Energy performance of buildings: comparison between a dynamic model and a normalized method

PAOLO VALDISERRI, KRISTIAN FABBRI and LAMBERTO TRONCHIN
DIENCA-CIARM, University of Bologna,
Viale Risorgimento, 2 I-40136 Bologna, Italy www.ciarm.ing.unibo.it

ABSTRACT
The European directive 2002/91 introduces some modifications regarding energy performance of buildings as well as of HVAC systems. Buildings are to be thought as "containers" where, by a careful planning of the envelope and plants within, the designer must foster indoor comfort conditions. These needs, together with the growing increase in the cost of energy, have led to a modification of the energy scenarios. The integration between HVAC systems and building envelope has now to meet both the requirement of higher life standards and the reduction in energy consumption.
The present work develops a dynamic model, employing DesignBuilder, a code in Energy Plus environment, for the evaluation of the primary energy needs.
DesignBuilder allows modelling buildings in 3D space environment. Moreover, it contains a rich database with many different materials and European climate information. It also allows changing of significant part of buildings.
The annual heating requirements have been evaluated for different building typologies, which are characterized by a variable number of floors and different values of the ratio between the dispersing surface and the volume.
The analysis has been conducted on constructions placed in Bologna, in the north-centre of Italy. The results are compared with those obtained applying the European Standard method.

1.INTRODUCTION

During the last decade new Directives of European Community have been directed on energy savings in the environments. Regarding building constructions, the Directive 2002/91/EC: "Energy Performance of Building" (EPB) and the Directive 2006/32/EC: "Energy use efficiency and energy services and repealing" concern with wrapper building and thermal plants efficiencies. Energy certification of buildings move into this direction: the best classes A and B represent a target in building design, which consider both enhancements in wrapper dispersion and thermal plant efficiency. Energy Audit becomes an important activity in building sector to promote energy efficiency solution and improvement retrofit. However, Energy Audits does not represent a simple application of software or model calculations but it is rather an "evaluation procedure" which includes the choice of calculation models.
In this paper two calculation methods (a dynamic model and a normalized method) are considered and applied to two different buildings typology located in the north-centre of Italy, divided into two subcategories of S/V ratio. The analysis will allow comparing the results obtaining from the two methods in order to evaluate the differences between the two methodologies, and to estimate the errors that would arise in case of application of the simplified method by a not-expert user.

2. METHODOLOGIES

The two methodologies utilised in this paper refer respectively to the European directive 2002/91/EC "Energy Performance of Buildings". In the first case the calculation has been carried out considering the EN ISO 832 and EN ISO 13790 calculation procedure, which consider the energy requirements of building in the static (or simplified) whilst in the second case the energy requirements have been calculated considering all parameters and all energy exchange during all year, and takes into account each day and meteorological variations.

2.1 STATIC (OR SIMPLIFIED) SIMULATION
The static simulation is based on EN 832 and 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. On the other hand, this method requires less input data, without graphic 3D models.
For the static simulation an excel worksheet has been developed, following the "CTI Recommendation R03/3" (CTI: Italian Termotechnical Committee is an Italian normative organism) and has been therefore utilised.

2.2 DYNAMIC SIMULATION
The second methodology is called "dynamic simulation" because it could include all parameters and all energy exchange during all the year, and takes into account each day and meteorological variations, and therefore it differs from other evaluation method (named "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: outside temperature, sun irradiation, etc.;
- Building geometry and building envelope thermo-physics characteristics;
- Use of building and metabolic data of final user;
- Plant system: heating and conditioning, lighting and electric domestic appliance.
- Renewable Energy Sources.

For the dynamic simulation the software DesignBuilder, based on Energyplus code provided with 3D interface and meteorological database, has been used. It is based on the most popular features and capabilities of BLAST and DOE-2, stand-alone simulation.

3 THE CASES STUDY

In order to compare the two methodologies, two detached buildings belonging to two different typologies have been considered: a line typology and a tower typology. In figure 1 the two plants of the buildings are shown. The buildings were both considered as located in Bologna, in the north-centre of Italy. The climate is fairly cold in winter and humid in summer, since Bologna is located at more than 100 km from the sea.

