DIPLOMARBEIT

A COMPARATIVE STUDY OF BIOCLIMATIC DESIGN STRATEGIES IN AUSTRIAN AND SPANISH BUILDING ENERGY CERTIFICATES

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ABSTRACT

Over the last years the European Union has released several restrictive regulations targeting the reduction of CO2 emissions caused by the building sector and has also set considerably ambitious goals for the future. Among the obligations already implemented, the obligation that caused a larger impact over the last decades is the introduction of a mandatory Energy Performance Certificate (EPC) for buildings. Even though the controversy of its introduction, the EPC is at present the only source of EU building stock energy consumption data, therefore crucial for the EU objectives.

Thus, the objectives of this Thesis are to identify if the EPCs in two European Union Member States (MS), Austria and Spain, are sensitive to the bioclimatic architecture. This approach to architecture, adapted to the regional climatic conditions, has already been largely studied and proved to have efficient strategies to create comfort in buildings with low energy consumption. Another objective is to recognize if the EPCs from the two MS are comparable and therefore if it could be possible to have a common single EPC for all EU MS.

In order to achieve the objectives of this Thesis a steps methodology has been developed for this study. The methodology starts with a comparative literature review of the legal framework, from the EU level to the local building codes. The comparison includes a detailed analysis of the indicators used in both EPCs. On a later step, a review of the bioclimatic architecture passive strategies described in the available literature is carried out. Also, the building stocks and climate conditions in both countries are analyzed to select passive construction strategies with potential to achieve thermal comfort. In the last steps, the evaluation part, it is assessed if the previously selected techniques are considered in the EPC schemes and if the comparability of both EPC schemes is feasible.

After following the steps methodology, the outcome of the comparative literature, based on 72 compared aspects, show that even if both countries are EU MS, and therefore share common directives, the EPC schemes present rather significant differences between Austria and Spain.

Also, the obtained results about the sensitiveness of the EPC schemes towards the bioclimatic architecture, are that neither the indicators nor the calculation of them with the available certification software options reflect the potential of the bioclimatic architecture in the EPCs of both countries, Austria and Spain. However, despite the same obtained outcome significant differences between the sensitiveness of the certification schemes towards bioclimatic architecture are found and described in this Thesis.

Looking at the results obtained, a possible interpretation is that at present the introduction of a single EPC for all EU MS is not considered feasible. However, in order to have reliable data to set more accurate carbon dioxide emissions reduction goals, the continuous introduction of future gradual changes to allow cross-national comparison of the EPCs is advisable. Based on the conclusions of this Thesis, potential measures to allow more comparability are considered feasible as the most relevant differences between EPC schemes found in this study do not rely on geographical or climate characteristics if not on the legislative aspects.

Keywords

EU Energy Efficiency Directives, Bioclimatic Architecture, Passive Design Strategies, Energy Performance Certificates, Energy Certification Tools, Building Regulations.

KURZFASSUNG

Während der letzten Jahre hat die Europäische Union mehrere einschränkende Bestimmungen beschlossen, um die durch den Bausektor verursachten CO2 Emissionen zu reduzieren und hat sich ambitionierte Ziele für die Zukunft gesteckt. Unter den Bestimmungen, die bereits in Kraft getreten sind, hat die Einführung der Vorschrift zur verpflichtenden Vorlage von Energieausweisen für Gebäude über die letzten Jahrzehnte die größte Auswirkung gehabt. Wenngleich die Einführung umstritten war, sind die Energieausweise gegenwärtig die einzige Quelle für Energieverbrauchsdaten des EU-Gebäudebestands und somit entscheidend für EU-Ziele.

Daher ist die Absicht dieser Diplomarbeit, festzustellen, ob die Energieausweise von zwei EU-Mitgliedsstaaten, Österreich und Spanien, auf die bioklimatische Architektur Rücksicht nehmen. Diese Herangehensweise an die Architektur, angepasst an die regionalen klimatischen Bedingungen, wurde bereits ausführlich untersucht und hat sich als effiziente Strategie erwiesen, um Komfort in Gebäuden mit niedrigem Energieverbrauch zu schaffen. Außerdem soll ermittelt werden, ob die Energieausweise der zwei Mitgliedsstaaten vergleichbar sind, und ob es möglich wäre, einen einheitlichen Energieausweis für alle EU-Mitgliedsstaaten einzuführen.

Um die oben genannten Ziele dieser Diplomarbeit zu erreichen, wurde eine stufenweise Methode für diese Studie entwickelt. Die Methode beginnt mit einer vergleichenden Literaturübersicht über die rechtlichen Rahmenbedingungen, angefangen auf EU-Ebene bis hin zu lokalen Bauvorschriften. Der Vergleich umfasst eine detaillierte Analyse der verwendeten Kennzahlen der Energieausweis-Programme beider Länder. In einem weiteren Schritt wird eine Übersicht über passive Strategien klimagerechten Bauens geschaffen, welche in der verfügbaren Literatur beschrieben wird. Ebenso werden die Gebäudebestände und Klimabedingungen beider Länder analysiert, um passive Baustrategien auszuwählen, die das Potential besitzen, Wärmekomfort zu erreichen. In den letzten Schritten, dem Bewertungsteil der Methode, wird evaluiert, ob die zuvor ausgewählten bioklimatischen Bautechniken in den Energieausweisen-Programmen berücksichtigt werden und, ob die beiden Energieausweis-Konzepte vergleichbar sind.

Nach Ausführung der Schritte zeigt das Ergebnis der vergleichenden Literatur, basierend auf 72 verglichenen Aspekten, dass der in dieser Studie ausgeführte Vergleich der gesetzlichen Rahmenbedingungen für die Energieausweis-Programme deutliche Unterschiede zwischen Österreich und Spanien aufweist, selbst wenn beide Länder EU-Mitgliedsstaaten sind und deshalb gemeinsamen Anordnungen folgen.

Die erlangten Resultate über das Eingehen der Energieausweis-Programme auf bioklimatische Architektur ergeben, dass weder die Indikatoren noch die Berechnung derselben mit den verfügbaren Optionen von Zertifizierungssoftware auf das Potential des klimagerechten Bauens in der Energieausweisen beider Länder, Österreich und Spanien, eingehen. Trotz desselben Ausgangs wurden im Zuge dieser Studie wesentliche Unterschiede zwischen der Zugänglichkeit der Ausweis-Systeme hinsichtlich bioklimatischer Architektur gefunden und werden in dieser Diplomarbeit aufgezeigt

CONTENTS

1 INTRODUCTION

1.1 Overview

Over the last years the European Union has released through a series of directives [1][2][3][4][5] several restrictive regulations targeting the reduction of CO2 emissions in all EU Member States and has set considerably ambitious goals for the near and distant future..

One of the most significant obligations that is already implemented and transposed in all MS local regulations is the obligation to issue Energy Performance Certificates for buildings, which came into force in 2002 and had a significant impact causing controversy within the construction sector.

Regarding future objectives, one of the most challenging goals, with its targeted implementation milestone is soon to be reached, is the obligation that all new buildings will have to be Near Zero Energy Buildings (NZEB) by the end of 2020. Also, there are more ambitious goals for the distant future like achieving a complete decarbonization of the building stock by 2050.

Since regulations and requirements for the EU building stock are frequently reviewed and strengthened, the construction industry is focused on developing materials, constructions and techniques that can be implemented to achieve low energy demanding buildings. Nonetheless the architectural traditions in different regions have already proved to be effective in achieving thermal comfort with the use of bioclimatic architecture passive design strategies that do require a low energy demand.[7]

The passive strategies of the bioclimatic architecture with potential to achieve thermal comfort in Austria and Spain are analysed in this Thesis following a steps methodology. Specifically, this study focuses on its integration in the current Energy Performance Certification schemes, narrowing down the research on the integration of the bioclimatic principles in the EPC indicators EPC software tools.

Furthermore the Thesis deals with the comparability of the EPC having previous research studies highlighted large differences in current EPC schemes between EU state Members [10].

1.2 Motivation

Considering the ambitious objectives for the EU building stock energy consumption reduction, the access by legislators and scientists to accurate and verified data of the building stock plays a crucial role to set up realistic strategies.

Despite the relevance of the data on current energy consumption, at present Energy Performance Certificates are the only source of information about the building stock energy consumption in the EU [15]. Therefore, its accuracy is a key factor and is considered a motivation to focus this piece of research in this field.

Additionally, an analysis of the current data extracted from available certificates shows that 97% of the buildings in the EU Member States stocks would need to be upgraded [16] ,with the use of more efficient construction materials and buildings systems, in order to achieve the EU goals. To this end, rather than directing this work on studying high performance materials, it is thought of interest for the scientific community to bring the findings of other research pieces, where the influence of bioclimatic architecture in achieving thermal comfort has been proved [7], into other research areas as the energy certification.

Thus, focusing this piece of research on the analysis of the EPC sensitiveness towards bioclimatic architecture passive design strategies is considered a motivation. This approach could help contributing to widen the number of available studies in this field and therefore to increase the interest of the academic community on this topic.

Besides, the potential contribution to create a methodology which could allow comparability of EPC schemes between any EU Member State and consequently the reliability of the building stock data at European level, is also considered a strong motivation for pursuing this Thesis.

1.3 Objective

Both bioclimatic architecture and the EPC implementation are extensive areas of study therefore two specific research questions have been formulated as the objective for this Thesis. Thus, following a steps methodology they will be addressed and answered in this study.

The research questions addressed in this study are the following:

- **RQ 1. Are Energy Performance Certificates in Austria and Spain sensitive to bioclimatic architecture passive strategies?**

  In order to answer this first rather large question with quantitative data the suggested methodology will focus more in depth in providing answers to these sub-questions:

  - Are the indicators sensitive to bioclimatic architecture passive strategies?
  - Are passive strategies possible input options in available certification tools?

The second research question that will be addressed is the following:

- **RQ 2 Based on current Austrian and Spanish certification processes, would it be possible to have a single EPC for all EU Member States?**

1.4 Background

1.4.1 Overview

Since the first EPBD (Energy Performance of Buildings Directive) was released [2], the scientific community has extensively studied its impact and influence in the building sector. Thus, there is a wide range of available publications that are relevant background for this study.

Among all literature, there are some research works that deal with the progress and effectiveness of the transposition of the directive in all EU Member States national building codes [9][10].

Other studies focus on the appropriateness of the methodologies used for the calculation of the Energy Performance Certificate, taking into account not only the methodologies but also the differences in the climatic conditions across the EU territories [6].

Also, few European organizations, such as BPIE (Buildings Performance Institute) and EuroACE (The European Alliance of Companies for Energy Efficiency) have released publications providing an overview of the EPBD transposition, the EU building stock energy use and the challenges that the new released version of the EPBD is facing [14][15][16][17].

On the other hand, the bioclimatic architecture, the other research area which this study deals with, is a field of research which the scientific community has always showed interest in. Therefore there are publications, considered as reference publication in the field, that describe the correlation between climate, architecture and thermal comfort [11]. Also there are recent works that precisely study the architecture strategies for achieving thermal comfort [7][12][13].

Considering the available literature found and even if there is extensive literature concerning the EPC and bioclimatic architecture passive strategies, there is a gap in research regarding the influence of the bioclimatic architecture passive strategies in the building's performance certification schemes.

Finally, the following pages of this section describe in detail the different legislative framework levels, a significant background for the building's energy certification schemes study. The levels of the legislative framework reviewed are (i) the EU level directives concerning buildings energy performance, (ii) the national transposition laws from the EU directive and (iii) the national building codes of each of the countries object of this study.

1.4.2 European Parliament and Council Directives

The following of this chapter describe the European Directives that deal with the Energy Performance of Buildings and highlight the key aspects of each of them.

Directive 93|76|EEC

This directive from 1993 [1] was the first European directive that introduced buildings energy efficiency and lead to the creation of programs to implement building energy performance certificates. Its main goal was to achieve CO2 emissions reduction through the improvement of residential buildings energy efficiency, as not only this sector played a major role in the consumption of primary energy but also was experimenting a development growth.

Other objectives of the directive were the implementation of correct building thermal insulation for new buildings adapted to the specific climatic conditions, periodic inspection of building systems and energy audits in industries with large energy consumption.

However, most of the EU state members did not achieve the objectives indicated by the directive therefore the Directive 93|76|EEC was finally derogated.

Directive 2002|91|EC

Following earlier EU legislations, the directive 2002|91|EC [2] was released with the aim to promote buildings energy efficiency, considering external climatic conditions, regional particularities and cost-efficiency effectiveness. The extent of this directive involved new and existing buildings, and, regardless of their use, residential or commercial, introduced the Energy Performance Certificates (EPCs) and minimum energy performance requirements.

The main aspects addressed by the EPBD were the following:

- The establishment of a methodology and a general framework to calculate the energy performance of buildings, considering all factors that influence energy use.
- The obligation for Member States to set minimum energy performance requirements for new buildings and for large buildings (more than 1000 m²) when they are refurbished.
- The establishment of national certification schemes for new and existing buildings with an Energy Performance Certificate (EPC) that needs to be available when a building is constructed, sold or leased. Furthermore, it needs to be displayed in public buildings.
- The obligation to introduce a national scheme for the inspection of boilers and heating systems as well as for air-conditioning systems.

This directive was a significant progress covering all aspects related to energy efficiency. The introduced EPC must now include an indicator that takes into consideration not only the quality of the insulation, the heating installations, the cooling installations, the energy for ventilation, the lighting installations, the position and orientation of the building, the heat recovery but also active the solar gains and other renewable energy sources

These indicators must allow buildings comparability so that users can compare the energy efficiency of the building. Also, the indicators must describe recommendations to improve the building energy efficiency.

Directive 2010|31|EU

In 2012 the European Parliament reviewed the directive from 2002 [2] and approved a recast of it, the EPDB 2010|31|EU [3] which aimed to clarify and widen the scope of its predecessor. The recast now encompassed all existing buildings as well as strengthened the buildings efficiency requirements. The objective of the EPBD recast is that the corresponding transposition directive in the respective Member States legislations will contribute to the modernization of Member States buildings codes and consequently achieve the EU efficiency goals.

The EPBD recast focused on the following aspects:

- Reinforced the general framework for the methodology based on European standards to calculate energy performance of buildings.
- Introduced the concept of nearly zero-energy buildings (NZEB) and the following obligations that:
    - By the end of 2018 all new public buildings would need to be nearly zero-energy buildings (NZEB)
    - By the end of 2020 all new buildings would need to be nearly zero-energy buildings (NZEB).
- Enlarged the obligations to undertake regular inspection to boilers and heating systems.
- Removed the 1000 m² threshold floor area to meet minimum requirements in existing buildings when they are object of a major refurbishment.
- Introduced the calculation of cost-optimal levels of minimum energy performance in buildings. This cost-optimal levels refer to the energy performance which leads to the lowest cost during the whole life cycle.

- Energy Performance Certificates need to include recommendations adapted to the specific building.
- Introduced minimum requirements for building elements of the envelope.

Directive 2012|27|EU

This Directive [4] did not change the energy certification obligation however it brought some improvements towards achieving the EU energy efficiency goals.

This new Directive resulted from the fact that European Union was not on the path to achieve the earlier set goals of increasing by 20% the energy efficiency before 2020. Thus, the European Union's legal framework on energy efficiency was updated, creating a common framework that would drive the EU, not only to reinforce this objective, but also to encourage energy efficiency improvements beyond 2020.

Directive 2018|844

In 2016, the European Commission proposed updating the Directive 2010|31|EU [3] on energy performance of buildings to help promote the use of smart technology in buildings, to rationalize existing standards and to accelerate the renovation of current building stock.

Later on, the European Parliament (in April of 2018) and the Council of the European Union (in May of 2018) formally approved the revision of the Directive 2010|31|EU [3] and the new revised EPDB [5] entered into force on July 2018, forcing the Member States to transpose the Directive into national laws by March 10^{th} 2020.

Some of the most significant amended goals are the following:

- EU MS are requested to implement stronger long-term renovation strategies, with the objective of decarbonizing MS national building stocks by 2050.
- EU MS are requested to express their national EPC in ways that cross-national comparisons will be possible.
- The creation of a common European scheme for rating the “smart readiness” of buildings.
- The further promotion of “Smart technologies” such as the installation of building automation and control systems.
- The promotion of health and well-being of users in buildings through an increased consideration of air quality and ventilation.

  EU MS are now requested to express their national EPC in ways that cross-national comparisons will be possible.

1.4.3 National Transposition Laws

With the first release of the EPBD [2] and later with the following recast versions [3][4][5], all EU MS were requested to transpose the EU Directives into their national laws.

In the following table (Table 1) the sequence of EU Directives and consequently the transposition to the national laws in the countries object of this study are reflected.

<table>
<tr><td rowspan="8">EU REGIONAL LEVEL</td><td>Directive 93|76|EEC</td><td>AUSTRIAN TRANSPOSITION LAWS FROM EU DIRECTIVES</td></tr>
<tr><td>Directive 2002|91|EC</td><td>Energieausweisvorlagegesetz (EAVG)</td></tr>
<tr><td>Directive 2010|31|EU</td><td></td></tr>
<tr><td></td><td>SPANISH TRANSPOSITION LAWS FROM EU DIRECTIVES</td></tr>
<tr><td>Directive 2012|27|EU</td><td>Real Decreto 47/2007</td></tr>
<tr><td></td><td>Real Decreto 235/2013</td></tr>
<tr><td>Directive 2018|844</td><td>Real Decreto 564/2017</td></tr>
</table>

Table 1 Overview of EPBD Transposition Laws

1.4.4 National Building Codes

National transposition laws [19][30] from the EU directives set the general framework for the EPC but in both countries, the national laws refer to the building codes. These codes establish all parameters that are considered in the certification calculation process.

