315: Energy performance calculation methods for the Italian existing dwellings: a comparison

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Abstract

The 40%, among the 27 million Italian dwellings is more than 30 years old. The energy refurbishment of the existing stock is needed is hence a priority. The definition of reliable calculation tools and methods to assess the energy performance of buildings is the first step for an effective implementation of the EPBD, especially to address the building renovation . The normative framework is still under definition and several tools based even on different methods are circulating in Italy. This study compares tools and methods of different level in terms of results accuracy and reproducibility. The tools include steady state simplified tools, steady state accurate instruments, dynamic calculation method. The qualitative and quantitative data input, the required skill for using the instrument, the calculation engine characteristics and potentialities, the allowed simplifications are presented and discussed. A single family house was then selected, with known geometry and thermo-physical properties. Same climatic data are defined, according to the reference national standards. Same operative and boundary conditions were applied. The study aimed at understanding how the different methods work and the effect on the energy performance assessment of existing dwellings. The influence of simplification and the drawbacks accuracy versus reproducibility is also discussed.

Keywords: energy performances, calculation method, building simulation

1. Introduction

The Energy Performance of Building Directive, 2002/91/CE, was the incipit of an impressive amount of work carried out at European and Member States level to define the new legislative and technical framework in terms of energy performance in the civil sector.

Activities are still on going in every country, even if the level of the directive implementation has reached different goals. The action is still undergoing in Italy for both, the legislative framework and the technical standards up to date. The situation is complicated by the possibility of each single Region of implementing the energy certification process and adopting its own calculation methodology, how defined in the national decentralisation decree dated 1998.

Actually two decrees, dated 2005 and 2006, formally implement the EPBD, in practice many issues are postponed to the publication of the national guidelines under preparation at the Ministry of Economic Development [1,2]. Some regions are conversely (almost) ready with their certification scheme and related methodologies.

One point is fixed at national level: the energy certification for residential and not residential buildings is limited to the primary energy consumption for the heating use only. This issue is critical, since a noticeable part of the national territory has a *cooling* priority. All the country, with peaks in the Mediterranean zones, is experiencing an impressive increase of electric consumption in dwellings, while appliances and artificial lighting systems get more efficient. This depends on the massive installation of compact air conditioning machines in dwellings: more than 8 million units sold between 2002 and 2006!

This crucial issue will be addressed in the next few years, now the rules are defined for the heating season only. They are:

- New and existing buildings: detailed designed monthly steady state method - as described in ISO EN 13790 [3].
- Existing buildings: simplified evaluation monthly steady state method - as described in above plus simplification fixed at national level by the relevant technical standards.
- New and existing buildings: dynamic methods are allowed.

The adoption of the simplified methods has three main objectives:

- Keep the certification costs as low as possible, especially for stimulating voluntary certification processes.
- Use the energy certificate, obtained with simple procedures and tools, as an instrument for stimulate renovation actions and improve the energy performance of the national building stock.
- Introduce the result reproducibility as an item as important as the result accuracy within the certification process stakeholders.

The last point is very important: existing buildings often lack in terms of information about the envelope materials and components, energy systems efficiencies, building use and

functionality. Under these conditions, detailed calculation methods would require expansive energy audits; if not may input data will be unavailable. Evaluation methods, using standard conditions and simplification at the input data level, can be more effective for the certification purpose and for the existing dwellings stock.
The paper is an attempt at comparing different tools, based on different method, to assess the energy performances of existing dwellings, going more into details of the building characteristics, respect to previous analyses [4]. Because of this background, the aim of the work is not a comparison/validation of different models or software, but it is mainly the evaluation of different methods and procedures. Strong differences are, in fact, faced not only in the algorithm structure, but also on the management of the input data, at geometry, operational and thermo-physical level when dealing with simplified methods.

2. Methodology

The study is based on the energy performance assessment comparison of a simple single one floor detached house in Milan, Rome, and Palermo. These three cities are respectively located in the north, centre and south of Italy, representing the typical climatic conditions.
The climatic data are defined in the relevant national technical standard and here summarised in Tables 1 and 2.

Table 1: Monthly mean air temperature Tm [°C] in the selected localities.

