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Numerical assessment of heating energy demand for office buildings in Italy

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Abstract

Buildings energy consumption depends on several parameters, such as climate, envelope typologies, occupant behavior, intended use, etc.; assessment of the energy performance of a building requires substantial input data describing constructions, environmental contexts, thermo-physical properties, geometry, control strategies and several other parameters influencing the thermal balance. In the last years, several numerical approaches dedicated to building simulation have been tested developing specialized software. On the other hand, simplified building models permit the evaluation of indoor conditions and heating/cooling loads with a good level of accuracy and without excessive computational costs or user expertize. The authors tried to establish a set of simple correlations to permit a fast preliminary assessment of heating energy demand for office buildings. Data employed to build the correlations come from detailed dynamic simulations performed in TRNSYS 17 environment; these models were build according to the legal limits of Italian standards and laws concerning low energy requirements. The authors identified specific locations for different Italian climatic zones and simulated three models with different shape factors (S/V = 0.24, 0.5 and 0.9). The obtained results allowed to determine simple and direct correlations among heating energy demand, Heating Degree Days and S/V values.

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Keywords: heating energy demand; HDD; shape factor; dymanic simulation.

1. Introduction

In the European Union (EU), buildings account for about the 40% of the total energy consumption and they represent the largest sector in energy end-user area, followed by transport with the 33% [1]; whereas in terms of CO_2

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emission, buildings are responsible for about 36% of it. Energy is employed for different purposes, but the dominant energy end-use is space heating [1,2]. In order to achieve relevant saving of primary energy, several potential mitigation measures can be implemented involving the building envelope, indoor condition, heating/cooling systems, etc. [3]. In this context, the 91/2002 ‘‘Energy Performance of Buildings Directive’’ (EPBD) [4] has been enacted to introduce several requirements for new and existent buildings within EU; in Italy this Directive was transposed into the 192/2005 Decree [5]. The energy consumption of a building can be influenced by several parameters, such as climate, envelope typologies, age of construction, occupant behavior, intended use, etc.; a detailed evaluation of the energy performance requires several input data to solve the energy balance. In this context, many simulation tools have been developed to evaluate building performances [6], based on different approaches and with a lack of common language [7]: numerical approaches have been developed and tested [8-11], and most of them have been implemented in software dedicated to building simulation such as DOE-2, BLAST, Energy-Plus, TRNSYS, ESP-r, and SPARK [12]. On the other hand, simplified buildings models permit the evaluation of energy requirements and indoor conditions with an acceptable level of accuracy without excessive computational costs [13]. Indeed, in the common standards, steady state models are used to determine the energy performance of a building [14,15]. Thanks to their fast calculations, this approach assesses the energy performance in a simple way and conducts long term analyses on different scenarios involving several energy efficiency measures [16,17]. These kind of models are commonly used for preliminary building design and for scenario analyses; in particular, among the climatic parameters, the Degree Days (DD) indicator can be used to quantify the heating and cooling energy demands permitting, in a simple way, to obtain a first assessment of buildings consumption [18,19]. Many studies used DD for analyzing regional climate characteristics and to predict energy demand [20-22]. The determination of the energy performance of a building taking into account only on climatic context, may lead to an imprecise evaluation because it is totally unlinked to the thermophysical characteristics of the envelope and to the shape factor of the building. The following work rises in order to help the designer for a preliminary assessment of the energy performance of a non-residential building, designed as dictated by national law. The use of a simple and reliable correlation can provide the thermal energy requirements, allowing the designer to not use any simulation software, and then to accelerate the entire evaluation process. The presented study is based upon the development of a set of dynamic models of “ideal non-residential buildings” in TRNSYS software environment [23] built according to the energy legal limits of different climatic zones of Italian peninsula [24]. For a more general approach, authors have chosen three cities that represent the maximum, minimum and average Heating Degree Days (HDD) value for each climatic zone; furthermore, for each city, three models with different shape factors (S/V = 0.24, 0.5 and 0.9) have been simulated. The results obtained from the detailed simulations in TRNSYS have been employed to build strong correlations among heating energy demand, HDD and S/V values. In detail, applying the least squared method it was possible to identify simple correlations, valid for each climatic zone and for the Italian territory, obtaining high correlation coefficients R^2

Nomenclature

DD	Degree Days [°C ·day]
H_d	heating energy demand [kWh/m^2 year]
HDD	Heating Degree Days [°C·day]
R^2	correlation coefficient
S	surface area with thermal losses [m^2]
S/V	shape factor or losses surface to volume ratio or compactness [m^{-1}]
T_i	average daily temperature [°C]
T_r	indoor thermal comfort temperature [°C]
T_s	reference temperature [°C]
U_{floor}	floor thermal transmittance [W/m^{2}K]
U_{roof}	roof thermal transmittance [W/m^{2}K]
U_{wall}	wall thermal transmittance [W/m^{2}K]
U_{window}	window thermal transmittance [W/m^{2}K]
V	heated volume [m^3]
θ_1	correction coefficient [kWh/m^{2}year]