THE ENERGY PERFORMANCE BUILDING AND EPBD: A ROUND ROBIN TEST

Kristian Fabbri[1], Lamberto Tronchin[2],
[1]Faculty of Architecture, University of Bologna, Cesena, Italy
[2]DIENCA - CIARM, University of Bologna, Bologna, Italy

ABSTRACT

Following the introduction of the Energy Performance of Building Directive 2002/91/Ce (EPBD) the energy performance evaluation of buildings takes on a significant role in respect to legal requirements and to the Energy Performance Certification market. The Directive 2006/32/Ce on Energy End Use Efficiency and Energy Services (EEESD) introduces some news related to EPBD, for example: Esco, Energy management, and Energy Audits. Consequently with these directives the role of software simulation takes on an important role related to energy and economic factors, to evaluate better technical and economic solutions.

In this paper we present a Round Robin Test between some software applied to an Italian case study, following the EN 13790 Standard and Italian Standard. The selected software are divided into:

- Commercial software

- Operational Rating Method, based on effective energy consumption (energy bills, tariffs) following the EN 15603 point 7 calculation procedure.

The results of “Operational Rating Method” are the baseline from which to compare other software evaluation results. This choice accords with art.7 “Energy Performance Certification” of EPBD, which provides for evaluating and to proposing recommendations for the cost-effective improvement of energy performance.

INTRODUCTION

Energy Performance Building simulation is a tool to measure, design and enforce energy policies regarding energy efficiency in the construction field.

Results and confidence intervals (in accordance with Annex F EN 15603) of EPB simulation could be used as:

- Energy labelling for the Energy performance certificate (art.7 Directive 2002/91/CE);
- Baseline for the improvement of energy performance and cost, and energy audit for energy services (art.12 Directive 2006/32/CE).

The aim of this paper is a Round Robin Test between ten evaluation methodologies provided by Italian Law (Table 1), but it could also be applied to European Law and standards because all methodologies are based on Standard EN 13790: 2008 and EN 15603:2007

Table 1
Evaluation methodologies

SCOPE	METHOD	INPUT		
		Use	Climate	Building
New building	Design rating	Standard	Standard	
Energy label Energy audit	Asset rating	Standard	Standard	As built
Energy Audit	Tailored rating	Related to use	Actual	As built
Energy label existing building	Operational rating	Energy billing	Actual	

AIM OF PAPER

In EPBD and EEESD the result is the promotion and design of new energy efficient solutions. The purpose of this paper is to underline the relationship between the different kinds of simulation in order to know the gap between simulations and energy bills. This aspect is very important, since to improve energy efficiency solutions it is necessary to know the error-gap between the simulations and the real energy consumption of buildings, and the reasons behind different kinds of error-gaps.

CASE STUDY

The Case Study is a residential building of reinforced concrete and brickwork with 3 levels (figure 1 and 2).

The building is located in Ravenna, in northeast Italy, near the Adriatic Sea. The apartment here considered is located on the first and second floor. They were built in two different stages.

The heating plant has a traditional boiler (Power 27,9 kW, efficiency η = 92%), with horizontal net distribution (low insulation) and cast iron radiator.

Table 2
Case study thermo-physics value

FLOOR	CONSTRUCTION	DESCRIPTION	TRANSMITTANCE (W/M^{2}K)
1^{st} floor	External wall	Header bond with low insulation	1.430
	Floor	Tile elements covered by cement	1.259
	Window frame	Aluminium frame with double glazing (4/15/4)	2.14 – 2.08 - 2.22 (*)
2^{nd} floor	External wall	Alveolar brick (30 cm)	1.091
	Roofing	Tile elements covered by cement with insulation (3 cm)	1.020
	Window frame	Aluminium frame with double glazing with argon (4/15/4)	2.23 – 2.74 – 2.83 – 2.71 (*)