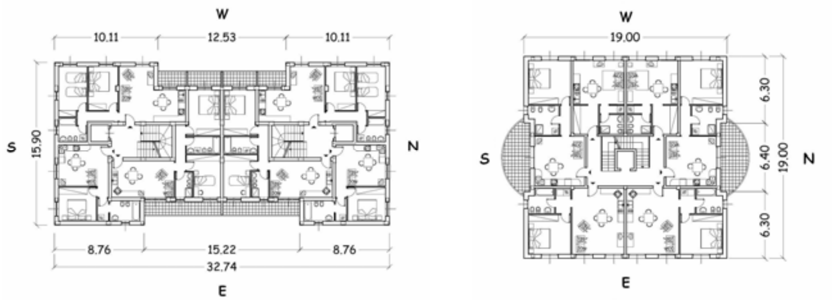


Figure 1. – Buildings' plants: line (sx) and tower (dx)

The two typologies differ each other for their S/V ratio, which would influence the energy performance of each building. Moreover, in both cases two different dimensions of the structure were considered: an 8-floor and a 16-

floor tower building, and a 2-floor and 5-floor line building. Consequently, the S/V ratio ranged from 0.262 to 0.536 [m^{-1}].

Table 1. S/V ratio for the four buildings.

	Line building		Tower building	
	2-floors	5-floors	8-floors	16-floors
S/V ratio [m^{-1}]	0.536	0.359	0.301	0.262

For each building the external walls are supposed to be composed with two layers of bricks, interposed with insulation material between them. Both the ground-floor, and the roof are made of concrete with thermal insulation. The window frames are made of wood and double-glazed.
The four buildings have the following internal net surfaces (table 2):

Table 2. Internal net surfaces for the four buildings.

	Line building		Tower building	
	2-floors	5-floors	8-floors	16-floors
Int. Surface [m^2]	755	1888	2426	4852

As required by the Italian decrees (DLs 192/2005 and 311/2006) the following values for transmittances for the climate zone of Bologna (which would be in force starting from 2006) have been considered throughout the simulations:

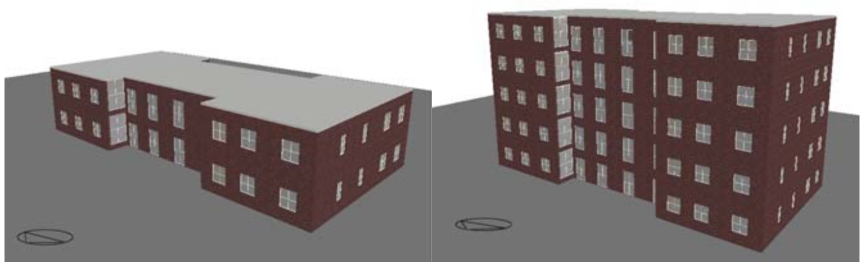
- 0.46 $\left[W/m^2K\right]$ for external walls;
- 0.43 $\left[W/m^2K\right]$ for the roof;
- 0.43 $\left[W/m^2K\right]$ for the basements and floors;
- 2.80 $\left[W/m^2K\right]$ for windows.

The heating plant is composed by a central heating generator having the following characteristics (table 3):

Table 3.characteristics of the thermal plants.

	Line building		Tower building	
	2-floors	5-floors	2-floors	5-floors
COP	0.80	0.81	0.81	0.82

In figure 2 the rendering of the four buildings utilised in the simulation are reported.