In the following tables (Table 2 and Table 3) an overview of all codes which set conditions for the EPC in Austria and Spain are shown.

AUSTRIAN BUILDING CODE	AUSTRIAN STRANDARDS
OIB Richtlinie 6 Energieeinsparung und Wärmeschutz	ÖNORM B 8110-5: Klimamodell und Nutzungsprofile ÖNORM B 8110-6: Grundlagen und Nachweisverfahren – Heizwärmebedarf und Kühlbedarf ÖNORM H 5056: Heiztechnik-Energiebedarf ÖNORM H 5057: Raumlufttechnik-Energiebedarf für Wohn- und Nicht-Wohngebäude ÖNORM H 5058: Kühlenergiebedarf ÖNORM H 5059: Beleuchtungsenergiebedarf ÖNORM H 5050: Gesamtenergieeffizienz von Gebäuden *Etc…*

Table 2 Overview of Austrian Building Codes and Standards

The table above shows that in Austria the volume of the national building code (OIB 6)[18] referring to energy efficiency relies on a series of National Standards [20][21][22][23][24][25] which include relevant parameters for the EPC calculation process. It is pertinent to mention that on May 2019 the building code has been updated and some adjustments have been recently done to include aspects of the latest recast of the EPBD [5].

SPANISH BUILDING CODE	
	HE - Ahorro de Energia
Codigo Tecnico de la Edificacion	HE 0 Limitacion del consumo energético
	HE 1 Limitación de la demanda energética
	HE 2 Rendimiento de las instalaciones térmicas
	HE 3 Eficiencia energética de las instlaciones de iluminación
	HE 4 Contribución solar mínima de agua caliente sanitaria
	HE 5 Contribucion fotovoltaica minima de energia electrica
RITE Reglamento de Instalaciones Térmicas en los Edificios	

Table 3 Overview of Spanish Building Codes

In Spain, there is a general building code (CTE) [26] with a volume (HE) that refers to the energy efficiency in buildings with a series of 6 chapters, each one of them dealing with different aspects of the energy use. Also, there is a specific code for the HVAC installations (RITE) [27].

With regard to the latest EPBD [5] the release of a new updated version of the Spanish building code (CTE) is expected to take place before the end of 2019.

2 METHOD

2.1 Overview

The objective of this Thesis is to evaluate the integration of the bioclimatic architecture passive design strategies in the EPC schemes of Austria and Spain, therefore a methodology based on a steps approach is suggested. The methodology embraces different areas of research as well as different evaluation methods. The suggested steps process starts with a literature review of the EPC framework (regulations, standards, etc.) from the most general level, the EU Directives, to the local aspects of the EPC. The evaluation continues with a review of the available literature on bioclimatic architecture and later doing an analysis of the current building stocks and climate conditions in the countries object of this study. In the final steps an evaluation of the validated EPC software tools is performed, and the formulated research questions are addressed.

Below (Figure 1) there is a chart that shows an overview of the methodology.

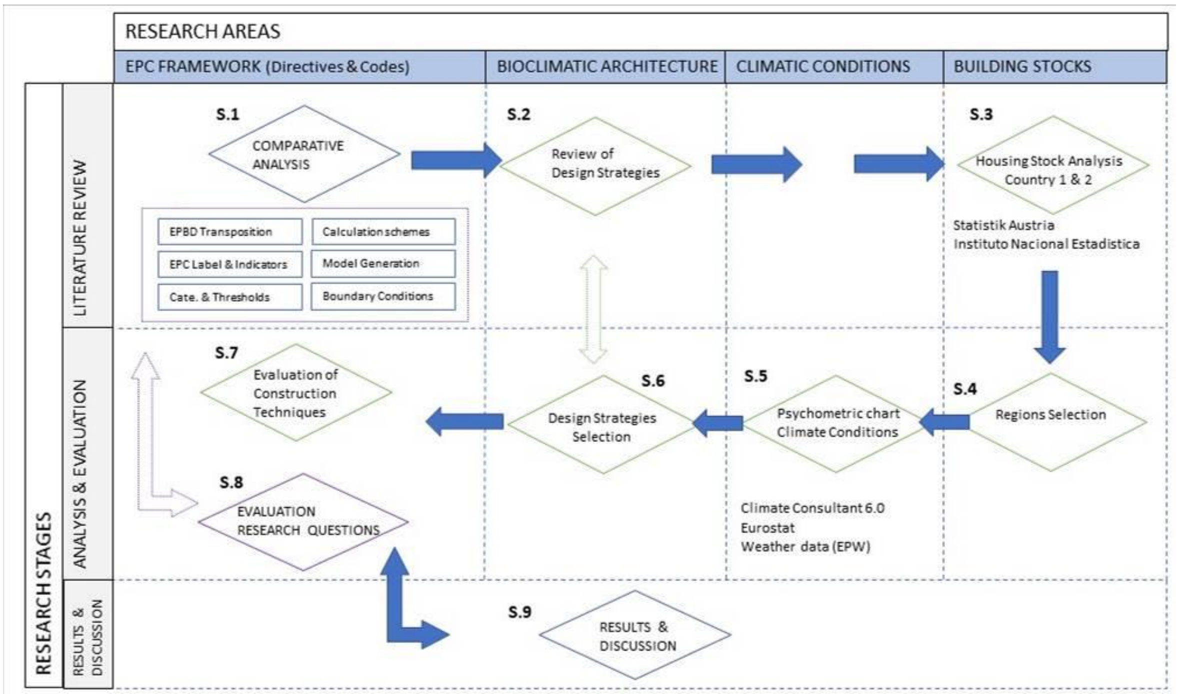


Figure 1 Methodology Overview

On the following pages each of the methodology steps is described at a glance.

2.2 Comparative Literature Review

This study starts (step 1 of the methodology) with a comparative literature review of the legislative aspects of the EPC that both countries object of this study have implemented in their national building codes and laws. In the previous chapter (Section 1.4 - Background) of this Thesis there is an overview of the legislative framework of both countries.

For the purpose of this study the comparative literature of the legislative framework is divided in two stages. First, a general comparison and later a focus specifically on the EPC indicators.

EPC Legislative Framework

The first stage of the comparative literature analysis of the general legislative framework is based on a comparison table of Austrian and Spanish certification obligations and schemes.

The comparison table embraces a total of 72 questions formulated to both countries and questions are presented grouped in 6 categories. These categories are listed and briefly described below:

- **Category 1 - EPBD National Transposition**. This group deals with topics such as the auditor's necessary accreditation, the required training, the obligation to issue and display an EPC, the duration of an EPC and other aspects related to the national transposition of the EPBD.
- **Category 2- EPC Indicators & Labels.** In this category topics related to the EPC indicators as well as all other information that appears in the Energy Label and EPC are compared.
- **Category 3 - EPC Threshold values & Categories.** All aspects concerning the categories, grading scales and threshold values are included in this group of questions.
- **Category 4 – Calculation schemes.** This category focuses on the calculation methodologies and available software tools.
- **Category 5 - Model generation.** The set of conventions used to generate the model are compared in this category.
- **Category 6 - Boundary Conditions.** In this group a comparison of topics such as internal gains, ventilation, envelope tightness and other aspects related to the boundary conditions are undertaken.

After all questions are addressed, a comparison using a three-level evaluation scale to identify their degree of resemblance is done. The figure below (Figure 2) shows the evaluation scale used to establish the comparison.

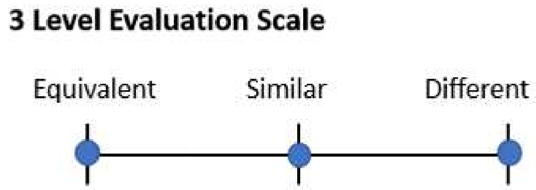


Figure 2 Evaluation Scale

EPC Indicators

As a next stage of the comparative literature review (Step 1), the study narrows down the EPC framework and focuses on a comparison of the EPC indicators being used in the EPC and the Energy Performance Label.

2.3 Bioclimatic Design Strategies Review

In this second step of the research methodology (Step 2) the available literature on bioclimatic architecture design strategies and construction techniques is consulted in order to identify which are the bioclimatic passive design strategies and their corresponding techniques that the scientific community considers effective in providing thermal comfort. The outcome of this step is (i) a summary table of the design strategies and (ii) a table of the construction techniques that correspond to each strategy.

2.4 Buildings Stock Analysis

In the following stage of the research methodology (Step 3) the statistics databases of both countries (Statistik Austria [32] and Instituto Nacional de Estadística [33]) are consulted to obtain information on Austria's and Spain's residential building stocks divided per regions. Information about national building stock is in a later step (Step 5) analyzed to select the regions to be used as location of the test case study houses in the evaluation of the EPC software tools.

2.5 Evaluation of EPC Certification Tools

The next steps (Steps 4 to 7) of the methodology followed in this Thesis comprise the evaluation of the EPC software tools. The goal of the evaluation is to assess if the design techniques, corresponding to bioclimatic architecture passive design strategies with potential to achieve thermal comfort, are possible input options in the approved EPC software tools in Austria and Spain. All the strategies and techniques that are evaluated are the outcome of a previous step (Step 3).

In order to carry out the evaluation of the software tool a series of steps are followed and described in the next paragraphs:

Regions Selection

Once analyzed both countries residential building stocks the objective of this step (Step 4) is to identify the regions in Austria and Spain with the with the highest potential to contribute to decarbonizing the building sector. For the purpose of this Thesis, the regions with the largest building stocks are considered also to have the largest potential.

These regions are used as location of the test case study house in the assessment of the EPC software tools (Step 7).

Climatic Conditions Analysis

Having selected the regions (Step 4), in this step of the methodology (Step 5) an analysis of their climatic conditions is carried out in order to compare the annual weather conditions between both regions. The objective is to understand possible differences on the ideal bioclimatic passive design strategies for each region.

In order to study the climate, *EPW Weather data files* [40][41] from *Energy Plus* [39] software is used to study climates by showing temperatures in a Psychometric Chart using *Climate Consultant* 6.0 [34] software tool.

Optimal Design Strategies & Techniques

Using *Climate Consultant 6.0* [34] software tool capabilities, as a next step (Step 6) the hours over a period of a year that, if passive design strategies are implemented, could potentially bring the interior conditions to the comfort zone (standard ASHRAE 55-2004) are shown in a Psychometric chart.

Once having identified the design strategies with a potential to achieve comfort, those which can provide more than 500 hours of comfort are selected.

The corresponding design techniques of the selected design strategies are evaluated in the following step (Step 7) of the methodology.

Design Techniques Assessment in Software Tools

In this final stage (Step 7) of the EPC software tools evaluation, the objective is to asses if the available software tools for issuing an EPC in both countries are considering as input options the identified design techniques (Step 6).

In the assessment the following two conditions will be evaluated:

I. Does the software have the construction technique as default input option?

II. In case that not, is the simulation of the technique through an approximation possible?

To carry out the evaluation the following tools have been selected:

- For Austrian EPC, *ArchiPHYSIK* [35] version 15 developed by A-NULL Development GmbH has been selected, as it is a widely used software in Austria. Also, there is a scholar free version available for TU Wien students.
- For the evaluation of the Spanish EPC tool, the software *SG Save* [37] developed by Efinovatic has been selected. It is a freeware version and also the latest tool approved by the Spanish Government. Additionally, it is based on *Sketchup* [38] and *OpenStudio* [36] for the model generation, and on *EnergyPlus* [39] as a calculation engine. Thus, it offers a high degree of flexibility in the model generation and in the EPC calculation.

To evaluate the conditions mentioned above the following sequence of steps are undertaken:

1) A definition of a test case study house geometry common for both countries.
2) In each of the countries, constructions and building systems are selected to meet local code requirements.
3) As a third step the two earlier indicated conditions (i) and (ii) are evaluated.

The following scheme (Figure 3) shows the steps for the evaluation of the EPC software tools.

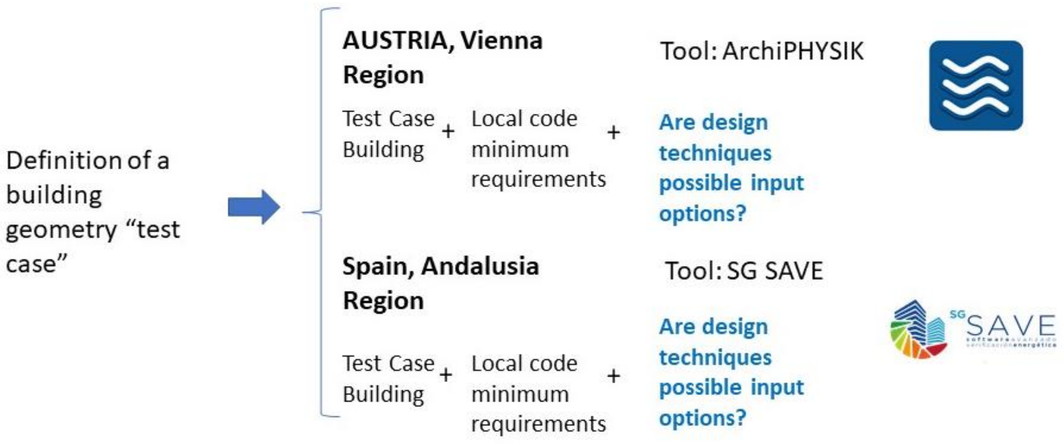


Figure 3 Steps for the EPC software evaluation

2.6 Evaluation of the Research Questions

As final steps of the methodology (Steps 8 & 9) the formulated research questions described in a previous section (Section 1.3 - Objective) will be addressed, discussed and answered.

3 COMPARATIVE LITERATURE REVIEW

In this section a comparative literature review of the legislative aspects and building codes which set the framework for the EPC obligation and certification procedures is carried out. The comparison starts with more general aspects (3.1 EPC Framework) to later focus specifically on the indicators used to categorize buildings in the EPC of both countries (3.2 EPC Indicators).

3.1 EPC Framework

Following the methodology described in a previous section, the EPC framework of both countries is compared in a series of tables each of them for one of the group categories earlier indicated. Also, the corresponding ratings for the evaluation of each topic is assigned.

Below a series of tables (Table 4 to Table 12), each of them corresponding to a different group.

Category 1 - EPBD National Transposition

it.	Question	Austria	Spain	Rating
1	What professionals are qualified to create an EPC?	In principle, many professionals may issue energy certificates. However, it is recommended that the Energy Performance Certificates are done by qualified construction and energy professionals, such as experienced architects, civil engineers and engineering consultants.	Architects and Engineers	Equivalent
2	Is there a mandatory training for professionals to be accredited as EPC auditors?	Not mandatory other than their professional qualification.	University degree that qualifies as architects or Engineers.	Equivalent
3	What transactions are requested to have an EPC?	Sale or lease	Sale or lease	Equivalent
4	What buildings are requested to have an EPC?	All buildings when a transaction of the property (sale or lease) takes place.	An EPC will be requested in the following cases: - New construction buildings. - Buildings or parts of existing buildings that are sold or rented to a new tenant, as long as they do not have a valid certificate. - Buildings or parts of buildings in which a public authority occupies a total area of more than 250 m2 and open to visitors.	Equivalent
5	What buildings are requested to display the EPC in a visible place ?	Buildings occupied by a public authority or other facilities with frequent visitors and with a surface of more than 250 m2.	The display of the energy label will be necessary, in a clearly visible place in the following cases: - Buildings occupied by a public authority with frequent visitors, and with a surface of more than 250 m2. - Privately owned buildings with frequent visitors, and with a surface of more than 500 m2.	Similar

Table 4 Comparative Literature Review of EPC Framework – EPBD National Transposition (part 1).

it.	Question	Austria	Spain	Rating
6	Are there exceptions in the obligation to issue an EPC (i.e. listed buildings)	For the following cases no energy certificate is requested: - Buildings where heating purpose is only frost-free - Buildings in ruinous condition (condition should be reflected in the sale advertisement) - Building for worship or other religious purposes - Buildings which are going to be used for two or less than two years - Industrial buildings, workshops and farm buildings (when most of the energy comes from its own waste heat) - Residential building that are occupied during a limited period of the year. - Detached buildings with a total floor area smaller than 50 m²	For the following cases no energy certificate is requested: a) Buildings and monuments listed because of their particular architectural or historical value. b) Buildings or parts of buildings used exclusively as places of worship and for religious activities. c) Temporary constructions with an expected period of use equal to or less than two years. d) Industrial, defense and agricultural buildings or parts thereof, in the part intended for workshops, industrial, defense and non-residential agricultural processes. e) Buildings or parts of detached buildings with a total area of less than 50 m2. f) Buildings that are purchased for major renovations or demolition. g) Buildings or parts of existing buildings used for a limited time per year and with an expected energy consumption of less than 25 percent of what would result from their use during all the year.	Similar
7	How long is the EPC valid?	10 years	10 years	Equivalent
8	Does the EPC necessarily includes recommendations for improving energy efficiency?	Yes, local directive requests to include recommendations in the EPC Appendix.	Yes, local directive requests to include recommendations in the EPC of existing buildings.	Equivalent
9	Are recommendations based on actual energy consumption, standardized or calculated?	Recommendations are based on obtained values calculated in the EPC.	Recommendations are based on actual building energy consumption	Different
10	Is the cost of the improvements reflected in the EPC?	Yes, recommendations must take into account technical, ecological and economical aspects.	Yes	Equivalent
11	Is the payback time calculated and reflected in the EPC?	Yes	Not requested.	Different
12	In new buildings in which design/construction stage is the EPC created?	The EPC is part of the project documentation submitted to obtain the Construction License. Also, after construction if there have been changes during construction, the EPC must be updated.	Project planning stage and after construction is finished	Equivalent
13	Are there different EPC formats for existing and new residential buildings?	No, however for existing buildings a simplified calculation method with values for the description of the building is used.	There is one single EPC format where it is reflected if the building is new or existing.	Equivalent
14	Are there different EPC formats for single detached houses or housing blocks?	No	There is one single EPC format for all housing categories where it is reflected if the building is a detached house or a housing block.	Equivalent

Table 5 Comparative Literature Review of EPC Framework – EPBD National Transposition (part 2).