	Rome	Milan	Palermo
Jan	8.0	1.7	12.8
Feb	8.8	4.2	13.0
Mar	10.8	9.2	13.8
Apr	13.2	14.0	15.5
May	17.3	17.9	18.7
Jun	21.0	22.5	22.4
Jul	24.1	25.1	25.6
Aug	23.9	24.1	26.2
Sep	20.6	20.4	23.9
Oct	19.6	14.0	22.9
Nov	12.1	7.9	16.3
Dec	9.3	3.1	14.1

Table 2: horizontal solar radiation Ho [MJ/m2] in the selected localities..

	Rome	Milan	Palermo
Jan	207	3.8	227
Feb	262	6.7	295
Mar	440	11.6	472
Apr	554	16.5	605
May	690	20.0	727
Jun	729	22.2	789
Jul	777	24.0	787
Aug	681	19.4	690
Sep	511	14.0	539
Oct	363	8.4	400
Nov	227	4.4	254
Dec	178	3.3	206

Only the heating energy demand is calculated. The energy performances during the heating season are calculated using 4 different tools, described in the next paragraphs. The first three tools are steady state methods [5].

2. 1 Simplified method

DOCET is a simplified tool working with the steady state method, with monthly energy balance and utilisation factors . It can be used for residential buildings, or single dwellings, only. The whole building is as a single zone model, unheated space can be coupled. The engine is based on the EN ISO 13790, but lots of simplifications are introduced assigning quantitative input from qualitative input, the user can easily defines after simple energy audits. Other data are pre-calculated by the software, according the characteristics of the national building stock as a function of the age and the most recurrent technological solutions.
The geometry input is very simple: the box is defined by the dimension in plan of the building and by its height. The window surface is pre-calculated, according to national standard references, or accurately defined by the user. The orientation is fixed according to the 8 main orientations.
Concerning the definition of thermal load the main contents of the tool are the following:

- Transmission losses: pre-calculated for different component solutions or edited by the user. Pre-calculated thermal capacity of the structure and of thermal bridges, according to the characteristic of the structure. Only one opaque component can be defined.
- Ventilation/infiltration: fixed pre-calculated value, according to the air exchange and permeability of the envelope.
- Internal gains: fixed pre-calculated value.
- Solar gains: modelling of the window, only few glazing units are defined. The user can edit the thermal losses coefficient. Pre-calculated data, according to the most typical colours and materials used in Italian buildings, define the solar gains through the opaque envelope. The reduction of solar gains is applied to the glazing units. Only a simple shading strategy is considered.

2. 2 Partially simplified method

BestCLASS is an instrument working with the steady state method, with monthly energy balance and utilisation factors. The method can be applied in new and existing buildings, even not residential; some restrictions apply in the latter case.
The whole building is as a single zone model, unheated space can be coupled. The engine is based on the EN ISO 13790, but some simplifications are introduced, according to a national working document developed by the Italian relevant standardisation body [6].
The geometry of the building is more accurate, since the orientation, the area and the thermal transmittance of the envelope must be defined for each external surface and for windows. Total surface and volume are to be inputted.