(*) depends on window dimensions

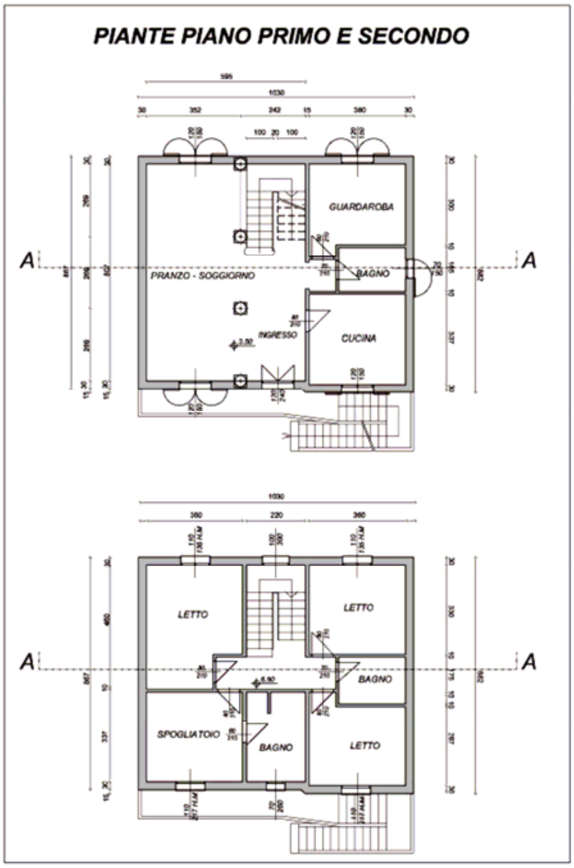

Figure 1 Case study: 1^{st} and 2^{nd} Floor

Figure 2 Case Study: Front

EVALUATION METHODOLOGIES

The evaluation methodologies used for the Round Robin Test are:

1. UNITS 11300 standards, by excel sheet
2. Commercial software elaborated by software, house in accordance with Italian Standard UNI EN 13790 and UNITS 11300
3. Operational rating method based on effective energy consumption (energy bills, tariffs), which follows EN 15603 point 7.

Method UNITS 11300 standards

This evaluation procedure is based on Italian Standard UNITS 11300, Part 1 and Part 2, which are the Italian standards for evaluating primary energy to heating and Domestic Hot Water (DHW), in accordance with UNI EN ISO 13790:2008 and EN 15316-1 and 15316-X (CEN Umbrella standards). This standard could be applied to the design rating, asset rating and tailored rating.

Following the UNITS 11300 procedure, an excel sheet (excel database) has been developed, making it possible to control each data input and calculation step by step. This is the reference from which to compare other simulations.

Commercial Software

Commercial software is software developed by national software-houses used by thermo-technical consultants to draw up administrative documents, building and plant projects, energy audits and energy certificates (labelling). They are the most common software tools. The software used for the Round Robin Test are:

- EDILCLIMA EC 501-EC 506, developed by the software house Edilclima. Geometrical into which input data could be inserted by numerical or graphical procedures, thermo-physical values for envelope materials (wall, floor, frame) are based on inside database and thermal bridges following UNI 14683 (empirical method called atlas of thermal bridges). The outputs are:

thermal power of a heat generator (calculated by UNI EN 832) and the "Indice di prestazione energetica EP" (Energy Primary Index by law) expressed in kWh/m^{2}year.

- STIMA 10 –TF, develop by Watts Industries, is similar to EDICLIMA, but can also be used with the ASHRAE (TFM) method to evaluate summer energy loads. However, the thermo-physical input data are not clear.
- MCSuite 2008, developed by MC4 software house, has only a graphical input in 3D from a DWG file. The data input of the heating plant is not so clear. All the data input could be translated in a database sheet for EnergyPlus 2.0.

The difficulty in using and comparing this selection of software lies in the uniformity of data input, especially regarding the heating plant output value

Operational rating

The operational rating procedure follows the EN 15603 point 7 procedure, and is based on effective energy consumption derived from energy bills (tariffs): natural gas bills and electric bills.

In the Case Study the consumption average of energy consumption for the years 2005, 2006 and 2007 has been evaluated and converted into primary energy. With the Lower Heating Value LHW natural gas is equal to: 37,69 MJ/m^3 and electric energy equal to: 1 kWh(primary energy)=0,36 kWh(electric energy) by the national coefficient.

The "Indice di prestazione energetica EP" (Energy Primary Index by law), expressed in kWh/m^{2}year, is the result of the primary energy average divided by the building floor area.

Table 3
Electricity consumption

PERIOD	CONSUMPTION (kWh)		
	2005	**2006**	**2007**
Jan-Feb	557.00	642.00	768.00
Mar-Apr	477.00	1261.00	649.00
May-Jun	467.00	595.00	637.00
Jul-Ago	745.00	1048.00	946.00
Sep-Oct	487.00	599.00	642.00
Nov-Dec	542.00	643.00	740.00
Total	**3275.00**	**4788.00**	**4382.00**
Average (kWh/year)		**4148.33**	
Average winter (kWh/year)		**1983.17**	

In Tables 3, 4 and 5 are reported the average energy consumption, divided by energy use.