Category 2 - EPC Indicators & Labels

it.	Question	Austria	Spain	Rating
15	Which are the required energy performance indicators that need to be displayed in the EPC label or on the EPC's first page?	Heating demand, Primary Energy Consumption, Carbon dioxide emissions and Overall Energy Efficiency factor	Primary Non Renewable Energy Consumption and Carbon Dioxide Emissions	Similar
16	What other energy performance indicators need to be displayed in the EPC?	Indicators of requirements completion regarding the heating and cooling demand, energy efficiency factor and percentage or renewable sources. There are also indicators hot water, heating energy, electricity and final energy demand as well as indicators for primary energy consumption, primary non renewable and renewable consupmtion, carbon dioxide emissions and photovoltaic exported energy.	Partial indicators of Heating, Cooling, Hot Water and Lighting of the Primary Non Renewable Energy Consumption and Carbon Dioxide Emissions. Also indicators of requirements completion regarding the heating and cooling demand.	Similar
17	Among all indicators displayed, which is the indicator used to obtain the overall energy rating?	Heating demand, Primary Energy Consumption, Carbon dioxide emissions and Overall Energy Efficiency factor	Primary Non Renewable Energy Consumption and Carbon Dioxide Emissions	Similar
18	Does the calculation tool/method used appears reflected in the EPC?	Yes, the name of the calculation software appears in the footer but it is not a required field of the standard template	Yes, it is a required field in the standardized template	Similar
19	Is the Near Zero- Energy Buildings level shown in the EPC ?	No	No	Equivalent
20	Is the Passivhaus level shown in the EPC ?	No	No	Equivalent
21	Do the tests carried out during site survey appear on the EPC?	No	Yes, the EPC has a section where the inspector can reflect on site tests and measurements taken	Different
22	Is there any indicator or information on the EPC that refers to the building Life Cycle?	No	No	Equivalent
23	What information other than floor area that defines the geometry is described in the EPC?	Values for the Thermal volume, Thermal Envelope Area, Compactness ratio and Characteristic length .	Only floor area.	Different
24	What are the CO2 emissions for electricity as primary energy?	227 g/kWh	There are different values for mainland and differnet Islands. The national average is 357 g/kWh.	Different
25	What are the CO2 emissions for gas natural as primary energy?	247 g/KWh	252 g/KWh	Equivalent
26	What is the conversion factor from final energy to total primary energy for electricity as energy source?	Conversion factor is 1,63 Kwh P en./Kwh F en	There are different values for mainland and for the different Islands. Conversion factor is 2,403 Kwh P en./Kwh F en.	Different
27	What percentage of primary energy with electricity as energy source is renewable and non renewable?	37,5% Renewable and 62,5 % Non Renewable	19,4 % Renawable and 80,6 % Non Renewable	Different

Table 6 Comparative Literature Review of EPC Framework – EPC Indicators & Labels (part 1).

it.	Question	Austria	Spain	Rating
28	What is the conversion factor from final energy to total primary energy for natural gas as energy source?	Conversion factor is 1,10 Kwh P en./Kwh F en	Conversion factor is 1,195 Kwh P en./Kwh F en	Similar
29	What percentage of primary energy with natural gas as energy source is renewable and non renewable?	100% Non Renewable	0,4 % Renawable and 99,6 % Non Renewable	Equivalent
30	Is on site energy produced with Renewable Energy Sources included in the Primary Energy Indicator?	Yes	No, on site produced energy is not considered in the primary energy consumption, it only counts the energy from external sources.	Different
31	Are both heating and cooling demand reflected in the EPC?	No, only heating demand	Yes	Different

Table 7 Comparative Literature Review of EPC Framework – EPC Indicators & Labels (part 2).

Category 3 - EPC Categories & Threshold values

it.	Question	Austria	Spain	Rating
32	How many grading categories has the EPC?	9 grades, A++,A+,A,B,C,D,E,F and G	7 grades, A,B,C,D,E,F and G	Similar
33	Are there different threshold values for existing and new residential buildings?	No	Yes	Different
34	Are there different treshold values for the different climatic regions?	No	Yes, there as much different values as different climatic regions, 12 for the Spanish mainland territories and 20 for the islands.	Different
35	What is the limit for heating demand to obtain the best category?	10 kWh/m²a	For the 12 regions on the mainland between 5,2 kWh/m²a and 47,5 kWh/m²a and for the 20 island regions between and 0 kWh/m²a and 47,5 kWh/m²a.	Different
36	What is the limit "Carbon dioxide emissions" to obtain the best category?	8 kg/m2a	For the 12 regions in mainland between 4,4 kg/m2a and 15,1 kg/m2a and for the 20 regions in islands between 0,6 kg/m2a and 17,5 kg/m2a.	Different
37	Are there different threshold values for single detached houses or housing blocks?	No	Yes	Different

Table 8 Comparative Literature Review of EPC Framework – EPC Cate. & Threshold values.

Category 4 - Calculation Schemes

it.	Question	Austria	Spain	Rating
38	Is the EPC based on measured or on calculated values?	Calculated values	Calculated values	Equivalent
39	If calculated, is the approved method a steady (season or month) or a dynamic method (hourly) ?	Both methods dynamic and steady (Monthly) are considered valid.	Dynamic method hourly	Similar
40	Is there a calculation tool prescribed?	Yes, these are the validated software tools. ArchiPHYSIK – A-NULL Development GmbH AX3000 - EDV-Software-Service GmbH & CO KG ecoline – IT-Concept Software GmbH Ecotech Gebäuderechner – BuildDesk Österreich GmbH Gebäudeprofi – ETU GmbH GEQ – Zehentmayer Software GmbH Grüner GmbH	Yes, these are the validated software tools: - SG SAVE - CE3X - Lider-Calener herramianta unificada (HULC) - Cerma v4.2.5 - CYPETHERM HE Plus	Equivalent
41	Do all prescribed tools need to use the same calculation method?	Not necessarily, calculation method is described in the standard ÖNORM B 8110-6, where both dynamic and steady methods are considered.	Yes, calculation method is described in building regulations.	Similar
42	Is it required to perform an on site survey and/or tests during the certification process?	Recommended	Yes, it is requested that the auditor verifies the accuracy of all information in the EPC during a site inspection	Different
43	Is it possible to obtain the EPC based on measured values?	No	No	Equivalent

Table 9 Comparative Literature Review of EPC Framework – Calculation Schemes.

Category 5 - Model Generation

it.	Question	Austria	Spain	Rating
44	What dimensions are used to calculate the floor area? (internal or external)	External	Internal	Different
45	Are both conditioned and unconditioned areas part of a house included in the EPC floor area?	In general only conditioned areas are included in the EPC area, however in some cases some unconditioned areas are considered in the EPC as well.	No, unconditioned areas are only included in the EPC floor area if they are inside the building thermal envelope.	Similar
46	Are unconditioned areas inside the building thermal envelope included in the EPC floor area?	There is a rule that if the temperature difference between a conditioned and an unconditioned is smaller that 4°Kelvin the unconditioned area is also considered in the EPC area.	Yes	Similar
47	Are staircases included in the EPC floor area?	Yes, staircases are included. A staircase wellhole if greater than 2 sqm is not included.	Yes	Equivalent
48	Is the area occupied by internal partitions included in the EPC floor area?	Yes	No	Different
49	Are other slab openings (i.e. Elevator shafts, installation shafts, etc.) included in the EPC floor area?	Yes, these are considered part of the Gross Floor Area and therefore included in the EPC Floor Area.	No	Different
50	Are floor areas below pitched roof included in the EPC floor area?	Areas with a clear height of 1.5m,with the addition of 40 cm as an exterior virtual wall, are part of the conditioned area.	Areas with a clear height of 1.5m are part of the conditioned area.	Similar

Table 10 Comparative Literature Review of EPC Framework – Model Generation

Category 6 - Boundary Conditions

it.	Question	Austria	Spain	Rating
51	Is the EPC a standard rating (standard climate & standard users behavior) or a real tailored rating?	Standard rating	Standard rating	Equivalent
52	Is it allowed to use tailored users behavior and climate?	No	No	Equivalent
53	Are standard climates used in the calculation adapted to each region ?	Standard climates, 7 different climates depending on geographical location and altitude	Standard climates, 12 different climates depending on geographical location and altitude for Spanish mainland territories and 20 for Spanish islands.	Equivalent
54	Which are the standard heating systems considered in the EPC ?	There are 8 standard systems that could be selected to calculate the heating energy demand using the standard ÖNORM H 5056 for the calculation.	If no specific system is defined, a heating system with "natural gas" as primary energy will be by default considered with a performance ratio of 0,92.	Similar
55	Which are the standard cooling systems considered in the EPC ?	In residential buildings cooling demand is not calculated.	If no specific system is defined, a cooling system with electricity as primary energy will be by default considered with a performance ratio of 2.	Different
56	Are the shades projected by other building elements (overhangs, window position in wall) considered in the EPC?	There is a shading factor considered in the solar gains from windows. Shading factor can be either calculated using values from standard tables or use an estimated default value.	There is a shading factor considered in the solar gains from windows calculated using tables or an specific value for the project.	Similar
57	Are the shades projected by surrounding elements (other buildings) considered in the EPC?	Same as for shades from other building elements. Either a simplified or a detailed calculation of the shading factor in windows is possible.	Yes, shades from surrounding elements can be considered in the shading factor.	Similar
58	Are there other solar protection systems (solar mobile protection, interior shades, decidious vegetation) considered in the EPC?	No	Yes	Different
59	Are parts of the building envelope in contact with the ground considered in the EPC?	Yes, there is a temperature correction factor that needs to be considered in slabs and walls in contact with the ground.	Yes, there are standard values for the thermal transmittance , density and specific heat. These values can be adjusted if there are more accurate values.	Similar
60	Are thermal bridges considered in the EPC calculation?	Yes	Yes	Equivalent
61	Are thermal bridges considered in the calculation specific of the building or standard values?	They can be either calculated for the project following ISO 10211 standard or use the standard values included in the building code.	They can be either calculated for the project with a specific tool or use the standard values included in the building code.	Similar
62	How is the themal envelope tightness considered in the EPC ? Is there a standard value for the infiltration rate?	There is a limit for the infiltration rate (ACH: 3 h^{-1}) that needs to be tested on site with a pressure difference of 50Pa.	There are standard values for the air infiltration through walls and windows, however some values can be adjusted if proved by a certificate.	Different

Table 11 Comparative Literature Review of EPC Framework – Boundary Conditions (part 1).

it.	Question	Austria	Spain	Rating
63	How is the ventilation considered in the EPC? Is there a standard value for the infiltration rate?	There is a minimum required ventilation rate for housing units of ACH: 0,28 h^{-1}	There is a default value of ACH 0,63h^{-1} that can be adjusted.	Different
64	Is the wind speed considered in the EPC calculation?	No	Yes, there are standard values for wind speed and pressure coefficients based on the building location and based on the exterior surface function (roof or wall) , slope and up or downwind position.	Different
65	Is the Air Change Rate specific for the building or a standard value?	It is specific for the building and will be tested during the licensing process after building construction completion.	Standard, however it can be adapted to the specific project conditions.	Different
66	How is the internal thermal mass reflected in the EPC?	The internal thermal mass of the building can be either selected from standard values (3 values) or using a more detailed calculation method following an ISO standard.	There is a standard fixed value for the density and specific heat for interior fittings.	Similar
67	How many days per month is the house occupied?	31 days	31 days	Equivalent
68	What is the average internal gain of people in a detached single house?	1,10 W/m2	2,47 W/m2	Different
69	What other parameters in addition to occupancy are considered as internal gains?	Equipment and Lighting.	Equipment and Lighting.	Equivalent
70	What is the average total daily internal gain by lighting, appliances and other equipment?	1,59 W/m2 Lighting not included	1,65 W/m2	Equivalent
71	What is the set point for cooling systems?	26 °C (only in non residential)	During the period from June to September; from 24 to 7 o'clock is 27°C, from 7 to 16 o'clock the system is not running (natural ventilation) and from 16 to 23 o'clock is 25°C . The rest of the year the system is not operative.	Different
72	What is the set point for heating systems?	22 °C	From January to May and October to December it is 20°C during the day and 17 °C at night. The rest of the year the system is not operative.	Different

Table 12 Comparative Literature Review of EPC Framework – Boundary Conditions (part 2).

3.2 EPC Indicators

After a general comparison of the EPC framework, this study focuses on the indicators used to compare buildings efficiency which are included in the EPC. To carry out the indicators comparison the mandatory templates to issue an EPC are analyzed.

In a later section of this thesis (Section 7 - Results) the indicators are presented as shown in the Energy Performance Certificates and Labels of each country.

4 BIOCLIMATIC DESIGN STRATEGIES REVIEW

In this stage the available literature on Bioclimatic architecture is reviewed, thus several publications are considered relevant for the objective of this Thesis.

There are publications that explain the principles of bioclimatic architecture on a general level, describing how the climate conditions affect buildings and influence the occupants thermal comfort [11]. These publications are considered as reference literature in the field.

Other publications [12] are meant to be a design guideline of energy efficient buildings for architects and engineers. Thus, these publications explain the fundaments of energy efficient architecture but hey suggest the utilization of not only passive but also active design strategies.

During the review, few consulted publications [7][12][13] are considered of high relevance for this Thesis. These publications describe the strategies of the bioclimatic architecture and the construction techniques to implement these design strategies in a building. One of these publications [7] analyses the potential of the bioclimatic architecture in different regions and climates globally whereas the other work [13] focuses on a northern region of Spain.

Bioclimatic design strategies of these two publications [7][13] are based on the Psychometric Chart of Givoni (Figure 4). This chart comprises 14 areas, two areas corresponding to the comfort range and permissible comfort range and 12 areas, each corresponding to an area where a design strategy could bring the building into the comfort zones.

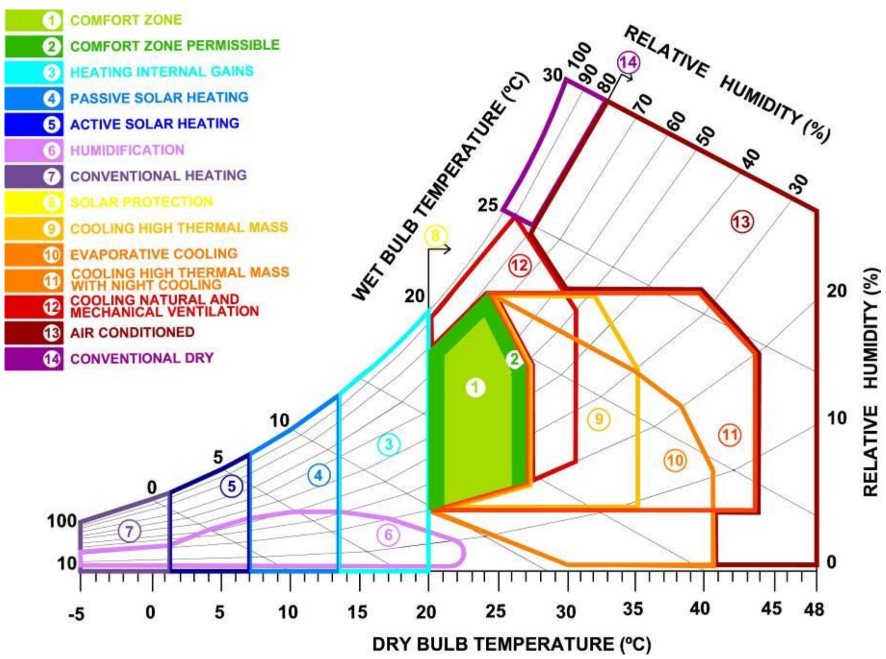


Figure 4 Givoni Psychometric Chart adapted by Manzano-Agugliaro et al.

However, *Climate Consultant 6.0* [34] , the software tool used to analyse the weather conditions of the regions selected in this study, uses a different subdivision of the areas of the Psychometric Chart. The comfort model used by *Climate Consultant 6.0* [34] is ASHRAE Handbook of Fundamentals Comfort Model 2005.