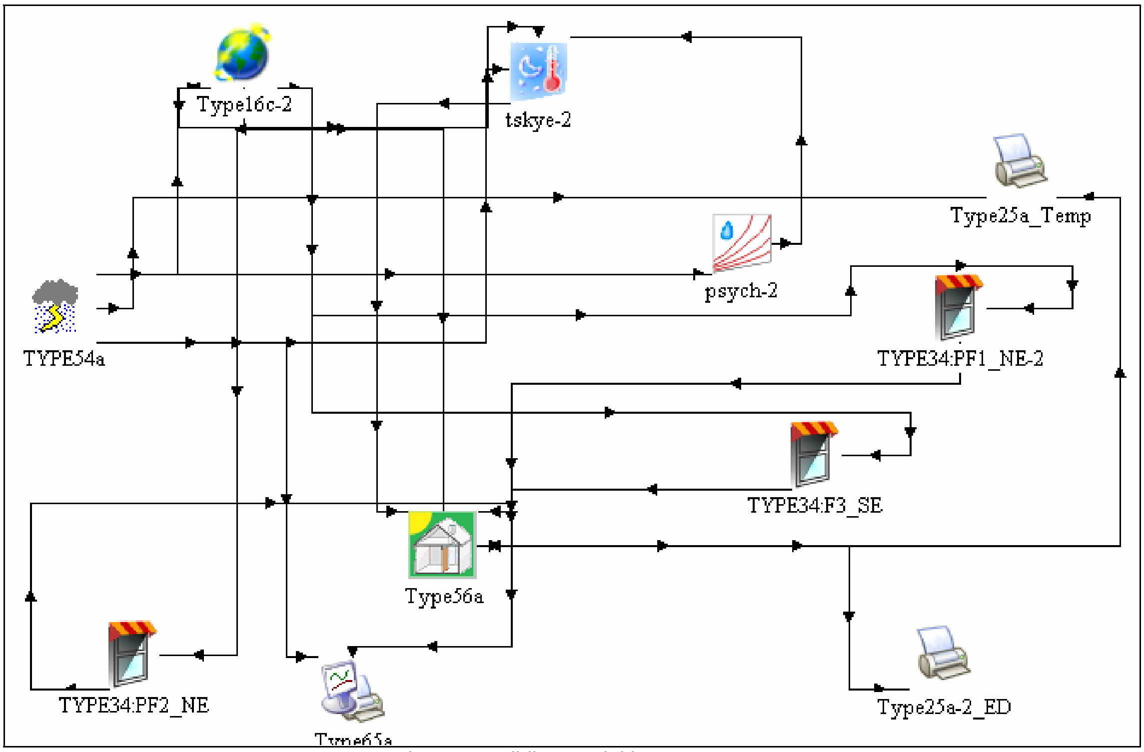

Figure 1: Building model in TRNSYS.

Concerning the definition of thermal load the main contents of the tool are the following:

- Transmission losses: the thermal transmittance must be inputted by the user. Pre-calculated thermal capacity of the structure and of thermal bridges, according to the characteristic of the structure. Several type of opaque surfaces can be defined.
- Ventilation/infiltration: fixed pre-calculated value, according to the air exchange and permeability of the envelope.
- Internal gains: fixed pre-calculated value.
- Solar gains: Several frames and flazing units are defined in the library. The user can edit the thermal losses coefficient and the solar factor. Solar gains through the envelope are neglected (or at least hidden to the user). Only a simple shading strategy is considered.

2. 3 Detailed steady state method

Recall PE is an instrument working with the steady state method, with monthly energy balance and utilisation factors. Being a design instruments, the method can be applied in new and existing buildings, even not residential.

The whole building is as a single zone model or can be divided into several zones, with or without thermal coupling. Unheated space, green houses and other solar passive systems can be coupled.

The engine is based on the EN ISO13790, fully implemented without simplifications. Among the others, the following features must be recalled:

- Thermal transmittance values are calculated starting fro the thermo-physical properties of the single layers. Thermal bridges must be accurately described and inputted.
- Thermal losses to the ground are defined according to the relevant standard procedures.
- Solar shading is evaluated by means of the obstruction coefficients.
- Solar absorptance of the opaque components must be inputted.

The dynamic parameters are calculated on the basis of accurate data inputted by the user, in terms of thermal capacity of the building structure.

2. 4 Dynamic Method

TRNSYS is one of the most famous and used instrument for the dynamic analysis of energy performance of buildings [7]. The instrument operates by means of hourly energy balance of the thermal zone, using the z-transform method. Because of its peculiarity the physical description comparison with other instrument is meaningless, on the other side the evaluation and the comparison of the results is interesting.

The TRSNYS project is presented in Figure 1, every object is a subroutine, whom a phase of the calculation is assigned to. In particular:

- Weather data Generator e Radiation Processor (Type 109) read and elaborate the external weather data. The relevant national standards were used as source in this case. The monthly temperature, specific humidity and solar horizontal radiation were inputted and transformed into hourly values.
- The Solar Radiation Processor elaborates the solar radiation data according to the selected sky model, then it calculates the amount of solar radiation on a generic surface with assigned azimuth and zenith angle.
- Psychometrics (Type 33): elaborates the temperature and specific humidity data and

calculates the related characteristic of the humid air.