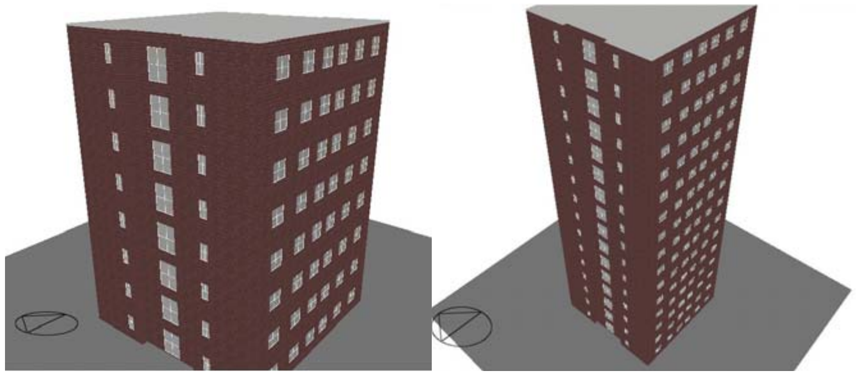


Figure 2 – View of Cases Study

4. RESULTS OF SIMULATIONS

In the following tables the results of both the methodologies are reported. All the energy parameters (e.g. Q_L, Q_G, Q and Q_V) have been calculated based on the reference period ranging from October 15th to April 15th, that corresponds to the standard heating period for Bologna, as required by the Italian law. DesignBuilder utilised the meteorological data referred to 2002-2003. The averaged external temperature used in the "static method" was 7.3 °C.

Table 4. Results of simulations for different evaluation methods

Total heat losses (Q_L) [kWh] (transmission + ventilation)	Line building		Tower building	
	2-floors	5-floors	8-floors	16-floors
"Dynamic simulation" (DesignBuilder)	69615	130874	138223	263411
"Static simulation" (EN 13790)	63287	127527	140842	265798

Total gains (Q_G) [kWh]	Line building		Tower building	
	2-floors	5-floors	8-floors	16-floors
"Dynamic simulation" (DesignBuilder)	21816	54331	66947	133995
"Static simulation" (EN 13790)	21648	54121	73559	147119

Energy use for heating (Q) [kWh]	Line building		Tower building	
	2-floors	5-floors	8-floors	16-floors
"Dynamic simulation" (DesignBuilder)	58794	92934	88189	155337
"Static simulation" (EN 13790)	53156	97814	98004	181078

The comparisons between total heat losses calculated with the two methods underlined a fair matching between static and dynamic methods, since they differed for a quantity less than 3%. A slight more mismatch was found in the 2-floor line building (9%). Comparing total heat gains (e.g. internal heat gains and solar gains), no appreciable differences were found in the "line buildings", whereas in the "tower building" the two methods gave slightly different results. The "static method" overestimated total heat gains for about 10% with respect to Designbuilder. The third table reports the energy use for heating. In this case, the results obtained by the two methods fairly differ each other. It would require including the ventilation heat losses during the evaluation.
A further analysis regarded the ventilation heat loss. The "static" method assigns a ventilation rate of 0.3 Volume (net) per hour, whilst the "dynamic" method considers one person per 25 m^2 and a ventilation rate of 10 litres per second per person. Moreover, during the simulation with DesignBuilder, the air infiltration has been set to 0.1.

Table 5. Results of simulations for different evaluation methods

Ventilation heat loss (Q_v) [kWh]	Line building		Tower building	
	2-floors	5-floors	8-floors	16-floors
“Dynamic simulation” (DesignBuilder)	19072	33876	34742	68438
“Static simulation” (EN 13790)	11277	28193	36219	72436

In table 5 the results coming from both the methodologies are reported. Considering the results of the line building, a relevant difference between the two codes was found. The 2-floor line buildings resulted quite variable, since the two methods differed for more than 40%. Nevertheless, the tower buildings fairly agreed.
In figure 3 and 4 the output data from Designbuilder are reported for the “Line 5-floors” and the “Tower 8-floors” buildings. These two buildings resulted significantly comparable each other for their energy requirements, even though the tower building has the internal net surfaces which is fairly greater with respect to the line building.