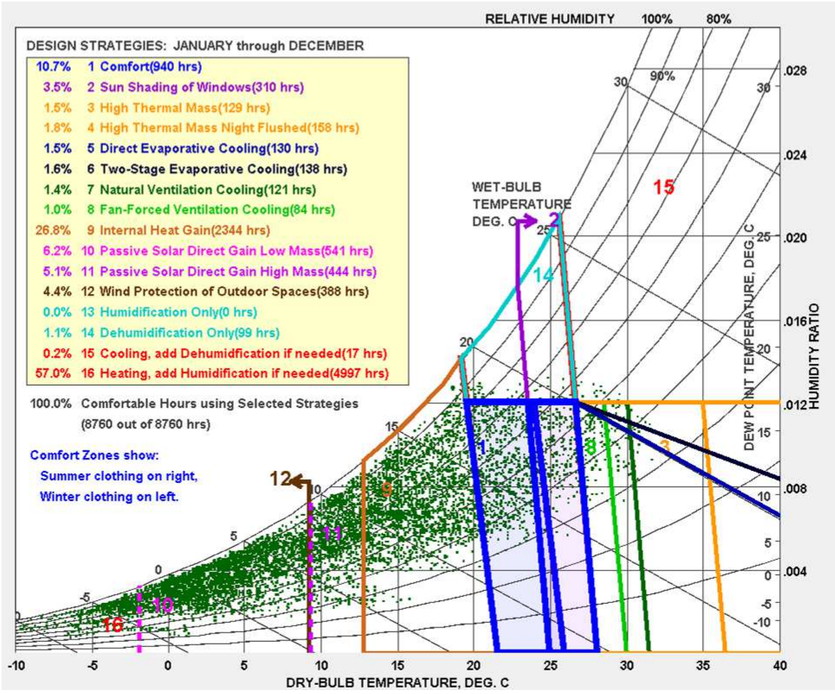


Figure 5 Psychometric Chart of Climate Consultant – ASHRAE 2005 Comfort Model

Design Strategies

As *Climate Consultant 6.0* [34] is used in a later stage of this Thesis to identify strategies with potential to achieve thermal comfort, the below table (Table 13) does a correlation of each of the strategies in the Psychometric chart of *Climate Consultant 6.0* [34] (Figure 5) with the strategies found in the available literature based which are based on the Givoni Psychometric Chart (Figure 4). The design techniques in the available literature and used in this Thesis correspond to design strategies based on the Givoni Psychometric Chart (Figure 4), therefore the correlation table is included here.

	Climate Consultant 6 Design Strategies ASHRAE 2005	Related to		Givoni Pyschometric Chart
1	Comfort	1 & 2	1	Comfort Zone
2	Sun shading of Windows	8	2	Comfort Zone Permissible
3	High Termal Mass	9	3	Heating Internal Gains
4	Hight Thermal Mass night Flushed	11	4	Passive Solar Heating
5	Direct Evaporative Cooling	10	5	Active Solar Heating
6	Two-Stage Evaporative Cooling	10	6	Humidification
7	Natural Ventilation	12	7	Conventional heating
8	Fan-Forced Ventilation Cooling	12	8	Solar Protectition
9	Internal Heat Gain	3	9	Cooling High Thermal Mass
10	Passive Solar Direct Gain Low Mass	4	10	Evaporative Cooling
11	Passive Solar Direct Gain High Mass	4	11	Cooling High Thermal Mass With Night Cooling
12*	Wind Protection of Outdoor Spaces	N/A	12	Cooling Natural and Mechanical Ventilation
13*	Humidification Only	6	13	Air Conditioned
14*	Dehumidification Only	14	14	Conventional Dry
15*	Cooling, add Dehumidification if needed	14		
16*	Heating, add Humidification if needed	6		

Table 13 Correlation of Design Strategies from ASHRAE 2005 to Givoni Psychometric chart Strategies

Some considerations regarding the correlation of the design strategies:

- The areas in both charts are not strictly the same, however in most of the areas, the differences are not considered relevant for the objective of this Thesis.
- The strategy of Wind Protection (12) in the ASHRAE Comfort Model Psychometric chart (Figure 5) does not have an equivalent in Givoni Chart (Figure 4).
- Passive design strategies (13) Humidification and (14) Dehumidification in the ASHRAE Comfort Model Psychometric chart of Climate Consultant 6.0 (Figure 5) present significant differences with areas in the Givoni Chart (Figure 4).
- The above-mentioned passive strategies (12), (13) and (14) that present differences between the areas in the two charts are strategies which are not significant in the regions studied in this Thesis.
- Strategies of Cooling (15) and Heating (16) shown in the ASHRAE Comfort Model Psychometric chart (Figure 5) include the area of both Active and Passive strategies.

Construction Techniques

Among all the consulted literature, the publications by Manzano-Agugliaro et al. (2015) [7] and by The American Institute of Architects (1993) [12] describe better the construction techniques associated to the design strategies mentioned in the previous section and include in the Givoni chart (Figure 4).

Below there is a table (Table 14) that summarizes and integrates in a single table the techniques described in the two publications [7] [12]. These techniques are in later stages (Section 6.4 - Design Techniques Assessment in Software Tools) of this Thesis used for evaluating the EPC software tools.

As a clarification of the following summary table (Table 14), the techniques that correspond to active bioclimatic strategies are not included. Also, in the Appendixes section of the Thesis (Appendix E) there is a table that describes all the techniques of each of the two publications and which of these are selected and included in the below table (Table 14).

3 Heating Internal Gains
- People
- Lighting
- Equipment

4 Passive Solar Heating
- Awning
- Radiation through openings
- Capacitative Flooring
- Roof Pond
- Glazed Gallery
- Adjoined Greenhouse
- Trombe Wall
- Roof Openings

6 Humidification
- Exterior Vegetation
- Interior Vegetation
- Accumulated Water
- Water Buried pipes

8 Solar protection

Exterior Shading devices
- Decidious Vegetation
- Pergola with decidious Vegetation
- Horizontal Projections
- Vertical Projections
- Eggcrate Shading devices
- Sunscreens
- Shutters
- Roller Blinds/Shades
- Awnings

Glazing
- Multiple Glazing
- Heat-Absorbing Glass
- Reflective Glass
- Glass Blocks
- Window Tilt

Interior Shading devices
- Insulating Shutters
- Opaque Shades
- Draperies
- Venetian Blinds/Interior Louvers

Façade Protecion
- Reflective materials or colors

9 Cooling through a high thermal mass
- Capacitative Materials idealy with Shading Protection (i.e. patio)

10 Evaporative Cooling
- Exterior Vegetation
- Water Ponds or Fountains
- Buried Water Pipes
- Patios with Vegetation & Water
- Vegetative Cover
- Exterior Water Spraying
- Indoor Water Spraying

11 Cooling High Thermal Mass With Night Cooling
- Capacitative Material with Phase Difference

12 Cooling Natural and Mechanical Ventilation
- Cross Ventilation
- Chimeny Effect
- Solar Chamber
- Subterranean Ventilation
- Wind Tower
- Evaporative Tower
- Vertical Spaces
- Patios

14 Conventional Dry
- Absorbent Salts
- Saline Cells

Table 14 Summary Table of the selected Construction Techniques

5 BUILDINGS STOCK ANALYSIS

In this section the results of the housing building stock analysis are presented.

Based on the available data on the Statistik Austria homepage [32], the following chart (Figure 6) shows the residential building stock in Austria in the year 2011.

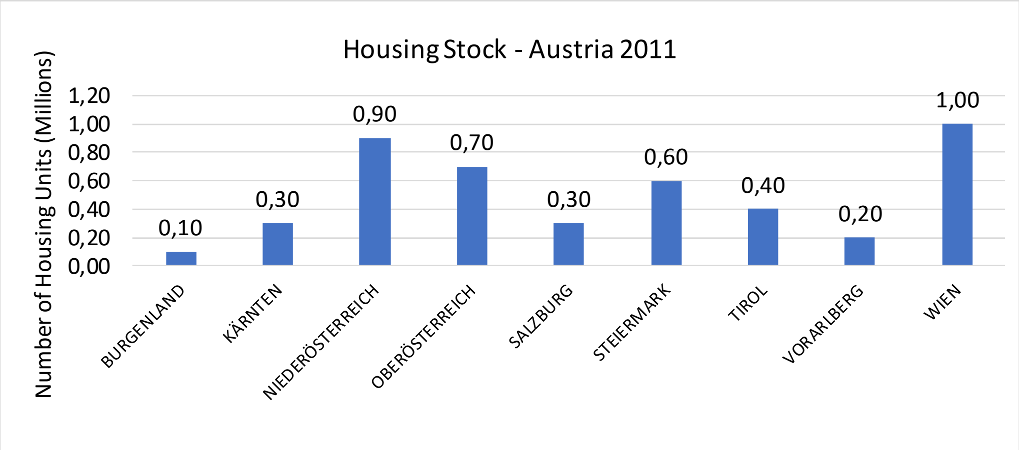


Figure 6 Housing Stock Austria 2011. Source: Statistik Austria

As reflected in the above shown chart, the region of Vienna (Wien), with 983.840 Housing units, is the region in Austria with the largest residential building stock, followed by Lower Austria (Niederösterreich) with 852.574 housing units.

The Spanish residential building stock as per the available data on INE (Instituto Nacional de Estadística) homepage [33] is reflected in the chart below (Figure 7).

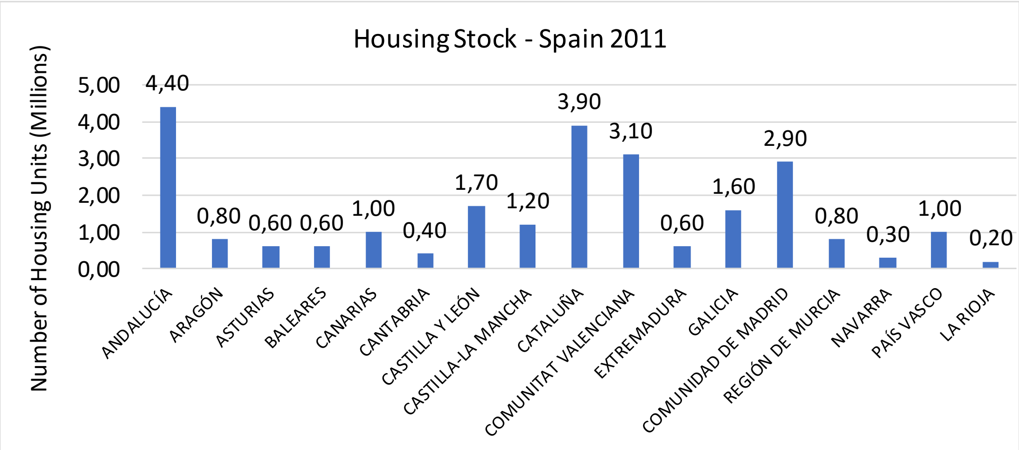


Figure 7 Housing Stock in Spain 2011. Source: INE

In Spain, the region with the largest building stock is Andalusia (Andalucía) with a total of 4.353.146 residential units followed by Catalonia (Cataluña) with 3.863.381 housing units.

6 EVALUATION OF EPC CERTIFICATION TOOLS

This part of the Thesis includes details of the steps followed for the evaluation of the EPC software tools. The objective is to assess if the design techniques corresponding to the bioclimatic architecture passive design strategies with potential to achieve thermal comfort are possible input options in the EPC software.

6.1 Regions Selection

After the study of the residential building stock in the previous step, the regions of *Vienna* in Austria and *Andalusia* in Spain are the regions selected as locations of the test case study house to carry out the evaluations of the EPC software tools.

The reason to select the regions with the largest stock for the evaluation is that are the regions with the highest emissions of carbon dioxide and consequently with the largest potential to contribute to decarbonizing the building sector.

6.2 Climatic Conditions Analysis

The outcome of the analysis of the climate in the selected regions is described.

As described in an earlier section of this Thesis, the software used to visualize the weather data files and climate representation charts and tables is *Climate Consultant 6.0* [34].

The weather data files source is the IWEC (International Weather for Energy Calculations) and files are obtained from the *Energy Plus* [39] website[40][41].

Additionally, to complete the climates description the Eurostat data base is consulted in order to obtain information about heating and cooling degree days [44].

Regarding the evaluation of the EPC software tool in the Austrian region of Vienna, it is important to mention that the selected weather data file from IWEC is strictly not located in Vienna. The weather station is situated in the region of Lower Austria, in the town of Schwechat, which is located at 18 km distance from Vienna and therefore considered valid for the purpose of this Thesis.

Concerning the weather data file of Andalusia region, the IWEC database has a weather data file from a weather station in the city of Seville, the capital and largest city of the region. Thus, it is used for this study.

6.2.1 Vienna Region Climatic Conditions

In this section the weather in the region of Vienna is described.

The first table (Table 15) describes the weather conditions as reflected in the IWEC file for Schwechat [40].

WEATHER DATA SUMMARY

LOCATION:	**VIENNA_ SCHWECHAT, -, AUT**
Latitude/Longitude:	48.12° North, 16.57° East, **Time Zone from Greenwich** 1
Data Source:	IWEC Data 110360 WMO Station Number, **Elevation** 190 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	96	162	230	296	334	341	361	355	262	179	102	74	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	68	180	197	208	212	211	247	287	181	146	74	53	Wh/sq.m
Diffuse Radiation (Avg Hourly)	76	92	132	163	184	192	185	163	156	111	76	59	Wh/sq.m
Global Horiz Radiation (Max Hourly)	320	530	686	833	897	909	900	855	715	594	369	275	Wh/sq.m
Direct Normal Radiation (Max Hourly)	617	840	886	836	816	845	829	838	762	770	440	558	Wh/sq.m
Diffuse Radiation (Max Hourly)	195	245	359	419	431	485	428	405	366	292	211	153	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	836	1597	2686	4011	5023	5383	5573	4994	3239	1915	925	611	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	583	1777	2269	2838	3201	3345	3806	4053	2232	1563	673	443	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	662	906	1552	2201	2766	3032	2854	2289	1943	1186	693	490	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	10654	17615	25218	32519	36843	37842	40011	39080	28904	19756	11276	8239	lux
Direct Normal Illumination (Avg Hourly)	5731	16524	18846	20380	20662	20339	23729	27630	17300	13606	6514	4374	lux
Dry Bulb Temperature (Avg Monthly)	0	0	5	10	15	17	20	19	15	10	4	0	degrees C
Dew Point Temperature (Avg Monthly)	-3	-3	0	2	8	10	13	12	9	6	1	-1	degrees C
Relative Humidity (Avg Monthly)	75	78	70	60	64	67	65	65	67	75	82	87	percent
Wind Direction (Monthly Mode)	130	130	0	280	280	280	330	290	140	140	130	120	degrees
Wind Speed (Avg Monthly)	6	3	4	4	3	3	3	3	4	5	3	3	m/s
Ground Temperature (Avg Monthly of 3 Depths)	6	4	2	2	5	8	12	15	16	15	13	10	degrees C

Table 15 Vienna IWEC Weather Data Summary

The table below (Table 16) shows Heating and Cooling Degree Days in Austria and in the selected region of Vienna [44] over a period of 10 years, from 2008 until 2017. Also, the average of all Austrian regions is shown in the table.

Region/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
HDD Austria	3.451,35	3.511,11	3.907,07	3.393,86	3.547,05	3.640,03	3.124,73	3.321,63	3.419,01	3.503,32	3.481,92
HDD Vienna	2.302,29	2.462,76	2.808,55	2.465,75	2.468,34	2.604,24	2.027,25	2.291,93	2.446,18	2.468,62	2.434,59
CDD Austria	7,16	9,87	25,16	18,25	31,15	46,37	9,75	67,31	12,28	34,91	26,22
CDD Vienna	114,39	116,35	137,13	122,67	219,66	196,82	112,66	281,64	115,91	213,46	163,07

Table 16 HDD & CDD Days in Austria and Vienna. Source: Eurostat

In the Appendixes section of this Thesis (Appendix H) a series of tables to describe the weather in Austria and in the selected region of Vienna more in detail are included.

6.2.2 Andalusia Region Climatic Conditions

In the following tables the weather in the region of Andalusia is described.

The first table (Table 17) describes the weather conditions as reflected in the IWEC file for Seville[41].

WEATHER DATA SUMMARY

LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, **Time Zone from Greenwich** 1
Data Source: IWEC Data 083910 WMO Station Number, **Elevation** 31 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	249	318	406	419	494	493	526	508	436	340	255	229	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	374	381	416	336	440	408	499	488	415	361	330	333	Wh/sq.m
Diffuse Radiation (Avg Hourly)	98	128	145	186	169	178	146	147	156	138	108	98	Wh/sq.m
Global Horiz Radiation (Max Hourly)	537	709	862	931	991	992	988	953	870	756	564	486	Wh/sq.m
Direct Normal Radiation (Max Hourly)	851	909	882	873	913	868	885	871	813	813	818	828	Wh/sq.m
Diffuse Radiation (Max Hourly)	288	353	404	654	480	472	457	453	387	394	289	240	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2423	3365	4810	5430	6937	7179	7517	6818	5349	3737	2541	2169	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	3621	4028	4941	4337	6181	5932	7117	6550	5089	3960	3264	3151	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	964	1360	1714	2433	2378	2590	2093	1975	1907	1525	1081	930	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	26838	34366	43817	45560	53446	53922	57730	55480	47612	37047	27606	24617	lux
Direct Normal Illumination (Avg Hourly)	33988	35830	40573	32908	42969	39834	49020	47786	39849	33949	30606	29820	lux
Dry Bulb Temperature (Avg Monthly)	10	11	15	16	19	24	27	26	24	19	13	11	degrees C
Dew Point Temperature (Avg Monthly)	5	7	6	6	9	11	15	14	12	13	8	7	degrees C
Relative Humidity (Avg Monthly)	74	76	59	56	55	50	53	53	50	69	72	77	percent
Wind Direction (Monthly Mode)	50	40	90	270	240	230	230	230	230	40	60	50	degrees
Wind Speed (Avg Monthly)	2	2	2	2	3	2	2	2	2	2	3	2	m/s
Ground Temperature (Avg Monthly of 3 Depths)	18	15	13	12	12	14	17	20	22	24	23	21	degrees C

Table 17 Seville IWEC Weather Data Summary

The following table (Table 18) shows Heating and Cooling Degree Days in Spain and in the selected region of Andalusia over a period of 10 years, from 2008 until 2017. Also, the average of all Spanish regions is shown in the table.

