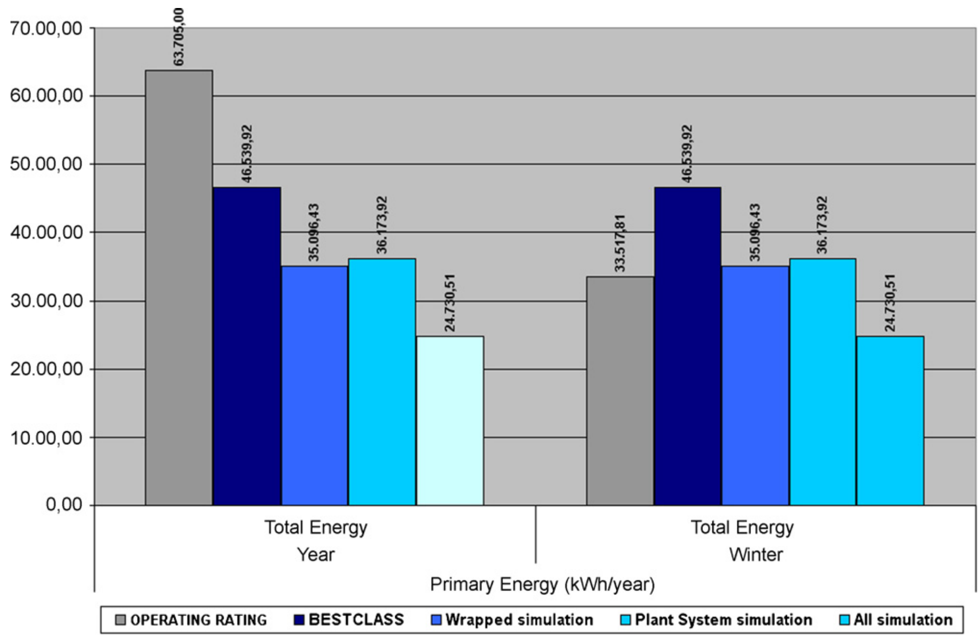

Fig. 16. Improvement comparison: primary energy (BestClass).

case B heating system (about 9% decrease). In case C, with both solutions, energy saving is enhanced (about 32%).

The result of simulation with method C (simplified) are reported in Figs. 16 and 17. A better energy saving was obtained with case A insulation (about 24% decrease) respect to case B heating system (22.3% decrease). In case C, where both solutions were used energy saving increases (about 47%). In this case the energy consumption due to electricity and summer regime has been considered.

The method B allows controlling the air exchanges and dispersion due to air infiltration through door and windows frames, taking into account the real use of the building. Therefore, the results are closer to real values. During the design of the building it is not feasible to compare the method B with the method C, since the method B does not allow to control thermal bridges. The standards prEN 13790, prEN 15603 and prEN 15316-x provide the elements to standardize data inputs and calculation procedure during the design of the building.

10. The software simulation and control from users

The European policy characterizes in energy certification the tool to promote the energy reduction in buildings sector. The aims are to reduce energy consumption and qualify the sector operators, designers, entrepreneurs, and constructors and energy service companies. In order to reduce significantly energy consumption in building's design, the EU policy promotes energy certification in existing buildings and