Table 4
Natural gas consumption

PERIOD	CONSUMPTION (kWh)		
	2005	**2006**	**2007**
Jan-Feb	435.00	428.00	432.00
Mar-Apr	254.00	254.00	244.00
May-Jun	130.00	132.00	125.00
Jul-Ago	75.00	70.00	68.00
Sep-Oct	136.00	131.00	125.00
Nov-Dec	343.00	340.00	339.00
Total	**1373.00**	**1355.00**	**1333.00**
Average (kWh/year)		**1353.67**	
Average winter (kWh/year)		**858.00**	

Table 5
Energy primary evaluation (EN15603 point 7)

ENERGY	ENERGY CARRIER (kWh)		
	NATURAL GAS	**ELECTRICITY**	**TOTAL ENERGY RATING**
Delivered energy	14172.14	4148.33	18320.47
Exported energy	0.00	0.00	0.00
Net delivered energy	14172.14	4148.33	18320.47
Weighting factors	1.51	3.06	
Weighted energy use	21399.93	12693.90	**34093.83**
Energy Primary Index		**239.00 kWh/m^{2}year**	

This data represents the input values necessary for evaluating the primary energy following EN 15603 point 7.

Operational rating assessment

We cannot ignore the energy use of buildings or the effectiveness of heating plants as they depend on user behaviour.

To compare the results of the operational rating with standard data input, we need to apply the assessment procedure (point 7.2 EN 15603).

The assessment parameters are:

- Hours of heating plant operation during the day (by the standard 24 hours/day by a user 8 hours/day, ratio: 24/8=3);
- Number of days in the heating season (by standard 183 day/year, by user 183 day/year, ratio=1);
- External average temperature winter season (by standard 10349 is 8,4 °C, by local meteorological station is 11,26°C, ratio 8,4/11,36 =0,7396)

The assessment coefficient is 2,2188, then:

Primary energy (assessment) = 2,2188*Primary Energy (real user).

RESULTS OF SIMULATIONS AND DISCUSSION

In the following tables are reported results of simulations with six types of methodology.

The energy index and parameter used for comparison are:

- Indice energetico EP (Primary Energy index – EP index) in kWh/m^{2}year, for heating and DHW;
- Indice energetico EP limit by law (Primary Energy index – EP index by law) in kWh/m^{2}year, depends on geometric data input: dispersion surface (S) ratio volume (V) S/V;
- Seasonal heating plant efficiency (η_g);
- Energy rating (class) by Regional Law (DAL 156/2008 Annex 9).

Table 6
Results of simulations

SOFTWARE	RATIO S/V	VOLUME	DISPERSION SURFACE	FLOOR SURFACE	THERMAL EFFICIENCY	EP INDEX	EP INDEX BY LAW
	(m^{-1})	(m^3)	(m^2)	(m^2)	(η_g) %		
1	0.68	567.12	384.92	144.23	83.93	171.20	74.18
2	0.68	567.12	384.92	144.23	80.00	183.61	74.20
3	0.68	567.00	385.00	144.00	75.10	198.00	74.20
4	0.69	622.85	429.78	157.64	77.04	188.64	75.09
5	-	-	-	144.23	-	122.85	74.18
6	-	-	-	144.23	-	187.84	74.18

The methodologies reported in the Tables are:

1. UNITS 11300;
2. Edilclima EC 506;
3. STIMA 10;
4. MCSuite 2008;
5. Operational Rating
6. Operational Rating Assessment

As we can see from the above Table 6, EP index by law change in order to change ratio S/V and thermal-efficiency.

In Table 7 are reported the gaps between the EP index for each method and reference EP index, which are:

- EP index by UNITS11300, because this is the standard reference;
- EP index by Operational Rating, because this is the real cost to the user.
- EP index by Operational Rating Assessment, because it considers the same heating plant as used in a standard condition.

Table 7
Energy Primary Index comparison

SOFT WARE	AS COMPARED WITH: UNITS 11300	OP. RATING	OP. RATING ASSESS.
1	0.00 %	28.24%	- 9.72 %
2	6.76 %	33.09 %	- 2.30 %
3	13.54 %	37.95 %	5.13 %
4	9.25 %	34.88 %	0.42 %
5	- 39.36 %	0.00 %	- 52.90 %
6	8.85 %	34.60 %	0.00 %

Another fundamental aspect for the Directive 2002/91/Ce is the Energy Certificate and attribution of Energy Class.

For all evaluation methodologies used the building is in Class F according to DAL 156/2008 Emilia-Romagna Region Annex 9. The building is in Class E only for the Operational Rating method.