Region/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
HDD Spain	1.871,16	1.734,43	1.945,45	1.562,94	1.863,22	1.907,18	1.566,49	1.639,98	1.729,21	1.597,89	1.741,80
HDD Andalusia	1.249,06	1.172,77	1.212,44	1.089,79	1.289,24	1.290,09	1.037,71	1.080,12	1.109,33	1.072,12	1.160,27
CDD Spain	175,93	243,23	238,45	220,94	268,36	204,99	171,39	286,79	278,25	306,91	239,52
CDD Andalusia	330,19	417,12	449,97	420,52	487,54	363,24	314,69	482,80	489,36	521,70	427,71

Table 18 HDD & CDD Days in Spain and Andalusia. Source: Eurostat

In the Appendixes section of this Thesis (Appendix I) there a series of tables to describe the weather in Spain and in the selected region of Andalusia more in detail are included.

6.3 Optimal Design Strategies & Techniques

After the regions´ selection, in this part of the Thesis the bioclimatic architecture passive design strategies and the corresponding construction techniques with potential to achieve thermal comfort are identified for each of the regions.

6.3.1 Optimal Design Strategies & Techniques in Schwechat (Vienna, Austria)

Design Strategies

In the following psychometric chart (Figure 8) elaborated with *Climate Consultant 6.0* [34], the temperatures (dry-bulb and dew point) and the humidity ratio of each hour over a period of a year in Vienna are represented.

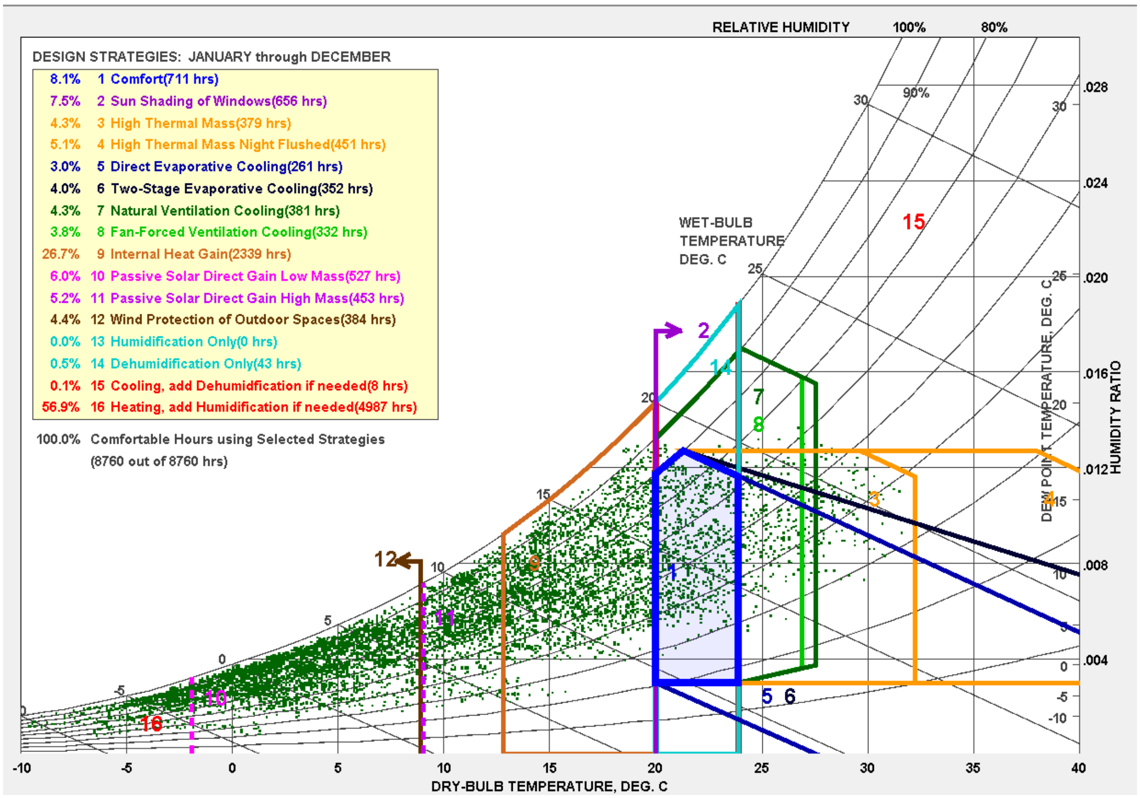


Figure 8 Psychometric Chart of Weather Conditions in Vienna

As shown in the chart above (Figure 8) the strategies that have the potential to achieve thermal comfort for a period of more than 500 hours are the following:

i. 2 Sun Shading

ii. 9 Internal Heat Gain

iii. 10 Passive Solar Direct Gain

iv. 16 Heating

Among the above mentioned strategies, the only ones that will be evaluated are (i) Sun Shading and (iii) Passive Solar Direct Gain. The other two strategies are not considered relevant as (ii) the

Internal Heat Gains considered in the Austrian EPC (people, equipment and lighting) are a fixed value and (iv) heating is an active strategy and not specifically a passive bioclimatic strategy.

Construction Techniques

The identified design strategies, based on the Psychometric Chart with ASHRAE Comfort model (Figure 8) from the previous paregraph, correspond to the following design strategies from the Givoni chart (Figure 4) and to the below construction techniques. In a previous section (Section 4 - Bioclimatic Design Strategies Review) the correlation between both Psychometric charts and the construction techniques is described.

4	**Passive Solar Heating**	8	**Solar protection**
	Awning		Exterior Shading devices
	Radiation through openings		Decidious Vegetation
	Capacitative Flooring		Pergola with decidious Vegetation
	Roof Pond		Horizontal Projections
	Glazed Gallery		Vertical Projections
	Adjoined Greenhouse		Eggcrate Shading devices
	Trombe Wall		Sunscreens
	Roof Openings		Shutters
			Roller Blinds/Shades
			Awnings
			Glazing
			Multiple Glazing
			Heat-Absorbing Glass
			Reflective Glass
			Glass Blocks
			Window Tilt
			Interior Shading devices
			Insulating Shutters
			Opaque Shades
			Draperies
			Venetian Blinds/Interior Louvers
			Façade Protecion
			Reflective materials or colors

Table 19 Optimal Design Strategies & Construction Techniques in Vienna

The techniques shown in the table above (Table 19) will be in later stages (Section 6.4) evaluated in *ArchiPHYSIK 15* [35] , the selected EPC software tool for Austria.

6.3.2 Optimal Design Strategies & Techniques in Seville (Andalusia, Spain)

Design Strategies

The below displayed Psychometric Chart (Figure 9) created with *Climate Consultant 6.0* [34] shows the weather conditions of each hour over a period of a year in the city of Seville

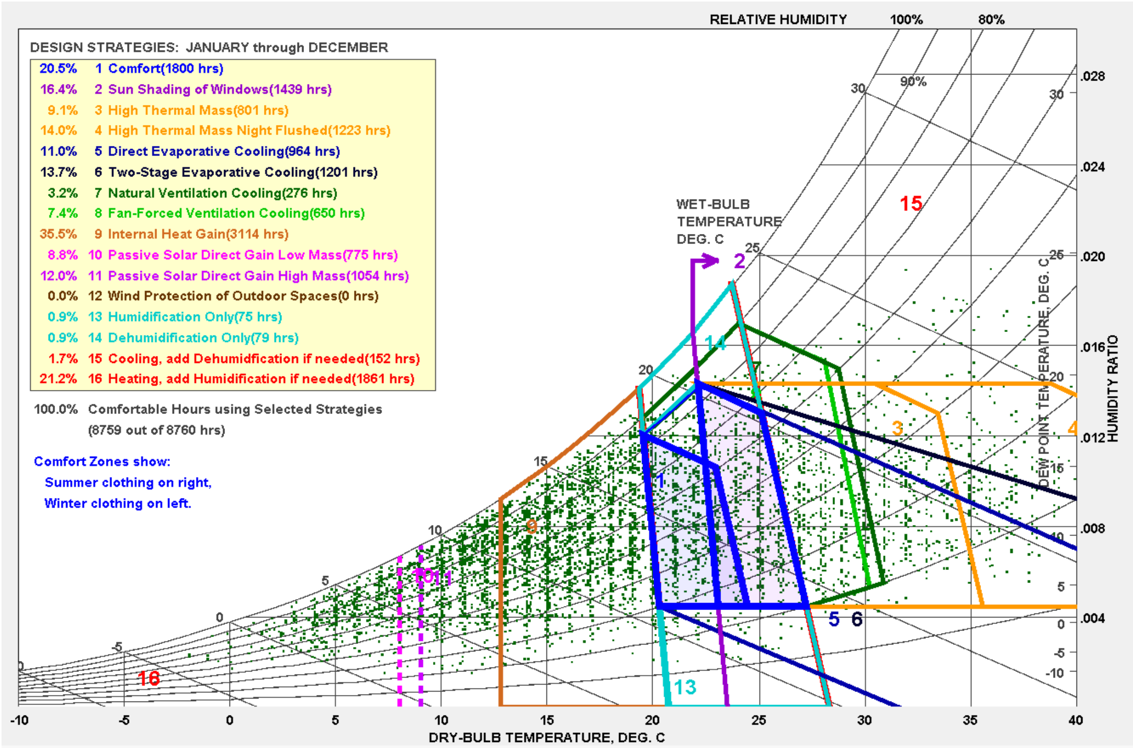


Figure 9 Psychometric Chart of Weather Conditions in Seville

As reflected in the above shown chart (Figure 9) the strategies that have the potential to achieve thermal comfort for a period of more than 500 hours are the following:

i. 2 Sun Shading
ii. 3 & 4 High Thermal Mass
iii. 5 & 6 Evaporative Cooling
iv. 8 Fan-Forced Ventilation Cooling
v. 9 Internal Heat Gains
vi. 10 & 11 Passive Solar Direct Gains
vii. 16 Heating

Among the above mentioned strategies, the strategies that will be evaluated are (i) Sun Shading, (ii) High Thermal Mass, (iii) Evaporative Cooling and (vi) Passive Solar Direct Gains. The other strategies of (iv) Mechanical ventilation and (vii) Heating correspond to active strategies and are therefore are not considered relevant for this Thesis. Also the strategy (v) Internal Heat Gains is a fixed value.

Construction Techniques

The identified design strategies (based on the Psychometric Chart with the ASHRAE Comfort model) from the previous paragraph, correspond to the following design strategies (from the Givoni chart (Figure 4) and consequently to the corresponding construction techniques.

4	**Passive Solar Heating**
	Awning
	Radiation through openings
	Capacitative Flooring
	Roof Pond
	Glazed Gallery
	Adjoined Greenhouse
	Trombe Wall
	Roof Openings

8	**Solar protection**
	Exterior Shading devices
	Decidious Vegetation
	Pergola with decidious Vegetation
	Horizontal Projections
	Vertical Projections
	Eggcrate Shading devices
	Sunscreens
	Shutters
	Roller Blinds/Shades
	Awnings
	Glazing
	Multiple Glazing
	Heat-Absorbing Glass
	Reflective Glass
	Glass Blocks
	Window Tilt
	Interior Shading devices
	Insulating Shutters
	Opaque Shades
	Draperies
	Venetian Blinds/Interior Louvers
	Façade Protecion
	Reflective materials or colors

9	**Cooling through a high thermal mass**
	Capacitative Materials idealy with
	Shading Protection (i.e. patio)

10	**Evaporative Cooling**
	Exterior Vegetation
	Water Ponds or Fountains
	Buried Water Pipes
	Patios with Vegetation & Water
	Vegetative Cover
	Exterior Water Spraying
	Indoor Water Spraying

11	**Cooling High Thermal Mass With Night Cooling**
	Capacitative Material with Phase Difference

Table 20 Optimal Design Strategies & Construction Techniques in Seville

The techniques on the above shown table will be evaluated in later stages of this Thesis (Section 6.4 - Design Techniques Assessment in Software Tools) evaluated in SG Save [37] , the selected EPC software tool for Spain.

6.4 Design Techniques Assessment in Software Tools

As described in the methodology, in this stage the objective is to evaluate if the available software tools for issuing an EPC in both countries are considering the design techniques corresponding to the bioclimatic architecture passive design strategies with potential to achieve thermal comfort (Sections 4 and 5) as input options.

In order to carry out this evaluation the three steps described in the are described in the succeeding sections of this sub-chapter.

6.4.1 Test Study Case House

The first step is to define a building geometry, that will be used for both countries as test study case in which the different design techniques will be tested.

The Thesis is focused on the residential typology; therefore, a simple single family one floor detached residential house has been defined.

The house has a total Gross Floor Area of 114,55 sqm and as shown in the below floorplan (Figure 10), the house includes three bedrooms, two bathrooms, a living room, a kitchen, a pantry, an entrance hall and a corridor.

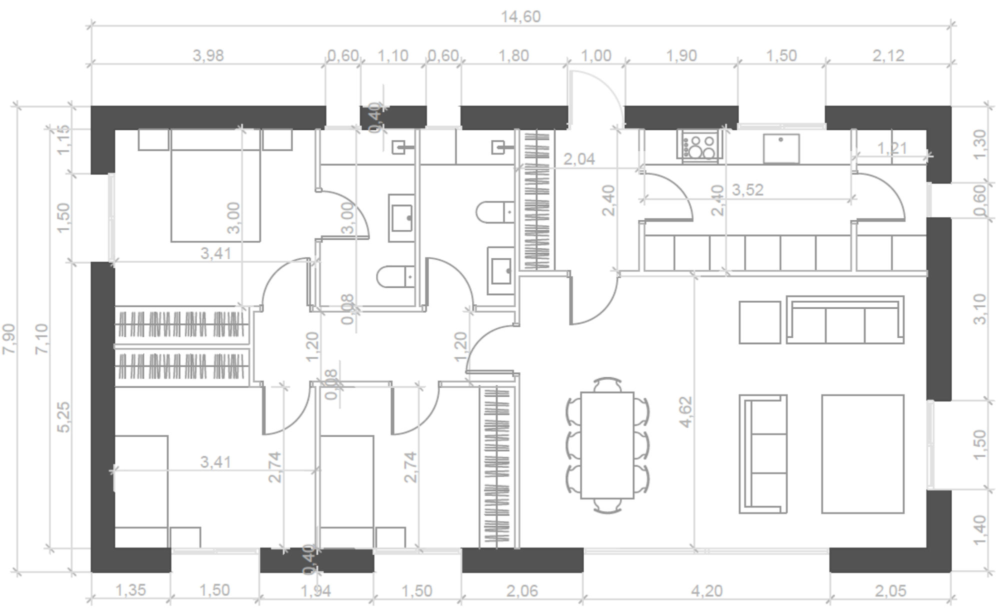


Figure 10 Test Case Study House Floorplan

For the definition of the geometry, especially with regard to the floorplan layout and to the size and position of the windows, the solar orientation has been taken into consideration.

In the Appendixes section of this document (Appendix D), more detailed information of the building geometry is included.

6.4.2 Constructions & Building Systems assignment

Before starting the assessment of the bioclimatic architecture strategies, different constructions for the building envelope, the openings and the building systems have been selected in order to achieve the minimum thermal comfort requirements.

The criteria used for the constructions (material layers and thicknesses) selection in each of the two countries is on one hand the achievement of the local building regulation requirements and on the other to select frequently used materials in local building traditions.

Building systems used are one of the default options in software tools which are the most commonly used in the countries object of this Thesis.

For the purpose of the evaluation of the EPC software tools, only the condition to meet local building codes is considered relevant. Any other aspects such as a potential optimization of the building performance, the cost of materials and labours costs or sustainability factors are not taken into consideration.

In the Appendixes section of this document more detailed information of the selected constructions is included (Appendix F).

6.4.3 EPC Software tools evaluation

Once having created a complete test case study model for the two regions in the selected software tools, *ArchiPHYSIK 15* [35] in Vienna and *SG Save* [37] in Seville, the design strategies and construction techniques identified in a previous section (Section 6.3 - Optimal Design Strategies & Techniques) are evaluated.

As introduced in the methodology description, the following two conditions are evaluated:

I. Does the software have the construction technique as default input option?

II. In case that not, is the simulation of the technique through an approximation possible?

In the next pages the evaluation of the conditions for each country are presented.

EPC Software Tools Evaluation in Austria

The table below (Table 21) shows the selected design strategies and construction techniques. Also, the outcome of the evaluation of the two conditions for each of the construction techniques in the region of Vienna is presented.

4	**Passive Solar Heating**	**Default option ?**	**Approx. possible?**
	Awning	Yes	-
	Radiation through openings	Yes	-
	Capacitative Flooring	Yes	-
	Roof Pond	Yes	-
	Glazed Gallery	Yes	-
	Adjoined Greenhouse	Yes	-
	Trombe Wall	No	No
	Roof Openings	Yes	-

8	**Solar protection**	**Default option ?**	**Approx. possible?**
	<u>Exterior Shading devices</u>		
	Decidious Vegetation	No	No
	Pergola with decidious Vege.	No	No
	Horizontal Projections	Yes	-
	Vertical Projections	Yes	-
	Eggcrate Shading devices	No	Yes
	Sunscreens	No	No
	Shutters	No	No
	Roller Blinds/Shades	No	No
	Awnings	No	No
	<u>Glazing</u>		
	Multiple Glazing	Yes	-
	Heat-Absorbing Glass	Yes	-
	Reflective Glass	Yes	-
	Glass Blocks	No	Yes
	Window Tilt	Yes	-
	<u>Interior Shading devices</u>		
	Insulating Shutters	No	No
	Opaque Shades	No	No
	Draperies	No	No
	Venetian Blinds/Int. Louvers	No	No
	<u>Façade Protecion</u>		
	Reflective materials or colors	No	No

Table 21 EPC Software Tools Evaluation in Austria

EPC Software tools evaluation in Spain

The following table (Table 22) shows the selected design strategies and construction techniques in Seville. Also, the outcome of the evaluation of the two conditions for each of the construction techniques is presented.

