Real consumption and numerical methodologies in energy performance of buildings

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Abstract: -
The evaluation of energy performance of buildings (EPB) depends on several factors, which are related to local climate contest. In northern Europe countries the evaluation of EPB depends of the energy heating dispersions, since climate is mostly cold all over the year. In these countries the design of buildings' technical solutions is comprehensive of super-insulation of the wrapped and frames, and of capture solar energy by frames and wall accumulation (solar passive solution). In southern Europe countries, where climate is mainly warm and dry, the buildings technical solutions are comprehensive of wind passive ventilation, cooling plant and thermal inertia of walls, which avoid overheating of indoor environments. In the Mediterranean area the climate do not justify neither of the aforementioned approaches. In these countries it is necessary to use flexible solutions, which could change in relation with climate conditions, taking advantage of their peculiar architectural elements, as: the porch, the court, the patio.
The models of buildings energy performance calculation become therefore very important to properly evaluate the EPB and the better solutions to increase the energy efficiency.
The calculation models should guarantee the uniformity and "globality" of energy performance evaluation, where "globality" means the overall energy consumptions, considering different countries and local climate conditions.

Key words: - Energy Performance of Building. Static and dynamic models. Real consumptions.
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INTRODUCTION

The challenges of the Directive 2002/91/EC: "Energy Performance of Building " (EPB) and the Directive 2006/32/EC: "Energy use efficiency and energy services and repealing" are to introduce in building sector the same energy efficient labelling applied in domestic appliance sector.
The "building labelling" or "Energy certificate" could be the key factor to increase energy saving and energy efficiency and Renewable Energy Sources in existing buildings and plant.
This labelling is an opportunity to increase own business and abilities for contractors and designers.
Considering the energy saving aspect, labelling in appliance domestic sector effect has been very useful because the appliance domestic labelling in worst Class (F or G) are not produced. All new products belong to Class B or A.
The application of the domestic sector in buildings sector perhaps is not possible because more existing buildings will be not dismissed, but this is the challenge: to improve the most part of existing and new building with a labelling. "However, the improvement of the overall energy performance of an existing building does not necessarily mean a total renovation of the building but could be confined to those parts that are most relevant for the energy performance of the building and are cost-effective." (Directive 2002/91/Ce).

The certification in accordance with article 7 of Directive 2002/91/Ce shall be regarded equivalent to an energy audit. The article 12 of Directive 2006/32/Ce report: "[…] the availability of efficient, high-quality energy audit schemes which are designed to identify potential energy efficiency improvement measures and which are carried out in an independent manner, to all final consumers, including smaller domestic, commercial and small and medium-sized industrial customer". The CEN European Committee of Normalisation is ending the CEN-Umbrella normative on EPB Directive.
Therefore Energy Audit is an important activity in building sector to promote energy efficiency solution and improvement retrofit. In the other hands Energy Audits are not only the simple application of software o model calculations but is an "evaluation procedure" which include the choice of calculation models.

The energy audit and calculation procedure are definite of "energy services". To enable a correct evaluation of energy performance of building reported in Energy Certificate the result of calculation procedure would be to allow comparable with real consumption.

THE CALCULATION METHODS

The EPB Directive defines the general framework for the calculation of energy performance in buildings, shall include the following aspect:
(a) thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include air-tightness;
(b) heating installation and hot water supply, including their insulation characteristics;
(c) air-conditioning installation;
(d) ventilation;
(e) built-in lighting installation (mainly the non-residential sector);
(f) position and orientation of buildings, including outdoor climate;
(g) passive solar systems and solar protection;
(h) natural ventilation;
(i) indoor climatic conditions, including the designed indoor climate.
The positive influence of the following aspects, where relevant in this calculation, shall be taken into account:
(a) active solar systems and other heating and electricity systems based on renewable energy sources;
(b) electricity produced by CHP;
(c) district or block heating and cooling systems;
(d) natural lighting.

In this paper 3 different evaluation methods will be considered:
·- The method measured rating based on the "Measured energy rating" calculation procedure report in point 7 of prEN 15603 "Energy performance of buildings — Overall energy use, CO2 emissions and definition of energy ratings";
·- The method "dynamic simulation", based on the Energyplus software calculation procedure based on the most popular features and capabilities of BLAST and DOE-2, stand-alone simulation;
·- The method "static simulation", based on EN 832 and EN 13790 calculation procedure.

A-Measured method

The measured rating is the reference model to compare results of different evaluation methods; it is based on procedure defined in point 7 of Directive prEN 15603.
In this evaluation method the amount of all energy carriers delivered to the buildings are divided by energy carriers and aims (heating, lighting, conditioning, etc…).
The data inputs of measured ratings are the energy bills. In the case study this are: methane gas consumption and electricity by national grid. To convert energy carriers in energy primary are used the "primary energy factors" defined in Annex E of prEN15603.

$$Ep = \sum (E_{del,i} \cdot f_{p,del,i}) - \sum (E_{\exp,i} \cdot f_{p,\exp,i}) \quad (1)$$

where:
E_{del} = delivered energy
E_{exp} = exported energy
fpj = primary energy factor for the delivered (or exported) energy carrier
To evaluate the energy primary we must to know three year proceeding (by energy bills) for each energy carriers. The result of this formula is the real consumption of energy primary reference.