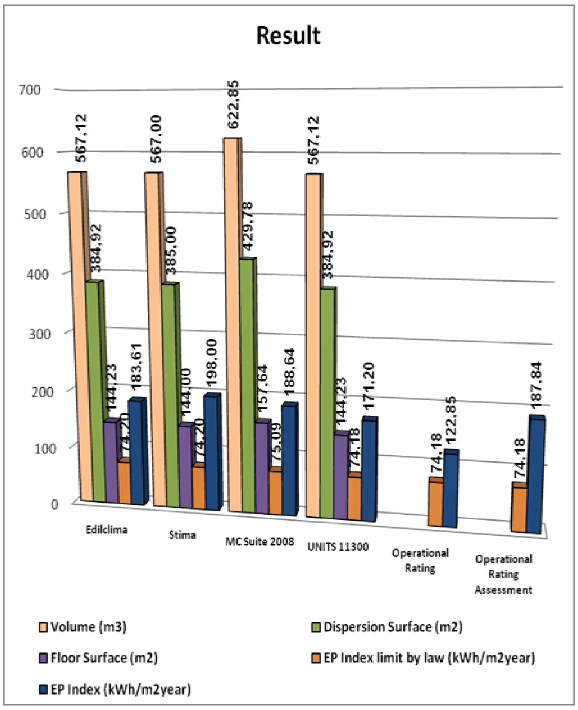

Figure 3 Results

In Figure 3 we can compare the gap between each software. The trend-gap is the same for data input (volume, floor surface) and results.

In Figure 4 are compared the results between the primary energy index, for each software, and the "reference methodologies": UNITS 11300 results, Operational Rating and Operational Rating Assessment.

How we can see the data input, areas and volume, is different, because each software creates a different model of building in spite of the same data input.

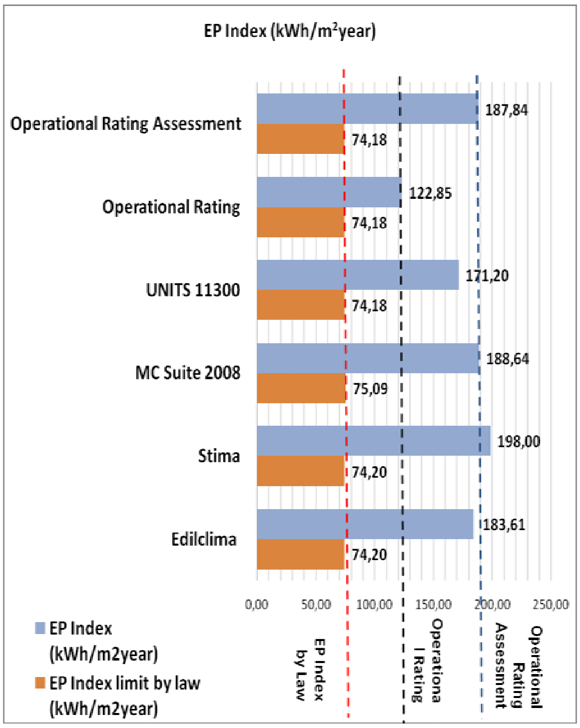

Figure 4 Result EP index (kWh/m²year)

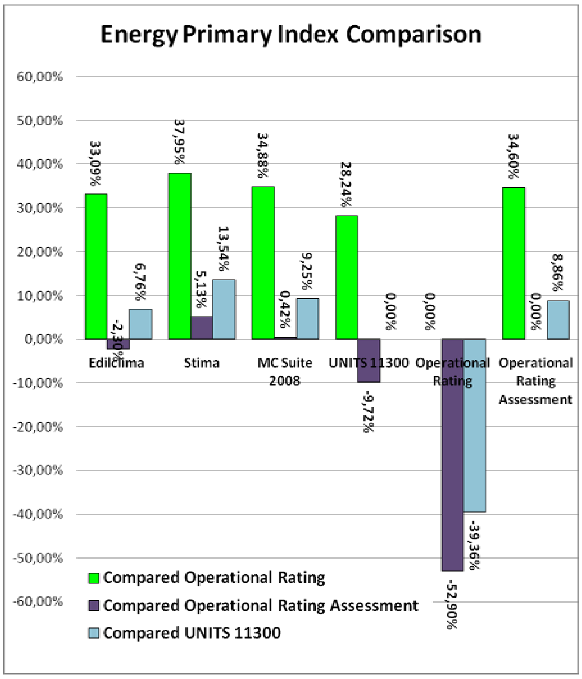

Figure 5 Energy Primary Index Comparison

In Figure 5 are reported the same gap in percentage: the result of each software divided by "reference methodologies".