4	Passive Solar Heating	Default option ?	Approx. possible?
	Awning	Yes	-
	Radiation through openings	Yes	-
	Capacitative Flooring	Yes	-
	Roof Pond	Yes	-
	Glazed Gallery	No	Yes
	Adjoined Greenhouse	No	Yes
	Trombe Wall	No	Yes
	Roof Openings	Yes	-

8	Solar protection	Default option ?	Approx. possible?
	Exterior Shading devices		
	Decidious Vegetation	No	Yes
	Pergola with decidious Vege.	No	Yes
	Horizontal Projections	Yes	-
	Vertical Projections	Yes	-
	Eggcrate Shading devices	Yes	-
	Sunscreens	Yes	-
	Shutters	Yes	-
	Roller Blinds/Shades	Yes	-
	Awnings	No	Yes
	Glazing		
	Multiple Glazing	Yes	-
	Heat-Absorbing Glass	Yes	-
	Reflective Glass	Yes	-
	Glass Blocks	No	Yes
	Window Tilt	Yes	-
	Interior Shading devices		
	Insulating Shutters	No	Yes
	Opaque Shades	No	Yes
	Draperies	No	Yes
	Venetian Blinds/Int. Louvers	No	Yes
	Façade Protecion		
	Reflective materials or colors	No	Yes

9	Cooling through a high thermal mass	Default option ?	Approx. possible?
	Capacitative Materials	Yes	-

10	Evaporative Cooling	Default option ?	Approx. possible?
	Exterior Vegetation	No	Yes
	Water Ponds or Fountains	No	Yes
	Buried Water Pipes	No	Yes
	Patios with Vegetation & Water	No	Yes
	Vegetative Cover	No	Yes
	Exterior Water Spraying	No	Yes
	Indoor Water Spraying	No	Yes

11	Cooling High Thermal Mass With Night Cooling	Default option ?	Approx. possible?
	Capacitative Material with Phase Difference	Yes	-

Table 22 EPC Software Tools Evaluation in Spain

7 RESULTS

7.1 Overview

Results of the analysis carried out through this Thesis are presented in this section. The order in which the results are presented corresponds to the order of the steps methodology. First the results of the EPC Framework Comparison are presented and later the results of the EPC indicators.

7.2 EPC Framework Comparison

The outcome of the comparative literature review is presented in two charts.

The first chart (Figure 11) shows the results of the comparison of all 72 questions using the earlier described three-level evaluation scale. The chart shows the percentage of all questions that have obtained the same result.

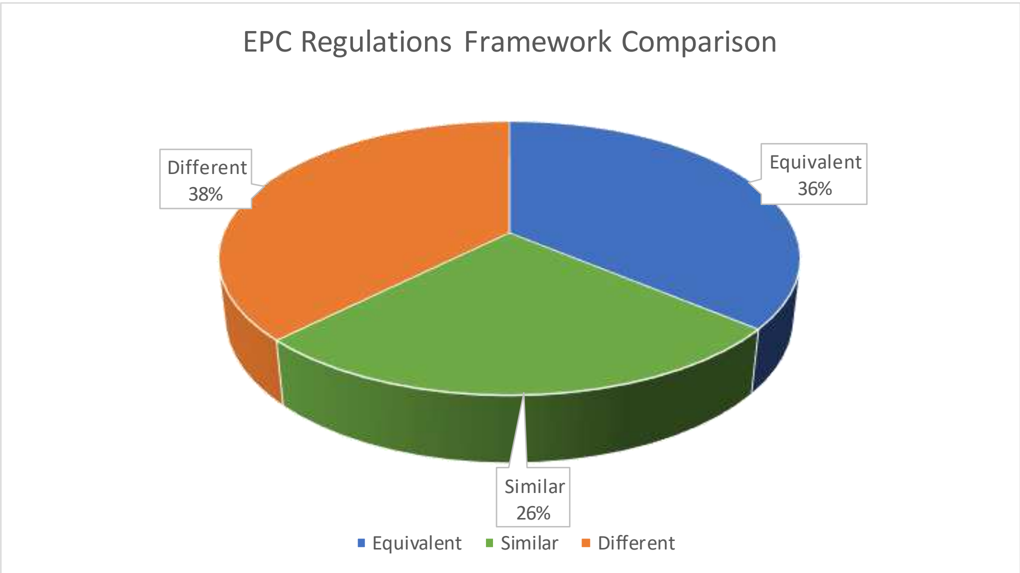


Figure 11 EPC Framework Comparison

The second chart (Figure 12) shows the percentage of each of the possible outcomes of the three-level evaluation scale used for the comparison but divided into each of the different six categories studied.

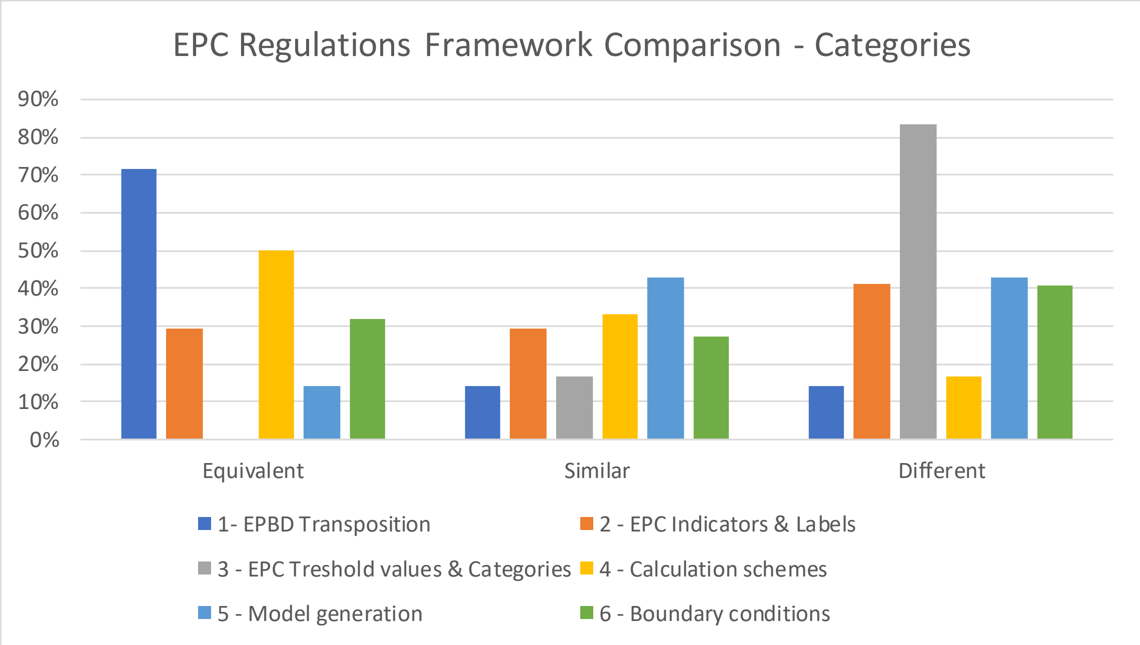


Figure 12 EPC Framework Comparison by Categories

Details of the answers to the 72 topics studied and the rate obtained in each of them are described in an earlier section of this Thesis (Section 3.1 EPC Framework).

7.3 EPC Indicators Comparison

After a general comparison of the EPC framework, in this section the analysis focuses on the indicators used to categorize buildings efficiency and compares the mandatory templates for the Energy Performance Certificates (EPC) and Energy Performance Labels in each of the countries.

The next pages of this section show the indicators of Austria and Spain respectively.

EPC indicators in Austria

The format and content of the Energy Performance Certificate in Austria is described in the Austrian building code [18] and for residential buildings the EPC is composed by two pages. The first page shows indicators used for the categorization of the building and on a second page several other additional indicators describing the building performance, geometry, as well as regulation compliance are included.

The indicators on the first page of the EPC are described in the table below (Table 23), and appear exactly as shown in the next image (Figure 13).

Indicator	Abbreviation	Units	Indicator (German language)
Heating Demand	HWB Ref,SK	kWh/m²a	Referenz-Heizwärmebedarf
Primary Energy Consumption	PEB SK	kWh/m²a	Primärenergiebedarf
Carbon Dioxide Emissions	CO2 eq SK	kg/m²a	Kohlendioxidemissionen
Overall Energy Efficiency factor	f GEE SK	-	Gesamtenergieeffizienz-Faktor

Table 23 Austrian EPC First Page Indicators

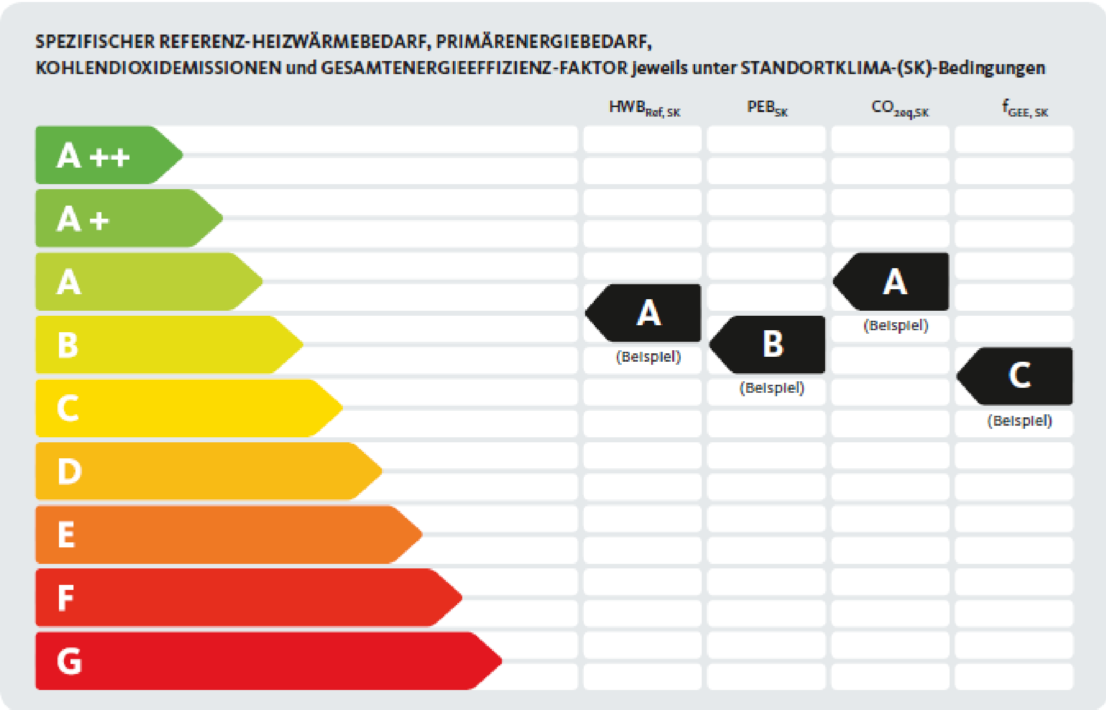


Figure 13 Indicators on the First Page of the Austrian EPC Template

On the second page of the Austrian EPC there appear other indicators divided in two groups. The first group are indicators that correspond to the energy demand and are based on a standard reference weather. These indicators are used for comparison and to indicate if the obtained value meets the requirements of the building regulation. The table below (Table 24) shows the indicators of this first group as they appear on the EPC (Figure 14) .

Indicator	Abbreviation	Units	Indicator (German language)
Reference Heating Demand	HWB Ref,RK	kWh/m²a	Referenz-Heizwärmebedarf
Heating Demand	HWB RK	kWh/m²a	Heizwärmebedarf
Final Energy Consumption (incl. Primary Energy Factor)	EEB RK	kWh/m²a	Endenergiebedarf
Overall Energy Efficiency Factor	f GEE	-	Gesamtenergieeffizienz-Faktor
Part of Renewable Energy Use	-	-	Erneuerbarer Anteil

Table 24 Austrian EPC Second Page Building Requirement Indicators

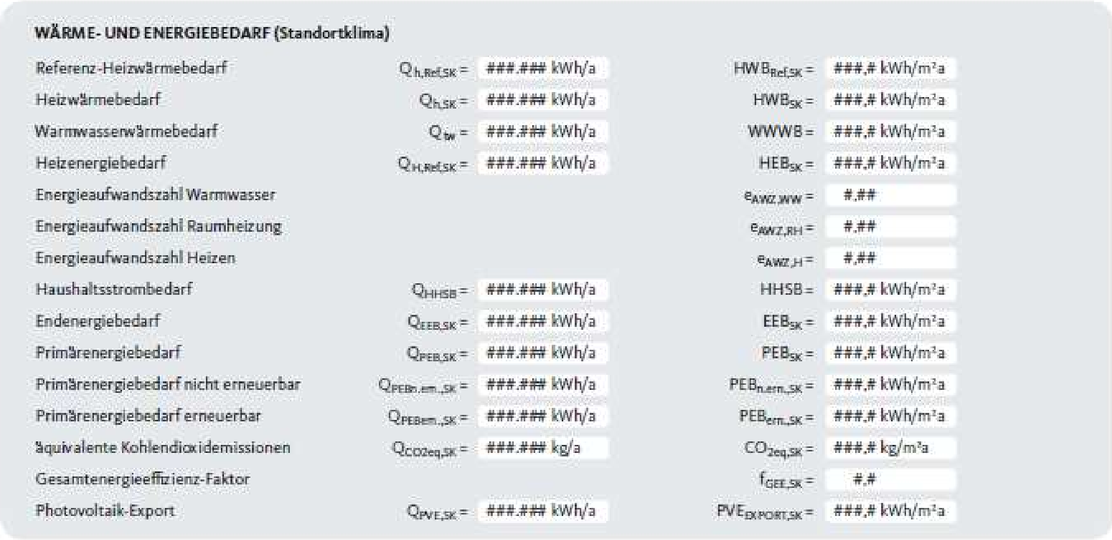
WÄRME- UND ENERGIEBEDARF (Referenzklima)				Nachweis über #####	
		Ergebnisse			Anforderungen
Referenz-Heizwärmebedarf	$HWB_{Ref,RK}$ =	###,# kWh/m²a	entspricht / entspricht nicht	$HWB_{Ref,RK,zul}$ =	###,# kWh/m²a
Heizwärmebedarf	HWB_{RK} =	###,# kWh/m²a			
Endenergiebedarf	EEB_{RK} =	###,# kWh/m²a	entspricht / entspricht nicht	$EEB_{RK,zul}$ =	###,# kWh/m²a
Gesamtenergieeffizienz-Faktor	$f_{GEE,RK}$ =	#,##	entspricht / entspricht nicht	$f_{GEE,RK,zul}$ =	#,##
Erneuerbarer Anteil	#########		entspricht / entspricht nicht	Punkt 5.2.3 a, b oder c	

Figure 14 Building Requirement Indicators on the Second Page of the Austrian EPC Template

The other group of indicators that appear on the second page of the Austrian EPC are indicators based on the actual building's location and complement the values shown on the first page of the certificate. This second group of indicators, included on the second page of the EPC (Figure 15), appears both as a total value and as area weighted value. Indicators weighted by building area are described in the table below (Table 25):

Indicator	Abbreviation	Units	Indicator (German language)
Reference Heating Demand	HWB Ref,SK	kWh/m²a	Referenz-Heizwärmebedarf
Heating Demand	HWB SK	kWh/m²a	Heizwärmebedarf
Hot Water Demand	WWWB	kWh/m²a	Warmwasserwärmebedarf
Heating Energy Demand	HEB SK	kWh/m²a	Heizenergiebedarf
Energy expenditure Factor – Hot Water	E AWZ WW		Energieaufwandszahl Warmwasser
Energy expenditure Factor – Room Heating	E AWZ RH		Energieaufwandszahl Raumheizung
Energy expenditure Factor – Heating	E AWZ H		Energieaufwandszahl Heizen
Household Electricity Demand	HHSB	kWh/m²a	Haushaltsstrombedarf
Final Energy Consumption (incl. Primary Energy Factor)	EEB SK	kWh/m²a	Endenergiebedarf
Primary Energy Consumption	PEB SK	kWh/m²a	Primärenergiebedarf
Primary Non-Renewable Energy Consumption	PEB n ern SK	kWh/m²a	Primärenergiebedarf nicht erneuerbar
Primary Renewable Energy Consumption	PEB ern SK	kWh/m²a	Primärenergiebedarf erneuerbar
Carbon Dioxide Emissions	CO2 SK	kg/m²a	Äquivalente Kohlendioxidemissionen
Overall Energy Efficiency Factor	FGEE		Gesamtenergieeffizienz-Faktor
Exported Photovoltaic Energy	PV Export SK	kWh/m²a	Photovoltaik-Export

Table 25 Austrian EPC Second Page Additional Indicators



WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	$Q_{h,Ref,SK}$ =	###.### kWh/a	$HWB_{Ref,SK}$ =	###,# kWh/m²a
Heizwärmebedarf	$Q_{h,SK}$ =	###.### kWh/a	HWB_{SK} =	###,# kWh/m²a
Warmwasserwärmebedarf	Q_{tw} =	###.### kWh/a	WWWB =	###,# kWh/m²a
Heizenergiebedarf	$Q_{H,Ref,SK}$ =	###.### kWh/a	HEB_{SK} =	###,# kWh/m²a
Energieaufwandszahl Warmwasser			$e_{AWZ,WW}$ =	#,##
Energieaufwandszahl Raumheizung			$e_{AWZ,RH}$ =	#,##
Energieaufwandszahl Heizen			$e_{AWZ,H}$ =	#,##
Haushaltsstrombedarf	Q_{HHSB} =	###.### kWh/a	HHSB =	###,# kWh/m²a
Endenergiebedarf	$Q_{EEB,SK}$ =	###.### kWh/a	EEB_{SK} =	###,# kWh/m²a
Primärenergiebedarf	$Q_{PEB,SK}$ =	###.### kWh/a	PEB_{SK} =	###,# kWh/m²a
Primärenergiebedarf nicht erneuerbar	$Q_{PEBn.ern.,SK}$ =	###.### kWh/a	$PEB_{n.ern.,SK}$ =	###,# kWh/m²a
Primärenergiebedarf erneuerbar	$Q_{PEBern.,SK}$ =	###.### kWh/a	$PEB_{ern.,SK}$ =	###,# kWh/m²a
äquivalente Kohlendioxidemissionen	$Q_{CO2eq,SK}$ =	###.### kg/a	$CO_{2eq,SK}$ =	###,# kg/m²a
Gesamtenergieeffizienz-Faktor			$f_{GEE,SK}$ =	#,#
Photovoltaik-Export	$Q_{PVE,SK}$ =	###.### kWh/a	$PVE_{EXPORT,SK}$ =	###,# kWh/m²a

Figure 15 Additional Indicators on the Second Page of the Austrian EPC Template

In the Appendixes section of this Thesis (Appendix C) the official templates for the Austrian EPC are included.