B-Dynamic simulation

The second methodology is called "dynamic simulation" because it includes all parameters and all energy exchange during all year, and takes into account each day and meteorological variations, and therefore it differs from other evaluation method (called "static simulation" or "simplified simulation").
The dynamic evaluation includes all the parameters that have influence on energy behaviour of building. They are:
·- Local meteorological database, sun irradiation, outside temperature etc.;
· -Building geometry and building envelope thermo-physics characteristic;
·- Use of building and metabolic data of user;
·- Plant system: heating and conditioning, lighting and electric domestic appliance.
·- Renewable Energy Sources.

The European Normative for thermal energy calculation the software uses a formula like:

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

with:
$Q_{H,nd}$= building energy need for heating (MJ)
$Q_{L,H}$= total heat transfer for heating mode calculated with:

$$Q_L = Q_T + Q_V \quad (3)$$

Q_T=heat transfer by transmission, depend on transmittance value for each wrapped components
Q_V=total heat transfer by ventilation
$Q_{G,H}$=total heat sources for heating mode calculated with:

$$Q_G = Q_I + Q_s \quad (4)$$

With:
Q_I= sum of internal heat source over the given period. This value of input is determinate by stochastic method and it's not too comparable with the real consumption. This value includes all energy supply inside building: cooking use, plant system, lighting, electrical plant, household appliance, etc…

Q_{sol}= sum of solar sources over the given period (depend of climate and meteorological data)
$\eta_{G,H}$= dimensionless gain utilisation factor

$$Q_{C,nd} = Q_{G,C} - \eta_{l,C} Q_{L,C} \quad (5)$$

With:
$Q_{C,nd}$= building energy need for cooling (MJ)
$Q_{L,C}$= total heat transfer for cooling mode calculated with formula (3)
$Q_{G,C}$=total heat sources for cooling mode calculated with formula (4)
$\eta_{L,C}$= dimensionless gain use factor

The heat energy dispersion and heat energy supply are calculated in relation with outside temperature variations, and insulation radiation during all year based on local meteorological data.
To evaluate the DHW consumption calculation the software uses a formula like:

$$Q_{h,w} = V_w \cdot \rho \cdot C \cdot n \cdot (t_w - t_0) \quad (6)$$

With:
V= volume of DHW consumed
ρ=water density
C = water specific heat 4186 J/KgK
n = number of day of period
t_w= temperature of water out
t_0= temperature of water in

This calculation model is affected by the difficulty about the input data for energy use standard: DHW, lighting, energy fro cooking, electrical consumption, natural ventilation.
The major problem of input data and database (not refer at really user behaviour) are DHW consumption because depend on a several factors:
- use destination, number of users, number of end user (tab, washer etc…);
- internal energy gain (or supply) from computers, electrical domestic appliance, electrical and gas cooking use, etc… all of this are standardize with the W/m^2 parameter;
- the natural ventilation factors are not the same value reported in Italian normative (and depends on users habit);
- the electrical lighting consumption (energy gain) are standardize in base on W/m^2 parameter, and not in relation of kind of lamps;

For the dynamics simulation the software DesignBuilder, and application of Energyplus software with 3D interface and meteorological database, has been used.

C-Static (or simplified) simulation

The static simulation is based on EN 832 and the actual version of EN 13790 (the CEN has recently changed and upgraded the EN 13790 and now it includes the energy requirement during "cooling regime").
A new and definitive CEN–Umbrella normative is actually required, and the static simulation method is used by national and local normative to evaluate the energy consumption and primary energy of buildings.
This evaluation method is called "static" because it uses a meteorological input data based on average value, and the time period is all season or each month.
This method doesn't include all plant system but only heating plant and domestic hot water plant.
The lighting and cooling plants are excluded, and the user habits are fixed by normative value. In the other hand this is simpler with less input data, without graphic 3D models.
For the static simulation the software BestClass, developed by Sacert and BEST - Department of Milan Polytechnic has been used. BestClass was developed to apply energy certification of building in Milan province.
BestClass respects the Italian normative "CTI Recommendation R03/3" (CTI: Italian Termotechnical Committee is an Italian normative organism) and has been therefore utilised.

THE CASE STUDY

In order to compare all the methodologies, a detached house building (one family composed by four people), located in centre Italy, (close to Rimini) was analysed. It is located 10 km of Adriatic sea, and the climate is not too cool in winter and not to hot and humid in summer, except in few day during the year.