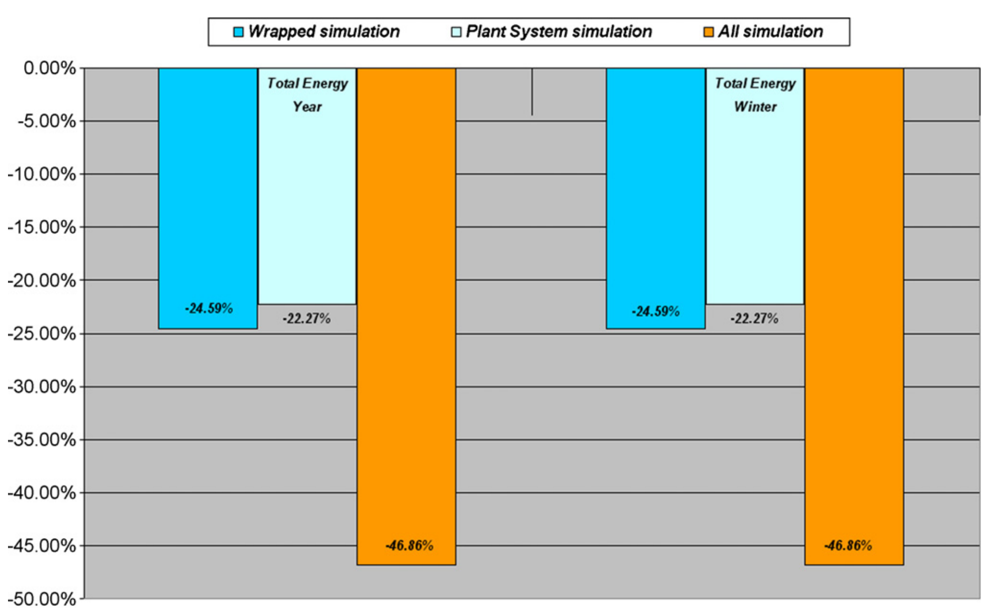

Fig. 17. Improvement comparison: energy saving percentage (BestClass).

technical background of sector operators as designers, entrepreneurs, constructors and energy service companies. On the other hand, during a design simulation, it is necessary to utilise easy calculation models to compare different solutions, with and acceptable interval of confidence. A standardized method of evaluation of energy performance in buildings became therefore strongly necessary to properly design buildings, which are able to reduce energy consumption. In the Mediterranean area the energy certification of buildings should include all energy use, and actually national standards do not have produced a unique method.

11. Conclusion

The calculation codes actually do not give a comparable result of energy consumption in the buildings. The intervals of confidence depend on local normative and different calculation models.

In order to develop and to accompany energy certification the calculation models and software should strongly follow the real estate market and the dynamics of building sector (as required in art. 10 Directive 2002/91/CE).

In the energy certification procedure this gap could create ambiguities in the evaluation of energy performance among different buildings. It became necessary to declare in the energy certificate of the building which calculation method has been used. Moreover, during the energy audit for simulation of the energy saving it is better to use the same calculation model for all simulations. Finally, in the Mediterranean area the relationships between energy and building create more complex relations between energy valuation and building design. In this way the architecture typology and historical construction techniques could be a reference to satisfy indoor comfort.

Acknowledgments

The authors thank Virginia Cermaria for the precious help during computer simulations and David J. Knight for his help during English proof.

References

[1] Normative EN 832, Thermal performance of buildings, calculation of energy use for heating, residential buildings.
[2] European Directive 2002/91/Ce, Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.
[3] Website CEN-normative, http://www.cenorm.be/cenorm/index.htm.
[4] CEN Umbrella Normative prEn 15603, Energy performance of buildings—overall energy use, CO_2 emissions and definition of energy ratings.
[5] CEN Umbrella Normative prEn 13790, Energy performance of buildings—calculation of energy use for space heating and cooling.
[6] Raccomandazioni CTI R03/3, Prestazioni Energetiche degli Edifici, Climatizzazione invernale e preparazione acqua calda per usi igienico-sanitari (CTI Italian Thermotecnic Commitee: Recommendation R03/3 Energy Performance of building. Winter heating and domestic hot water).
[7] Website Software Designbuilder, http://www.designbuilder.co.uk/.
[8] Provincia di Milano, Politecnico di Milano BEST, Certificazione energetica degli edifici-Tavolo energia e Ambiente, Software BESTClass developed by Politecnic of Milan and Province of Milan.
[9] ANSI/ASHRAE Standard 140-2001: standard method of test for the evaluation of building energy analysis computer programs.
[10] Italian Laws: D.Lgs 192/05 (adoption of Directive 2002/91/Ce), Law about energy performance during winter regime: L.10/91 and DPR 412/93.

Please cite this article in press as: L. Tronchin, K. Fabbri, Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation, Energy & Buildings (2007), doi:10.1016/j.enbuild.2007.10.012