EPC Indicators in Spain

In Spain there are two template documents described in official publications [26][28] to be used for the building's energy performance categorization, a template for the Energy Performance Label as well as one for the Energy Performance Certificate.

In the EP Label and the EPC, the two indicators used to rank the buildings performance appear. The table below (Table 26) shows the indicators and the two images (Figure 16 and Figure 17) show the indicators as they appear in the EP Label and EPC.

Indicator	Units	Indicator (Spanish language)
Primary Non-Renewable Energy Consumption	kWh/m²a	Consumo de energia primaria no renovable
Carbon Dioxide Emissions	kgCO2e /m²a	Emisiones de dióxido de carbono

Table 26 Energy Performance Label and Certificate Indicators

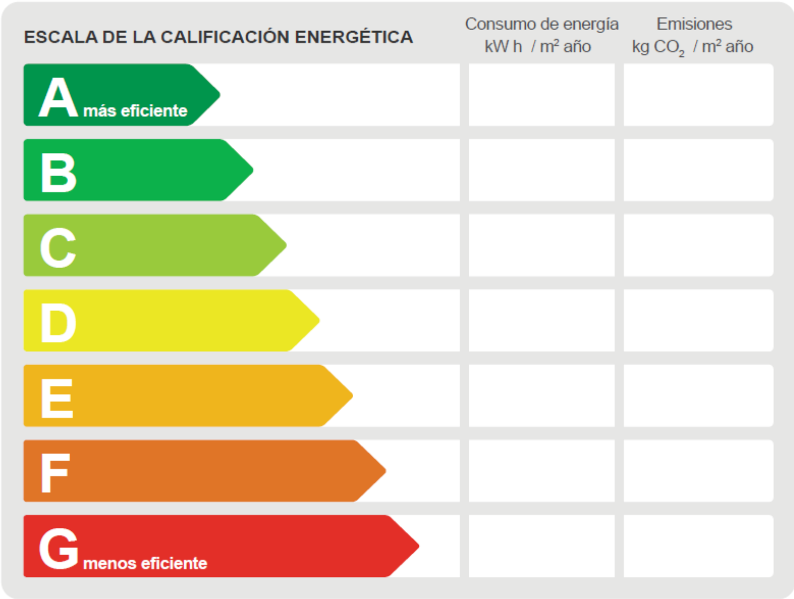


Figure 16 Indicators in the Energy Performance Label

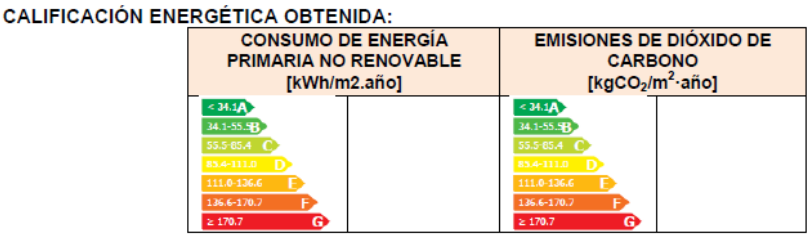


Figure 17 Indicators in the Energy Performance Certificate

In order to provide more detailed information, in the Spanish EPC Annexes the indicators described above appear again but in the Annex they are shown together with a breakdown of the total value into the different building systems. Additionally, in the EPC Annex there are other indicators for the heating and cooling demand which indicate if the building meets the requirements of the building regulation.

The following table (Table 27) and image (Figure 18) show the breakdown of the Carbon Dioxide Emissions indicator divided by building system categories that appear in the Spanish EPC Annexes.

Indicator	Units	Indicator (Spanish language)
Carbon Dioxide Emissions	kgCO2e /m²a	Emisiones globales
Heating - Carbon Dioxide Emissions	kgCO2e /m²a	Emisiones calefacción
Hot Water - Carbon Dioxide Emissions	kgCO2e /m²a	Emisiones ACS
Cooling - Carbon Dioxide Emissions	kgCO2e /m²a	Emisiones refrigeración
Lighting - Carbon Dioxide Emissions	kgCO2e /m²a	Emisiones iluminación
Carbon Dioxide Emissions - energy source electricity	kgCO2e /m²a	Emisiones Co2 por consumo eléctrico
Carbon Dioxide Emissions - other energy sources	kgCO2e /m²a	Emisiones Co2 por otro combustibles

Table 27 Spanish EPC Carbon Dioxide Emissions Indicator additional breakdown

INDICADOR GLOBAL		INDICADORES PARCIALES			
		CALEFACCIÓN		ACS	
< 34.1 A 34.1-55.5 B 55.5-85.4 C 85.4-111.0 D 111.0-136.6 E 136.6-170.7 F ≥ 170.7 G		Emisiones calefacción [kgCO$_2$/m^2·año]		Emisiones ACS [kgCO$_2$/m^2·año]	
		REFRIGERACIÓN		ILUMINACIÓN	
Emisiones globales [kgCO$_2$/m^2·año][1]		Emisiones refrigeración [kgCO$_2$/m^2·año]		Emisiones iluminación [kgCO$_2$/m^2·año]	

La calificación global del edificio se expresa en términos de dióxido de carbono liberado a la atmósfera como consecuencia del consumo energético del mismo.

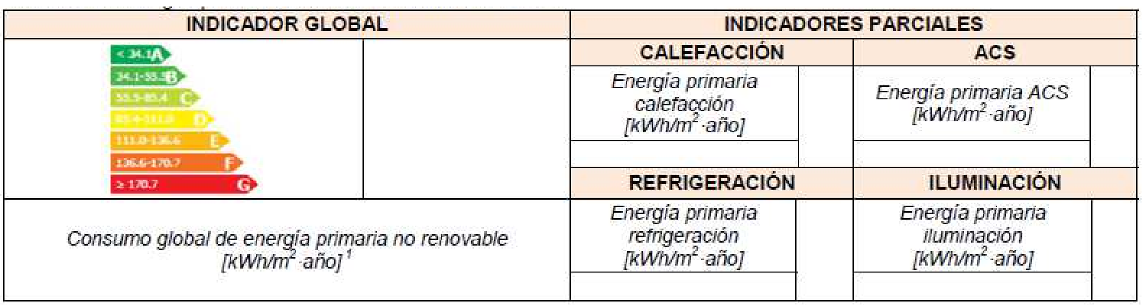
	kgCO2/m2.año	kgCO2/año
Emisiones CO2 por consumo eléctrico		
Emisiones CO2 por otros combustibles		

Figure 18 Additional breakdown of Carbon Dioxide Emissions Indicator in the Spanish EPC

The table (Table 28) and image below (Figure 19) show the breakdown of the Primary Non-Renewable Energy Consumption indicator divided by building system categories that appear in the Spanish EPC Annexes.

Indicator	Units	Indicator (Spanish language)
Total Primary Non Renewable Energy Consumption	kWh/m²a	Consumo global de energía primaria no renovable
Heating - Primary Non Renewable Energy Consumption	kWh/m²a	Energía primaria calefacción
Hot water - Primary Non Renewable Energy Consumption	kWh/m²a	Energía primaria ACS
Cooling - Primary Non Renewable Energy Consumption	kWh/m²a	Energía primaria refrigeración
Lighting - Primary Non Renewable Energy Consumption	kWh/m²a	Energía primaria iluminación

Table 28 Spanish EPC Primary Non-Renewable Energy Consumption Indicator additional breakdown



INDICADOR GLOBAL		INDICADORES PARCIALES			
		CALEFACCIÓN		ACS	
< 34.1 A 34.1-55.5 B 55.5-85.4 C 85.4-111.0 D 111.0-136.6 E 136.6-170.7 F ≥ 170.7 G		Energía primaria calefacción [kWh/m^2·año]		Energía primaria ACS [kWh/m^2·año]	
		REFRIGERACIÓN		ILUMINACIÓN	
Consumo global de energía primaria no renovable [kWh/m^2·año][1]		Energía primaria refrigeración [kWh/m^2·año]		Energía primaria iluminación [kWh/m^2·año]	

Figure 19 Additional breakdown of Primary Non-Renewable Energy Consumption Indicator in the Spanish EPC

The following table (Table 29) and figure (Figure 20) show the Heating and Cooling demand which indicate if the building meets the requirements of the building regulation.

Indicator	Units	Indicator (Spanish language)
Heating Demand	kWh/m²a	Demanda de calefacción
Cooling Demand	kWh/m²a	Demanda de refrigeración

Table 29 Spanish EPC Heating & Cooling Demand Indicators

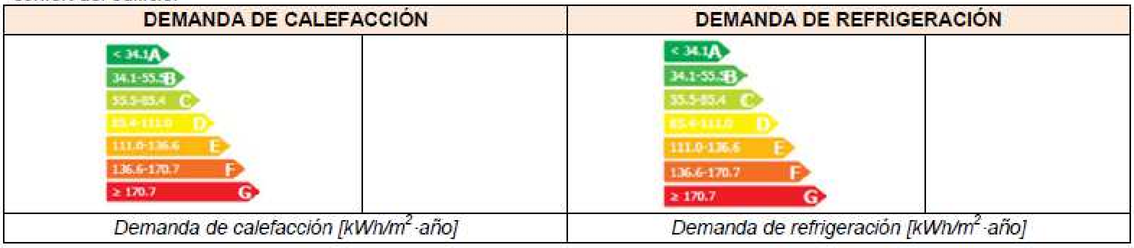


Figure 20 Heating & Cooling Demand Indicators in the Energy Performance Certificate

In the Appendixes of this study, the official templates for the Spanish Energy Performance Label (Appendix A) and the Spanish Energy Performance Certificate (Appendix B) are included.

7.4 EPC Software tools Comparison

Results obtained in the evaluation of the integration of bioclimatic passive architecture strategies in the EPC software tools in Austria and Spain are presented with charts in this section (Figure 21 and Figure 22).

Austria

The chart below (Figure 21) shows that the software tool in Austria, *ArchiPHYSIK 15.0* [34] , had the evaluated construction technique as a default input option in approximately half of the occasions (48%) tested in this study. In the rest of the occasions (52%) in which the technique was not a default option, only in a small percentage (7%) of the cases the simulation was possible, either by creating a new material or by adapting the building geometry in the software. In the remaining percentage of the situations (45%) neither was it a default option, nor was it possible to simulate the technique by an approximation.

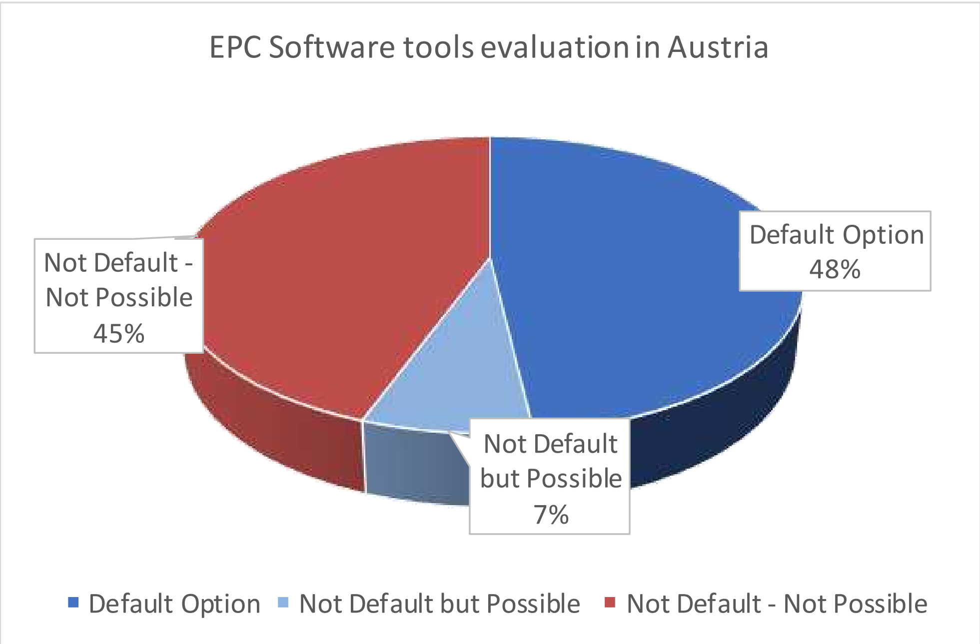


Figure 21 Evaluation of EPC Software Tools in Austria

Spain

In Spain, the evaluation of the selected tool *SG SAVE* [37] presented a rather different outcome as shown in the chart below (Figure 22). In almost half of the occasions (47%) the construction technique was a default input option in the software. In all other occasions (53%), even if the construction technique was not a default option, the simulation of it through an approximation of either the geometry or of the parameters of the calculation engine (*EnergyPlus*) was possible.

A relevant result of the evaluation of the EPC Software tool in Spain, is that all of the construction techniques (100%) were possible to simulate even if approximately half of them (53%) were not default options.

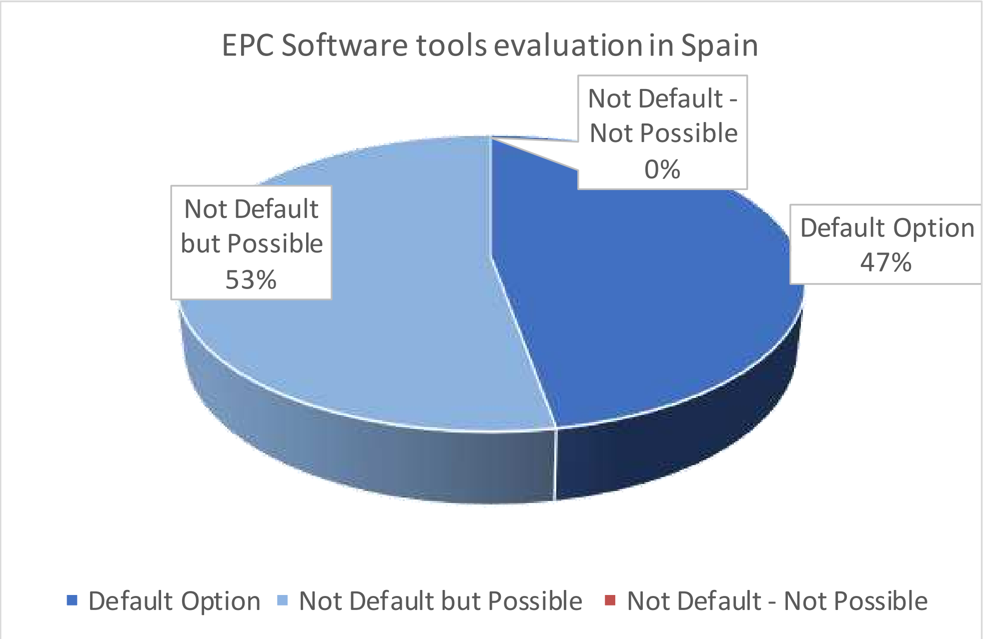


Figure 22 Evaluation of EPC Software Tools in Spain

8 DISCUSSION

The obtained results after following the steps methodology presented in the previous section (Section 7 - Results) are interpreted and discussed.

The results are discussed in the same order of the methodology, first the EPC framework comparison, then the EPC indicators comparison and finally the EPC Software tools evaluation.

Also, after the analysis of the results, the formulated research questions are answered.

8.1 EPC Framework Comparison

Regarding the analysis of the 72 aspects of the EPC framework compared in this Thesis the earlier presented chart (Figure 11) showed that the comparison of the EPC schemes of the two countries object of this Thesis resulted in similar percentages for all three possible evaluation outcomes. The number of occasions where the comparison outcome was either *equivalent* (36%), similar (26%) or different (38%) are close, showing differences between them of 12% or lower.

A relevant aspect of this comparison is the fact that only approximately one third (36%) of the compared topics resulted evaluated as “equivalent” even though both countries (Austria and Spain) are EU Member States and therefore have the same common legislative framework.

If we focus the interpretation on the results of the EPC Framework comparison by categories, the obtained results in the different categories present significant differences between them as shown in the next chart (Figure 23).