The aim of this comparison is to know the gap between each methodology and respectively:

- The real energy consumption (Operational Rating), to know the gap between simulation and real energy bills
- The UNITS 11300 Standardized method, to know the gap between software algorithm and result by standard (interval of confidence)
- The Assessment energy consumption, to know the gap between real (or predictable) energy bills, and software simulations.

Efficiency errors

In Table 6 there are four different values of η_g. Seasonal heating plant efficiency (η_g) is calculated with the following formula (1) where each methodology uses a different efficiency value.

$$\eta_g = \eta_e * \eta_d * \eta_r * \eta_p \qquad (1)$$

where:

η_e= efficiency emission heating plant subsystem

η_d = efficiency distribution heating plant subsystem

η_r = efficiency regulation heating plant subsystem

η_p = efficiency production (boiler) heating plant subsystem

In Table 8 are reported results of homogenized EP index in respect to efficiency (h_g), using the following formula (2).

$$\frac{(EP)_{software}}{(EP)_{UNITS11300}} = \frac{(\eta_g)_{software}}{(\eta_g)_{UNITS11300}} \qquad (2)$$

Table 8
Energy Primary Index homogenized

SOFT WARE	EP INDEX	EP INDEX HOMOGENIZED	DIFFERENCE (%)
1	171.20	171.20	0 %
2	183.61	163.18	- 13 %
3	198.00	153.19	- 29 %
4	188.64	157.15	- 20 %

Both methodologies and software used in simulations have different methods of considering the data input. The seasonal heating plant efficiency value describes the quality of heating plant performance.

As we can see from Table 8 above and formula (2), the confidence intervals depend on the seasonal heating plant-efficiency (η_g). In the same way as the geometrical data input, the gap between each evaluation depends on geometrical and efficiency data.

CONCLUSION

The results of this Round Robin Test confirm the important role of methodologies and software choice.

The Commercial Software have confidence intervals of about ± 8 % in relation to the UNITS 11300 Standard (between 6.67% / 13.54 %), about ± 15 % relative to the Operational Rating Assessment (between -9.72% / +5.13%), and more than ± 30% in relation to the Operation Rating, but this depends on user behaviour which is unpredictable and not provided for in the law.

In order to aim the evaluation we can use different intervals of confidence with respect to the standards.

- For Energy rating (Energy Class) the confidence interval may be ±10-15%
- For Design rating the confidence interval may be ±5-10%
- For Energy Audit and Cost Evaluation the confidence interval may be ±1/2-5%.

The CTI (Comitato Termotecnico Italiano - Italian Thermo-Technicians Committee) is working with a "Software Validation procedure" with a confidence interval of ±5%.

During the Round Robin Test evaluation we have identified some problems regarding non-homogeneous data input:

- Geometrical input, since some software uses 3D models while others use 2D models, causing a confidence interval between ±7% and ±15% propagation of errors
- Thermo-physical value (materials and components), especially of the Standard reference for conductivity and other parameters
- Heating plant performance and thermal-efficiency value, where most problems are due to software using a different value of heating plant sub-system of thermal-efficiency value. This is the cause of confidence intervals ±15% propagation of errors (see Table 8)

These are causes of the propagation of errors, in accordance with the definition of Annex J EN 13790. It is impossible to determine the propagation owing to contemporary non-homogeneous data input.

A better solution could be to elaborate a common file format and database for all software as for each materials thermo-physical value and Boiler, Heating Pump and other HVAC plant devices.

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EN 15603:2008 "Energy performance of buildings – Overall energy use and definition of energy ratings"

UNITS 11300 part 1 "Prestazioni energetiche degli edifici –Parte 1: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale" (Energy performance of buildings – Part 1 - Calculation of energy use of the building space for cooling and heating)

UNITS 11300 part 2 "Prestazioni energetiche degli edifici – Parte 2: Determinazione del fabbisogno di energia primaria e dei rendimenti per la climatizzazione invernale e per la produzione di acqua calda sanitaria" (Energy Performance of builsings –Part 2 – Method for calculation of system primary energy requirements and thermal-efficiency for heating system pant and Domestic Heating Water in buildings)

DAL 156/2008 Regione Emilia Romagna "Atto di indirizzo e coordinamento sui requisiti di rendimento energetico e sulle procedure di certificazione energetica degli edifici" (Emilia-Romagna Regional Coordinating Act on Energy performance requirement and Energy certificate of buildings procedure)

Software:

- Ediclima EC 506 (Edilclima software house)
- MC Suite (MC4 software house)
- STIMA 10 – TFM (Watt Industries software house)