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# Tightening the energy consumptions of buildings depending on their typology and on Climate Severity Indexes

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ABSTRACT

This paper aims to present the more recent advances regarding the climatic zoning based on the Climate Severity Index and its relation with the building energy requirements. Three are the major contributions in this paper, the first one is the comparison of the energy performance requirements in different European Union Member States; secondly the definition of the global Climate Severity Index, and finally the definition of the Climate Severity Index for tertiary buildings. Regulators and building designers are the most interested in these results. The comparison of the energy requirements, gives to the regulators, valuable information in order to establish a consistent requirement in their own country. Thanks to the definition of the Global Climate Severity Index, the previous can be done in terms of global-heating plus cooling-energy needs, allowing a homogeneous comparison along Europe or Worldwide. Also, these results allow comparing the energy requirements in one country to those with similar climate. From the designer point of view, the results of this paper could be used to estimate the thermal properties – *U* values – of the building envelope, and the solar shading factor of the windows of a tertiary building assimilating it to a residential building in an equivalent climatic zone.



## 1. Introduction

The Spanish Technical Building Code is one of the three royal decrees that were approved in Spain as a consequence of the transposition of the European Directive on the energy performance of buildings (2002/91/EU) [1]. One basic document of the Technical Building Code deals with the limitations in the energy needs of buildings, this Document was approved by Royal Decree 314/2006 of 17th on March [2]. Nowadays, due to the recast of the European Directive on the energy performance of buildings (2010/31/EU) [3], a revision process of the current regulations has begun, starting with the Technical Building Code, with its first revision envisaged for the end of 2011. In this article we, as collaborators in this revision process, describe and analyse the main advances and applications regarding the Spanish climatic zoning that are going to be introduced in the "new" Technical Building Code (TBC).

The concept of Spanish climatic zoning was introduced by Sánchez et al. [4] in accordance with a variable specifically defined for such purpose known as climatic severity [5], and starting from a concept formulated by Markus [6] whom defined a methodology which allows characterizing the hardness of any given climate on a building of known characteristics. This methodology is carried out by means of the calculation of the Climatic Severity Index (CSI), a single number on a dimensionless scale which is specific for each building and location. In [4] this methodology is implemented for Spain and the CSI is assessed as the ratio between the heating or cooling needs of a certain building and that which the same building has in a reference locality. Following this procedure, the Spanish TBC classify the 52 provincial capitals into 12 climatic zones resulting from feasible combinations of the 5 winter climatic zones and the 4 summer climatic zones; the winter climatic zones are identified by a letter from A (less severe) to E (more severe), on the other hand the summer climatic zones are identified by a number from 1 (less severe) to 4 (more severe).

This paper describes the definition of the climatic zones using the Climate Severity Index, and shows how the energy performance requirements fit with this index. It can be said that this work is the logical continuation of the future works described by Markus et al. [7]. This paper also includes the definition of a Global Climatic Severity Index that is introduced as a new concept; and the definition of the Climate Severity Index in tertiary buildings that is defined and related to the Climate Severity Index in dwellings.

## 2. Definition of climatic zones using the Climate Severity Indexes

To comply with the Spanish TBC in a given location, it is necessary to know the climatic zone since the energy performance

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**Table 1**
Coefficients of the winter Climatic Severity Index (WCSI) correlation.

| *a* | *b* | *c* | *d* | *e* |
|---|---|---|---|---|
| 3.546E−04 | −4.043E−01 | 8.394E−08 | −7.325E−02 | −1.137E−01 |

**Table 2**
Coefficients of the summer Climatic Severity Index (SCSI) correlation.

| *a* | *b* | *c* | *d* | *e* |
|---|---|---|---|---|
| 3.052E−03 | 1.784E−01 | −1.343E−07 | −2.339E−01 | −2.041E−01 |

**Table 3**
Assignation of climatic zones as a function of Severity Climatic Index for winter (left) and summer (right).

| Winter climatic zones | Winter Severity Climatic Index | Summer climatic zones | Summer Severity Climatic Index |
|---|---|---|---|
| A | $0 < \text{WSCI} \leq 0.23$ | 1 | $\text{SSCI} \leq 0.5$ |
| B | $0.23 < \text{WSCI} \leq 0.5$ | 2 | $0.5 < \text{SSCI} \leq 0.81$ |
| C | $0.5 < \text{WSCI} \leq 0.94$ | 3 | $0.81 < \text{SSCI} \leq 1.35$ |
| D | $0.94 < \text{WSCI} \leq 1.51$ | 4 | $\text{SSCI} > 1.35$ |
| E | $\text{WSCI} > 1.51$ | | |

requirements depends on it. The climatic zoning of a location depends on the winter and summer climatic severity of this location.