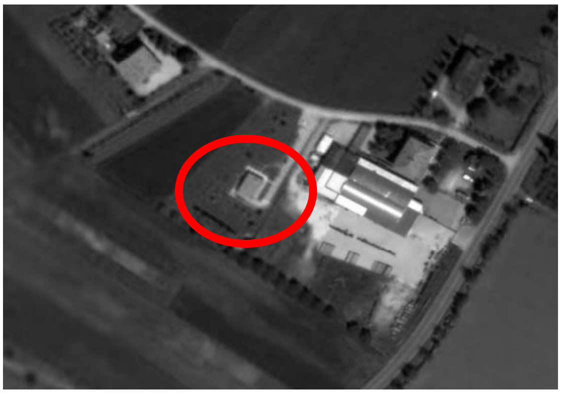

Fig. 1 Aerial View of Case Study

Fig. 2 View of Case Study

RESULTS OF SIMULATIONS

The results of simulations are divided by two periods: winter regime and annual regime. In this way the gap related to heating and/or cooling consumption could be evaluated. In table 1 are reported the results.

	Year regime		Winter	
	Primary En. (kWh/year)	CO_2 emission ($kgCO_2$/year)	Primary En. (kWh/year)	CO_2 emission ($kgCO_2$/year)
A	63725	26902	33517	13977
B	58504	20195	33280	10894
C	46539	-	46539	-

Table 2 Results of simulations with 3 different evaluation methods

Comparing figure 3 and figure 4, during annual regime the confidence interval between measured rating method and dynamic simulation is less than 8,9%, whereas the gap between measured rating method and static method is less than 36,9%.

In order to evaluate the difference between real energy consumption and the simulation methods is better to use and dynamic method because it includes all real meteorological data input and variations. During winter regime the gap between measured and dynamic is still less (0,71%).

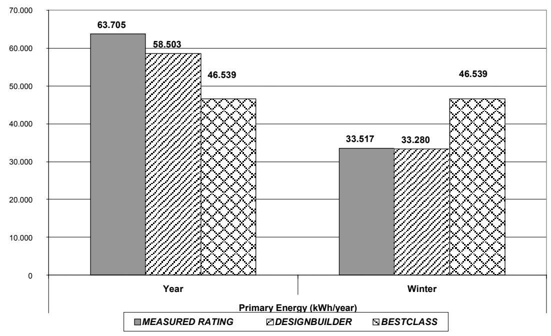

Fig. 3 Comparison of Primary Energy Results with 3 Evaluation Methods (From Table.1)

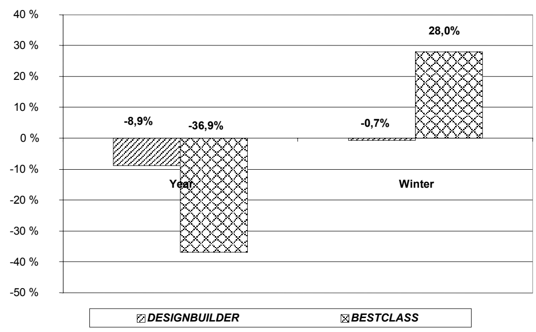

Fig. 4 Comparison Gap between Result with Dynamic Method and Static Method During Annual and Winter Regime

Since the "static methods is an "hybrid" method, which evaluates the heating need during winter regime and domestic hot water during all year regime, it should not be used to evaluate properly the consumption. This is a reason of two different interval confidences between measured method, less than 36,9% during all year and more than 28% during winter regime.

The difference between dynamic and static method is due also to the input and output data. In dynamic method the input includes heating and cooling plants, and electric and lighting plants. It includes also wrapped thermo-physic characteristics and all energy use, and the output is reported to gas and electric grid consumption during year regime for heating, cooling, domestic hot water, and lighting standard use.

On the other hand, the static model (based on EN 832 and En 13790) includes only the input data related to wrapped thermo-physic characteristics and heating plan parts and coefficient of performance, and the outputs are reported to heating and domestic hot water used without considering the energy carriers, the data meteorological variation during each month, and cooling and electric uses.

Finally the "static method" used in this simulation is based on EN 832 and EN 13790, now planned to change and upgrade with CEN-Umbrella normative. The all CEN-Umbrella normative will be definitely approved within 2007 and translated and adopted in each UE State members maybe during 2008.

CONCLUSIONS

After the analysis of the three methods a question may arise: Is it correct to compare this evaluation method if the input data and output data are so much different? It would be correct because all the methods could be used to calculate the energy performance indexes used to report the energy-rating label in energy certificate of building. Nevertheless, the evaluation method utilised to calculate (and to report in energy certificate) the energy performance becomes fundamental for being able to have a coherent expression of energy index calculated with real energy consumption of buildings.

The energy certificate should be clear and should allow the comparison with the real energy consumption of buildings. All evaluation methods (static or dynamic, analytic or simplified, calculated or measured) should reduce the interval confidence between the real energy consumption and the calculation procedure in order to evaluate energy consumption in standard conditions. The labelling of the buildings could help an easy and clear comparison of the energy performance of buildings, and also the choice of the improvement solutions.

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NOMENCLATURE

Ep= Primary Energy
$E_{,del,i}$ = delivered energy for energy carrier j
$E_{,exp,i}$ = exported energy for energy carrier j (by RES for example photovoltaics)
$f_{p,del,i}$ = primary energy factor for the delivered energycarrier j (Annex E prEN 15063)
$f_{p,exp,i}$ = primary energy factor for the exported energycarrier j (Annex E prEN 15063)
for the case study the primary energy factor are:
Gas f_p=1,36
Electricity by grid f_p=3,14

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