- Effective sky temperature for long-wave radiation exchange (Type 69) is used to calculated the thermal radiative exchanges between the sky and the external building envelope
- Multi-zone building (Type 56): models the building (or the single zones it is divided in) thermal behaviour. Thermo-physical properties of the building as well as the energy systems characteristics and operative set point are here defined and inputted.
- Overhang and fins shading (Type 34) defines the solar shading due to fixed element of the structure projecting shades on the glazing units.

2. 5 The reference building

A simple reference building was selected for this exercise. It is a single story detached family house, representing a not negligible portion of the national residential building stock, in terms of geometry, size and typology.

The building is located in Rome, climatic zone D with 1415 heating degree days. The net area is 103 square meters and the volume is 289 cube meters, typical Italian house in size, as emerged in the last census held in 2001. The shape is a simple parallelepiped, rectangular in plan and with the flat roof.

The building was modelled in two ways: a single thermal zone (for all the four selected software) and two thermal zones (for the two detailed instruments), respectively night and day zone. This option was chosen in order to verify the loss in accuracy when modelling in mono-zone. The building plan and its thermal zones are shown in Figure 2. The south east/north east building façade view is presented in Figure 3.

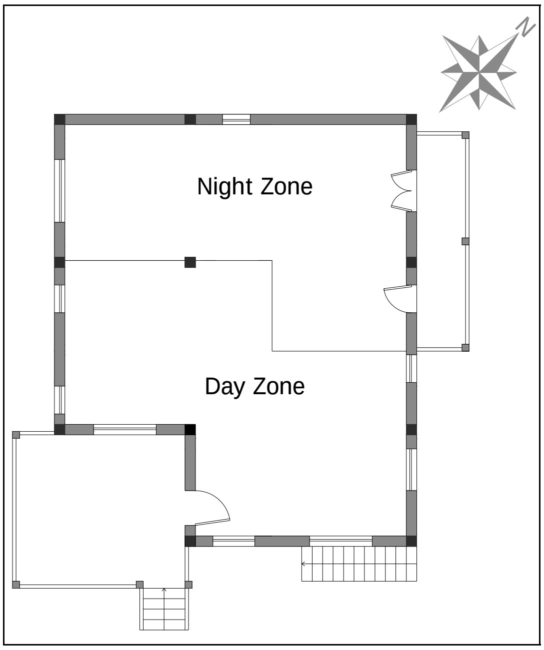

Figure 2 Plan view of the reference building. To be noted the external awnings and the two thermal zones, night and day respectively.

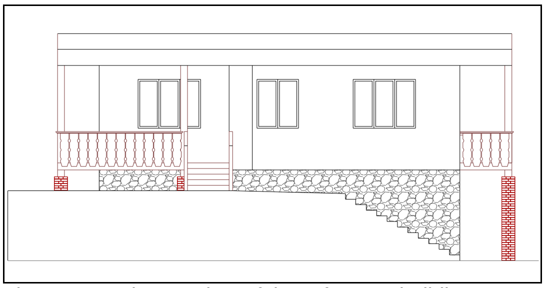

Figure 3 South east view of the reference building

Concerning the operative set point, the internal temperature is fixed at 20°C. The heating system is working 24 hours per day. The set point is operative for all the heating season, lasting from 1st of November until mid April, according to the national relevant law. The heating power is unlimited, acceptable approximations being working on the net energy demand only. Other specific operative conditions are summarised in Table 3.

Some comments are needed. The simplified tools are based on pre-calculated values that cannot be changed. They are also lked to the way the tools recalculate some geometry data starting from the way they were inputted. This means, in practice, that not all the operative set point are the same for all the software: as an example DOCET has 3 W/m^2 as internal gains, while BestCLASS has 2.25 W/m^2. The same apply with the ventilation/infiltration rates, linked to the net and gross volume of the building. These differences are born with the models and cannot be changed. The situation is even more critical with the solar gains management. Detailed tools allow the implantation of effective shading due to overhang and fins, simplified tools have internal pre-calculated reduction factors, which cannot be controlled nor edited.

The reason of such differences is the necessity of calculating in standard conditions, issue followed by all the tools developed with energy certification objectives.

Table 3: Operative set point of the building.

Parameters	Operative Set-point
Heating Temperature	20
Heating Power	Unlimited
Ventilation Rate	0,6
Solar Control	Fixed
Internal gains	3

Table 4: Characteristics of the opaque and transparent envelope components.