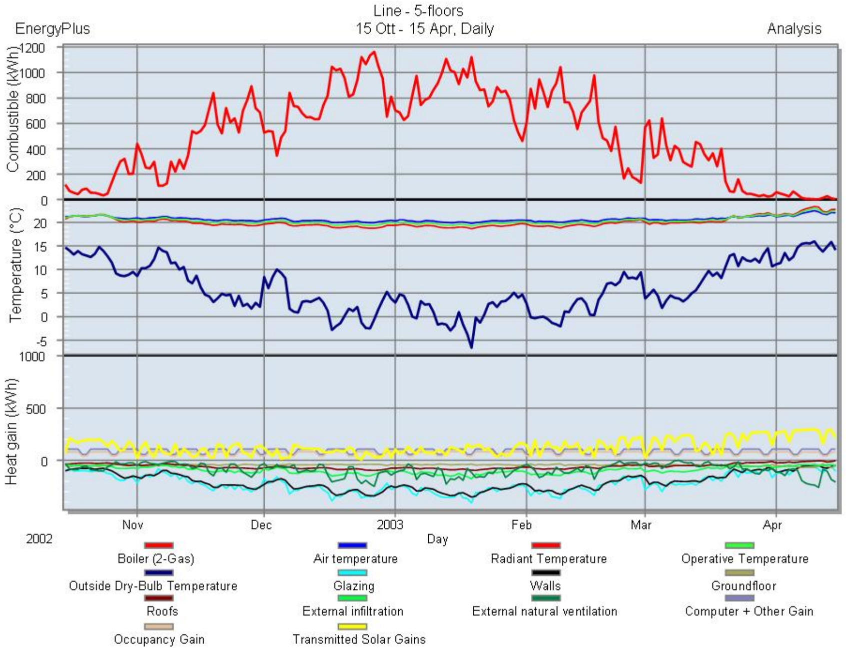


Figure 3 – Output data from DesignBuilder –Line 5-floors

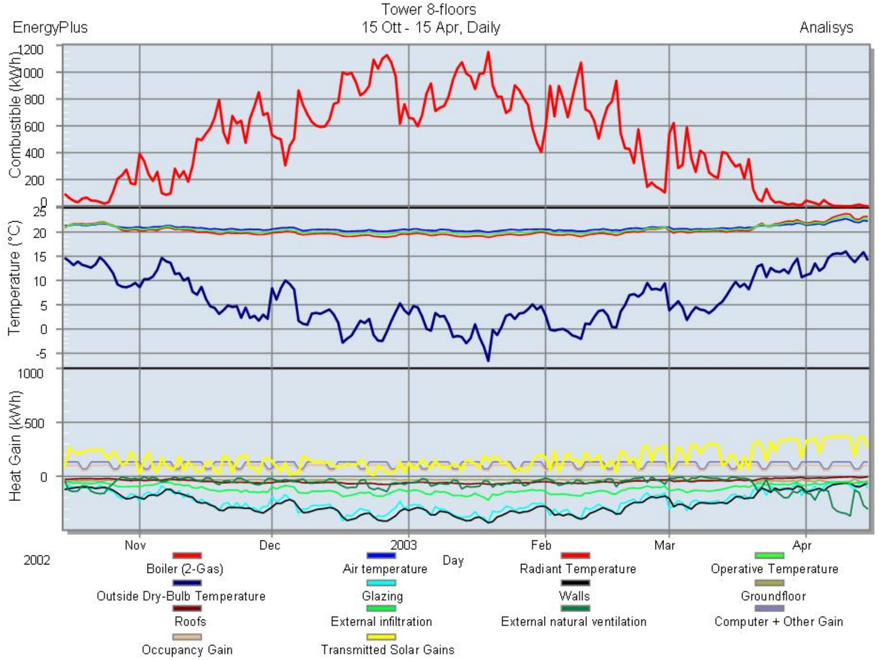


Figure 4 – Output data from DesignBuilder – Tower 8-floors

Input and output data, which differ considerable in the two methods, influence the behaviour of the two methods. Heating plants, and electric and lighting plants are included in the dynamic method, as well as wrapped thermo-physic characteristics and all energy use. Moreover the output is reported to gas and electric grid consumption during year regime for heating, cooling, domestic hot water, and lighting standard use.
The static method, which is based on EN 832 and EN 13790, includes only the input data that are related to wrapped thermo-physic characteristics and heating plant. The outputs are reported to heating without considering the energy carriers, the data meteorological variation during each month, and electric uses.

5. CONCLUSION

The comparison between the two methodologies underlined some relevant results. The “static method”, which is based on the EN 832 and EN 13790, allowed an easy calculation of heat losses and energy requirements even for quite complicated buildings. On the other hand, the “dynamic method”, which evaluates the energy efficiency of buildings based on the local meteorological conditions, provides much more detailed information. However, the large number of data input required by DesignBuilder, could have an effect on the results. In order to obtain results comparable with real energy requirements, a proper knowledge of thermo-physics of buildings and of the software is required.