In order to assign climatic zones with climatic severities, two correlations were developed by Sánchez et al. [8]. In general, these correlations give the climatic severity as a function of degree-days and radiation. There is a bi-univocal correspondence between the climatic zone and the climate severity, each climatic zone corresponds to a range of climate severity.

For the winter Climatic Severity Index (WCSI), the correlation depends on the winter degree-days in basis 20, DD, and, on the ratio between the total number of hours with sun and the total maximum hours with sun, n/N. Both parameters are evaluated for the months from October to May. Next equation has to be used:

$$\text{WCSI} = a \times \text{DD} + b \times \frac{n}{N} + c \times \text{DD}^2 + d \times \frac{n}{N}^2 + e$$

With the next coefficients (Table 1):

Summer Climatic Severity Index (SCSI) is assessed from the same parameters than winter climatic severity but evaluated in the summer months; this is from June to September. The equivalent equation is the next:

$$\text{SCSI} = a \times \text{DD} + b \times \frac{n}{N} + c \times \text{DD}^2 + d \times \frac{n}{N}^2 + e$$

where the coefficients that have to be used are the next (Table 2):

The assignation of the climatic zone as a function of the Climatic Severity Index follows the next criteria (Table 3).

Next table shows the feasible (white) and unfeasible (gray) climatic zones in Spain (Table 4):

**Table 4**
Feasible and unfeasible climatic zones for the Iberian Peninsula.

| | α | A | B | C | D | E |
|---|---|---|---|---|---|---|
| 1 | | | | C1 | D1 | E1 |
| 2 | | | | C2 | D2 | |
| 3 | | A3 | B3 | C3 | D3 | |
| 4 | | A4 | B4 | C4 | | |

**Table 5**
Maximum heating energy needs (kWh/m$^2$) in single-family and multi-family dwellings in Spain.

| | Winter climatic zone | | | | | |
|---|---|---|---|---|---|---|
| | α | A | B | C | D | E |
| Single-family dwellings | – | 19.9 | 28.6 | 50.7 | 75.1 | 97.6 |
| Multi-family dwellings | – | 10.0 | 16.8 | 32.9 | 50.2 | 65.4 |

## 3. Energy performance requirements as a function of the climatic zone

The tightening of the Technical Building Code was carried out by determining new requirements in order to limit the energy needs for heating and cooling. The required energy savings were fixed for the heating needs using a cost-optimal approach. This methodology evaluates the energy savings as a function of the life cycle cost. The optimum is defined as the point where the life cycle cost is minimized. To limit the cooling needs, energy savings of 20% are fixed acting only on modifications of the solar factor. Using this approach the next values were proposed in the update of the Spanish Technical Building Code (Tables 5 and 6):

The contribution of this article described in this chapter, is the comparison of the previous values with the energy requirements in other EU countries. This comparison is possible if we graphic them as a function of the CSI.

The definition for the CSI for heating or cooling needs is the ratio between the heating or cooling needs of a certain building and that which the same building has in a reference locality. In particular, for Spain, Madrid is the reference locality, but this can be changed without loss of generality for any other location. We developed a CSI with Brussels as reference location to compare the normative energy requirements in buildings throughout Europe. Once, the pivot climatic location is selected the next step is to select a sample of building typologies common in the geographic area, this selection consisted on a 3 stories, multi-family, detached house; finally, the climatic conditions covering the different climates of Europe (typically by means of their TMY or TRY) were selected. The cities below represent such climates:

- Bruxelles (Belgium, BE)
- Prague (Czech Republic, CZ)
- Berlin (Germany, DE)
- Copenhagen (Denmark, DK)
- Paris (France, FR)
- Oslo (Norway, NO)
- Roma (Italy, IT)
- Helsinki (Finland, FI)
- Amsterdam (Netherlands, NL)
- Warschau (Poland, PL)
- Sevilla, Madrid, Burgos (Spain; SP S, SP M and SP B respectively)

The energy needs of the buildings under 16 different scenarios were calculated via computational simulations in each location. Every scenario is a combination of 4 orientations and 4 insulation levels. The results of every combination run for the selected climatic conditions were reduced and provided the CSI for this combination.

**Table 6**
Maximum cooling energy needs (kWh/m$^2$) in single-family and multi-family dwellings in Spain.

| | Summer climatic zone | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Single-family dwellings | – | 10.0 | 17.2 | 26.7 |
| Multi-family dwellings | – | 10.0 | 11.6 | 18.3 |