Structures	Thickness [m]	U-value [W/m^{2}K]
Wall	0.33	0.342
Ground floor	0.36	0.351
Flat roof	0.46	0.314
	[mm]	
Windows	4-16-4	2.5

The structure of the building is in reinforced concrete. Vertical walls are made of two hollow brick layers, with air gap and insulation in between. The horizontal components are made o a mixed concrete and clay tiles structure with insulation, the floor is directly coupled to the ground. The U values of the building components are presented in Table 4. The data were chosen according to the minimum required values for the building envelope, as defined by the national laws for the climatic zone Rome belongs to. The windows have U-value of 2.5 W/m^{2}K, obtained with a conventional double glazing unit (16 millimetres of air gap) and wooden frame. The solar absorptance of walls and roof is respectively 0.6 and 0.75. Because of the aim of the study, the same data were also used in Milan and Palermo, even if according to the national regulation, different values have to be adopted, being in different climatic zones-

3. Results

The simulations were run for six configurations:

1. DOCET single zone
2. BestCLASS single zone
3. Recall PE single zone
4. Recall PE two zones
5. TRNSYS single zone
6. TRNSYS two zones

The results, obtained for the selected cities and, expressed with the official indicator kW/m^2 per year, are summarised in Table 5. The results, following commented, show a good accordance among the steady state methods, despite their accuracy. The TRNSYS results are lower of 25 to 35%, for the different software.

Table 5: Net energy calculation results.

Tool	**Net energy** [kW/m^2 year]		
	Rome	Milan	Palermo
1	60.8	110.7	30.8
2	59.9	105.9	29.5
3	56.1	100.7	28.3
4	56.0	100.8	28.4
5	40.7	75.51	17.5
6	40.8	76.7	17.3

Table 6: Steady state instruments - comparison of energy balance.

Tool	**Energy Flow** [kW/m^2 year]		
	Gains	Transmission	Ventilation
		Rome	
1	36.2	76.4	17.7
2	22.7	59.5	22.8
3	53.9	67.7	22.7
		Milan	
1	32.3	113.5	26.6
2	20.6	91.5	35.0
3	54.2	103.9	34.9
		Palermo	
1	27.9	45.5	10.5
2	20.1	35.4	13.6
3	36.7	38.2	12.8

More details are needed to analyse how the not dynamic instruments work. Table 6 compares the energy balance of the steady state methods (Recall PE mono-zone only). It is clear that differences are present in the single energy *fluxes* and in the calculation of utilisation factors.

Recall PE has higher gains, since Docet and BestCLASS have internal correction factors that reduce the solar gains. BestCLASS, moreover, does not consider solar gains through he opaque components of the envelope. Recall PE and BestCLASS are very close for the ventilation losses, while the latter seems to underestimate the transmission losses respect to the former. DOCET acts on the opposite way, probably due to internal incremental correction factors, but seems underestimating the ventilation losses.

These factors are estimated in a different way: BestCLASS has an utilisation factor conversion practically 1 in all the cases. Recall PE factors range between 61 (Palermo) and 70% (Milan). DOCET factors are very close to 90% in the three cities.

To be noted that the steady state instruments are close to each other (always less than 5% respect to the average value) and the more simplified is the tool, the more conservative is the result. Moreover, the simplified instrument DOCET is conservative by less than 10% respect to the detailed Recall PE.

4. Conclusions

The exercise showed how steady state tools, even if based on different method and approximations, lead to very close results in terms of net energy demand. Larger differences are found when analysing the single energy fluxes and the utilisation factor on season bases. It is hence important entering more in detail in the various methods, to find out the way the simplifications influences the calculation engines. It is also important repeating the exercise with other building sizes and geometry.

In general we can admit that evaluation methods are acceptable, especially for existing buildings. In those cases detailed method are time and money consuming and, more over, the results show that not big differences are calculated.

The TRNSYS results are by far lower, and this was partly surprising. A lower energy demand, was generally, expected but not with this magnitude. Such differences need to be interpreted more in detail, to check if and how where methods diverge: overestimation of losses in steady state methods, or may under estimation of solar gains? This aspect will be covered in the next figure when a larger set of tools (from simplified to fully dynamic) will be investigate and compared.

Next step of the research will also include the investigation of different building types in terms of geometry and thermal properties.

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