6. REFERENCES

- DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002 on the energy performance of buildings
- DIRECTIVE 2006/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC
- prEN 15603 "Energy performance of buildings — Overall energy use, CO2 emissions and definition of energy ratings"
- prEN 15217 "Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings"
- prEN ISO 13790 REVIEW "Thermal performance of buildings - Calculation of energy use for space heating and cooling (ISO/DIS 13790:2005)"
- UNI EN ISO 13790:2005 Prestazione termica degli edifici - Calcolo del fabbisogno di energia per il riscaldamentoThermal performance of buildings - Calculation of energy use for space heating
- UNI EN 832:2001 "Prestazione termica degli edifici - Calcolo del fabbisogno di energia per il riscaldamento - Edifici residenziali. Thermal performance of buildings - Calculation of energy use for heating – Residential buildings."
- K. Fabbri, "Energy performance of buildings: consumption and methodologies", Proc. of CLIMAMED 2007, Genoa, Italy, 5-7 September 2007
- K. Fabbri and L. Tronchin "Level of comfort in a traditional architectural typology: study the change to the level of comfort to know a ga-energy-need in a sustainable perspective" proc. of PLEA 2004 – The 21 Conference on Passive and Low Energy Architecture, Eindhoven, Netherlands 19-22 September 2004.

COMPUTER PROGRAMS
Software "DesignBuilder software 1.3.3" Ltd 2005-07 http://www.designbuilder.co.uk/

Energy performance of buildings: comparison between a dynamic model and a normalized method

PAOLO VALDISERRI, KRISTIAN FABBRI and LAMBERTO TRONCHIN
DIENCA – CIARM, University of Bologna,
Viale Risorgimento, 2 I-40136 Bologna, Italy www.ciarm.ing.unibo.it

Presenter:

Arch. Kristian Fabbri's CV

Kristian Fabbri bachelor in Architecture degree to Milan Polytechnic. Since 2002 collaborate with Valerio Tarabusi and Ing.Lamberto Tronchin in Environmental Physic Technique in University of Bologna - Faculty of Architecture. In the same time is an Architect professional man and adviser about energy: renewable energy sources and energy saving in buildings and urban planning. Since 2006 collaborates with NuovaQuasco and Emilia-Romagna region to adopt the 2002/91/Ce European Directive and urban planning. He is an author of several papers on energy behaviour in traditional architecture and plant in retrofitted building, energy saving in buildings and energy certification.

ABSTRACT

Prestazione energetica degli edifici: confronto tra un modello dinamico e un modello normalizzato

PAOLO VALDISERRI, KRISTIAN FABBRI and LAMBERTO TRONCHIN
DIENCA – CIARM, University of Bologna,
Viale Risorgimento, 2 I-40136 Bologna, Italy www.ciarm.ing.unibo.it

La Direttiva europea 2002/91 introduce alcune modifiche in relazione alla prestazione energetica degli edifici, nonché degli impianti termici. Gli edifici devono essere considerati come contenitori, all'interno dei quali attraverso una attenta progettazione dell'involucro e degli impianti all'interno, il progettista deve garantire confort interno ed esterno. Queste necessità, assieme al crescente costo energetico degli edifici, ha portato a modificare l'approccio energetico della progettazione dell'edificio. L'integrazione tra impianti termici e involucro edilizio deve ora andare incontro sia alla richiesta di uno standard di vita superiore, sia alla riduzione dei costi energetici

Nel lavoro qui presentato viene sviluppato un modello dinamico del funzionamento energetico dell'edificio, all'interno del codice di simulazione DesignBuilder, che opera in ambiente Energy Plus, in grado di valutare le esigenze di energia primaria. DesignBuilder consente di modellare in tre dimensioni gli edifici. Inoltre, esso contiene un ampio database dei dati climatici relativi a numerose città sparse nei vari stati europei. Esso infine consente di effettuare modifiche in parti significative degli edifici.

Le esigenze energetiche degli edifici sono state valutate su diverse tipologie di edifici, che si differenziavano per diversi numeri di piani e rapporti tra superficie disperdente e volume. L'analisi è stata condotta su edifici collocati nell'area climatica di Bologna. Infine, tali dati sono stati confrontati con quanto ottenuto applicando il metodo europeo suggerito dalla norma EN 832 e EN 13790(metodo statico).