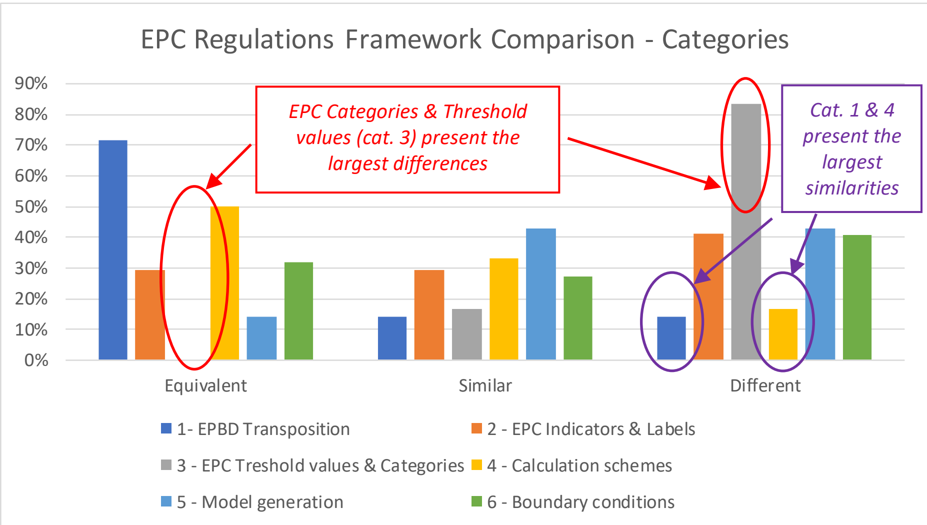


Figure 23 Analysis of EPC Framework Comparison by Categories

As observed in the chart above, the evaluation outcome of “Similar” is the only category that does not present very significant differences, being the difference between the highest and lowest values lower than 40%.

About the results obtained in the different categories, Category 3 (EPC Threshold Values & Categories) presents the larger differences between certification schemes of both countries. In this category there is no topic where the comparison resulted in “Equivalent” and in more than 80% of the topics the outcome was “Different”.

On the contrary, Categories 1 (EPBD Transposition) and 4 (Certification schemes) are the categories which presented the largest resemblance, as the majority of compared topics resulted either “Equivalent” or “Similar” and only approximately 15% of the compared aspects obtained the evaluation outcome of “Different”.

A general aspect after carrying out the EPC Framework comparison, is that the countries of this study presented noticeable differences on both a general level and in the different categories. A possible interpretation of the results is that these large differences are caused by the fact that, even if there is a common EU directive, the methodologies, tools, codes and standards which set the framework for the EPC are nation based and each MS has a different framework.

After the discussion of the results obtained in a general level, the following paragraphs present the most significant aspects identified in each of six categories in detail:

8.1.1 Category 1 - EPBD National Transposition

This category presented a large resemblance between the two countries, as the aspects compared in this category deal with the transposition of the EU directives, thus the obligation of MS to follow a common framework and therefore the resemblance in the results obtained. However, significant differences have been observed in the recommendations for improving the buildings included in the EPCs. Both countries include recommendations but in Austria they are merely based on calculated values and in Spain the recommendations must be based on actual energy consumption bills. Moreover, even auditors in both countries must take into consideration economic aspects in the given recommendations, but only in Austria the payback time of the potential improvement cost is considered.

8.1.2 Category 2- EPC Indicators & Labels

The second category obtained a rather balanced evaluation outcome. In 29% of the compared topics the outcome was either "Equivalent" or "Similar" and in 41% of the occasions the outcome was "Different". However, there are important aspects that highly influence the building's energy performance reflected in the indicators. These differences are as significant as the variation of the CO2 emissions for electricity as energy source (227 g/kWh in Austria and 357g/kWh in Spain) and the percentage of the total primary energy that comes from renewable sources (37,5 % in Austria and 19,5% in Spain) when electricity is the building energy source.

8.1.3 Category 3 - EPC Threshold values & Categories.

This category presents the largest differences, also the aspects evaluated as "Different" are rather significant regarding the comparability between the Austrian and Spanish EPCs.

The most remarkable aspect of the evaluation outcome is the fact that in Austria the threshold values for each of the EPC categories are the same in each region, whereas in Spain, to obtain the Energy Grade there are 12 different scales for the territories on the mainland and 20 for the islands. Also, the number of grading categories is not the same, having nine in Austria (from grade A++ to grade G) and seven in Spain (from grade A to grade G).

These differences show that in Spain, a country with various climatic conditions, the EPC grading is consequently adapted to take the climate severity of each region into consideration. Thus, the differences within all EU MS climate conditions could be weighted in a single grading system but with different scales.

8.1.4 Category 4 - Calculation Schemes

The obtained results of the evaluation in the category that compares the calculation methodologies indicate a noticeable resemblance, as in 50% of the topics the evaluation outcome was "Similar". In both countries only the certification based in calculated values is accepted and even though in Austria both dynamic and steady (monthly) calculation methods are accepted, in Spain only the dynamic method is accepted. However, while both countries do not allow on site measured values as a calculation method and therefore have a similar calculation approach, only in Spain the auditor is requested to perform a site survey and describe the on-site test carried out.

This difference in the requirement to perform on-site testing is considered an argument to challenge the accuracy of the current data of the building stock based on the EPC in Austria and in other MS.

8.1.5 Category 5 - Model Generation

The results in this category showed a significantly low percentage of aspects in which the outcome was “Equivalent”, only in a 14% of the aspects. Among the aspects which are considered either different in some extension the topic that has the largest influence in the results is the calculation of the conditioned areas. In Austria the conditioned area is limited by the external wall outer perimeter and therefore included elements as staircases and shafts, whereas in Spain it is limited by the inner perimeter and these ancillary building areas are excluded from the condition area.

The difference in the calculation of the conditioned area are highly influencing the obtained Energy Performance Indicators and are considered a key aspect to state that at present certification schemes of Austria and Spain are not comparable.

8.1.6 Category 6 - Boundary Conditions

The aspects compared in this category highly influence the values of the indicators in the EPC. Thus, even if the evaluation outcome of the compared subjects in each category is balanced (32 % “Equivalent”, 27% “Similar” and 41 % “Different”) the importance of the aspects being categorized as “Different” is reason enough to consider the EPCs of Austria and Spain as not comparable.

The topics which present remarkable variance between the two countries are key subjects such as the considered set points for heating and cooling, ventilation and infiltration rates and internal gains among others. All the values for this boundary conditions are not comparable between the countries object of this Thesis.

8.2 EPC Indicators Comparison

The analysis of the results obtained in the specific comparison of the indicators used in the Energy Performance Certificates of both countries showed some significant differences that are described and interpreted in the following paragraphs.

As shown in the previous sections where a comparison of the EPC framework is carried out (Section 3.1 - EPC Framework) and the section where the results of the EPC indicators comparison are presented (Section 7.3 - EPC Indicators Comparison), the information in the indicators and number of them used for buildings categorization is significantly different, being four the number of indicators used in Austria and only two in Spain.

If we focus on the two indicators that appear on the Energy Performance Label in Spain, the “Carbon Dioxide Emissions” and the “Primary Non-Renewable Energy Consumption”, only the first one is the indicator that both countries have in common.

However, as seen in a previous section (Section 3 – Bioclimatic Design Strategies Review Literature Review), the conversation factor from Final Energy to CO2 emissions for the same energy source are significantly different between both countries.

Regarding the second indicator that is used in the Spanish EP Label, the "Primary Non-Renewable Energy Consumption", even if the general approach is similar to the "Primary Energy Consumption" that appears in the Austrian EPC, the information that both reflect is rather different. In Austria the indicator includes both the "On site produced energy" from Non-Renewable energy sources and the "Energy from the Source Grid" whereas in Spain the indicator only shows the energy from Non-Renewable Energy Sources.

In addition to the indicators used for the EPC grading, as shown earlier on this Thesis (Section 7.3 - EPC Indicators Comparison) in both countries the EPC, either on a second page (Austria) or in the mandatory Annexes (Spain), they include other indicators. These indicators present differences in the information they show and the number of them, nevertheless the objective is similar.

These additional indicators could be categorized in two groups, a first group of indicators that show the building performance and compares them to the building regulations, and a second group that provide a breakdown of the main indicators in the different consumption systems and energy sources.

Considering the abovementioned aspects, it is considered that the main indicators used in the Spanish and Austrian EPCs to categorize the building stocks present significant differences. They also they present large differences in other parameters included in the EPC to describe the building geometry and the compliance with local regulations. These differences on the indicators makes the comparability between EPC a rather complex task and not feasible with only looking at the indicators, if not a detailed study is needed to understand the particularities of each of the EPC.

8.3 EPC Software tools evaluation

The obtained results of the EPC software tools evaluation for each of the two countries object of this study are compared and discussed in the following paragraphs. As earlier described in the methodology (Section 2 - Method) the evaluation consists of assessing if the selected software tools for issuing an EPC in both countries are considering the design techniques corresponding to the bioclimatic architecture passive design strategies with potential to achieve thermal comfort as input options.

The analysis of the results presented in the previous section (Section 7.4 - EPC Software tools Comparison) show rather different values. On one hand the total percentage of construction techniques that are default input options in the selected tools are almost identical in both countries, 48 % in Austria and 47% in Spain as shown in the previous charts (Figure 21 and Figure 22). However, taking a closer look to the remaining percentage of occasions were the construction technique was not a default input option, we find completely opposite outcomes. In Spain the total number of construction techniques that are not default options (53%), are all possible to simulate through an approximation, while in Austria only in a small percentage (7 %) is possible, thus in a significant percentage (43%) the simulation was not possible at all.

The reasons behind these noticeable differences is the fact that *SG Save,* [37] the selected program among the approved ones by the Spanish Authorities, is using *Open Studio* [36] as a user interface and *Energy Plus* [39] as a calculation engine. These programs are energy simulation tools with high capabilities which provide accurate results of buildings performance.

Basically, with *SG Save* [37] you can simulate all kind of buildings and constructions with the only limitation of the parameters of mandatory use, which are specified in a guideline document for EPC software tools [29] and are not modified through the simulation process.

However, even though *SG Save* [37] is a powerful tool, as it is a rather new tool (2018) it doesn't have an interface as user friendly i as other available software tools, it seems that it is not yet widely used in the Spanish building sector.

In Austria, *ArchiPHYSIK 15* [35] is a tool which its main purpose is the buildings Energy Performance Certification therefore the amount of options for the simulation of passive bioclimatic strategies are more limited.

Considering the above described factors, a reasonable interpretation is that even if there are available software tools for the simulation of bioclimatic architecture passive design strategies, the current EPC software tools (list in Section 3.1) are not necessarily allowing the simulation of these strategies. Only *SG Save* [37], a tool in Spain, which uses a powerful simulation engine allows an approximate simulation.

8.4 Research Questions

After the analysis of the results in this section of the Thesis the proposed research questions are discussed and addressed.

The first research question including the corresponding sub questions is the following:

- RQ 1. Are Energy Performance Certificates in Austria and Spain sensitive to bioclimatic architecture passive strategies?
    - RQ1.1 Are the indicators sensitive to bioclimatic architecture passive strategies?
    - RQ1.2 Are passive strategies possible input options in available certification tools?

To answer this question and sub questions, the suggested approach is to first discuss the more specific sub question and then answer the general question.

8.4.1 Research Question 1

RQ1.1 Are the indicators sensitive to bioclimatic architecture passive strategies?

Regarding the first sub question and considering the different aspects identified in this research and described in the following points, the answer is that the indicators are not sensitive to bioclimatic architecture passive strategies. Below the identified reasons:

- **No indicator of bioclimatic architecture design efficiency.** All indicators used in the EPC rating refer to the total building energy demand and consumption, but no indicator refers to the effectiveness of the design in terms of passive bioclimatic design. As shown earlier in this Thesis (Section 7.3 - EPC Indicators Comparison), in the Austrian EPC there is an indicator, the “Overall Energy Efficiency Factor”, which compares the efficiency of the building with a reference building. Also, there are some figures to describe the geometry which show the intention to describe an architecture sensitive to the climate.
  Even if there is an intention to reflect architecture efficiency there is no information of the estimated influence in the energy demand of the bioclimatic passive design strategies such as natural ventilation, solar protection and direct solar gains.

- **Heating & cooling with comfort zone tolerance.** It is considered that EPC indicators must reflect both heating and cooling demands. Even if in Spain both demands are included in the EPC, in neither Spain nor in Austria, a permissible range of some hours during the year where the building interior temperature is out of comfort zone is allowed. In passive bioclimatic architecture it is generally considered that users adapt their clothing therefore to allow some tolerance would reflect a better bioclimatic passive architecture. It might be possible that in some cases the installation of an active building system would be even not necessary if some tolerance in the comfort zone is allowed.

- **Total Primary Energy.** Both countries indicate the use of the primary energy, however as seen in a previous sections (Section 8.2 - EPC Indicators Comparison) they use a rather different approach in terms of considering the primary energy from renewable energy sources. The EPC must indicate the "Total Primary Energy" as the addition of the "On Site Produced Energy from Renewable Energy Sources" and the "Energy coming the Grid". Only following this calculation approach the influence of passive bioclimatic architecture could be reflected in the EPC. At present, in the Spanish EPC scheme, two buildings obtain the same EPC Grade even if they have significant different thermal performances, as the current scheme allows to compensate the inefficiency of the design with the onsite energy production contribution.

RQ1.2 Are passive strategies possible input options in available certification tools?

Even if results obtained in the evaluation of the EPC software tools presented significant differences as shown in earlier pages of this Thesis (Sections 6.4 and 8.3) the answer to this sub question would be the same for both countries.

In Spain the outcome of the evaluation is that the software used in this Thesis allows for an approximation in the simulation of the construction techniques, which is not the case in Austria. Nevertheless, in both countries the bioclimatic construction techniques are a default input option only in an approximately 50% of the situations.

Considering the obtained results and the abovementioned reasons, the answer to this sub question would be that bioclimatic passive architecture design techniques are not possible input options in available certification tools.

Having addressed the sub questions of the first research questions, in the next paragraphs the main research questions is addressed.

- **RQ 1. Are Energy Performance Certificates in Austria and Spain sensitive to bioclimatic architecture passive strategies?**

Considering the argumentation given to address the sub questions, the answer to the first research question would be that Energy Performance Certificates in Austria and Spain are not sensitive to architecture passive strategies.

The reasoning behind the answer is that even if there are aspects in the indicators that have the goal to indicate the efficiency in terms of energy use of the buildings neither the indicators themselves nor the calculation of them have been proved to reflect the bioclimatic construction techniques.

Moreover, the available certification software options, which are the auditor's tools to issue the certificate and therefore highly influential in describing the building energy performance in the EPC, also have been proved to be not sensitive to bioclimatic architecture design strategies and to the corresponding construction techniques.

8.4.2 Research Question 2

Throughout the next paragraphs the second research question will be discussed and answered, taking also into consideration the interpretation of the first research question.

- **RQ 2 Based on Austrian and Spanish current certification processes would it be possible to have a single EPC for all EU Member States?**

During the literature review and the software evaluation carried out in this Thesis many significant differences have been identified between the two countries object of this study. *Thus, the answer to the question is that even if it would be positive, the current legislative framework with the national implementation of the EU directives and the local building codes make a common EPC for all EU MS impossible at present.*

Contrary to what might be the first thought, the most significant differences are not based on geographical related aspects such as the local building traditions and the weather conditions, if not the relevant aspects, as shown in the results of this Thesis (Section 8.1 -

EPC Framework Comparison), are the national approaches used in the countries to set the different EPC categories, threshold values, the conventions for defining the building geometry and the indicators used in the EPC label.

This last aspect, the differences in the indicators used, which have been studied thoroughly in this work, is considered the most relevant characteristic. The whole certification process is summarized in the EPC indicators, which not only present remarkable differences in the calculation if not that there are differences in the number of indicators as well as in the information they provide.

Regarding the initial impression, that geographical related aspects could oppose the introduction of a single EPC, based on the results of two countries studied, climatic condition and building traditions are not a reason to avoid the introduction of it, since within the territories of the countries object of this Thesis, especially in Spain, there are significant differences in climatic conditions which are captured in the calculation schemes.

9 CONCLUSION

In the efforts described in this Thesis, significant aspects regarding the integration of the bioclimatic architecture in the EPC schemes of Austria and Spain have been identified. Thereby, the comparability of their EPC schemes and legislative frameworks have been examined as well.

Regarding the comparability of the EPC schemes, some significant differences have been identified at all levels during this research. These differences indicate that at present the introduction of a single EPC for all EU Member States is considered not achievable. However, it is thought that even if a single EPC is discouraged at the moment, introducing any step (e.g. new standards, common EU software, etc.) in the direction of the homogenization of the MS certificates would be beneficial in order to achieve reliable data in a near future. This data could potentially be used as the basis to set more accurate strategies for the reduction of the EU CO2 emissions.

The identified differences on the EPC Framework comparison rely on the fact that the parameters that set the creation of the EPC are established at a national level, creating a disparity in the obtained results between countries and consequently are not facilitating the cross-national comparability.

As for the bioclimatic passive design strategies, after following a step methodology for the evaluation of the integration of these strategies in the EPC schemes, it is considered that both Austrian and Spanish EPC are not sensitive to bioclimatic architecture. In the case of Austria, both the EPC main and additional indicators showed a better description of the buildings in terms of its design sensitiveness towards the weather conditions compared to the Spanish EPC. However, the evaluated software tool for Austria presented difficulties in the simulation of bioclimatic construction techniques.

On the contrary in Spain, with a recently approved tool, the capabilities to simulate and consider the contribution of bioclimatic principles in the EPC are larger than in Austria. Nevertheless, the EPC indicators and the EP Label presented a lack of parameters to express the bioclimatic architecture contribution in energy efficiency.

Regarding the future development of the EPCs, even if it is advisable to improve their comparability, prior to releasing any new regulation, it is crucial to analyze, debate and capture the influence of factors such as Life Cycle Analysis and the financial costs, in addition to the subjects discussed in this Thesis. Furthermore, an important aspect that must be considered are the constant changes and new obligations that frequently come into force in the building sector. These often create confusion, controversy and therefore difficulties in the adoption of any new change by building sector professionals.

INDEX

List of Figures

List of Tables

LITERATURE

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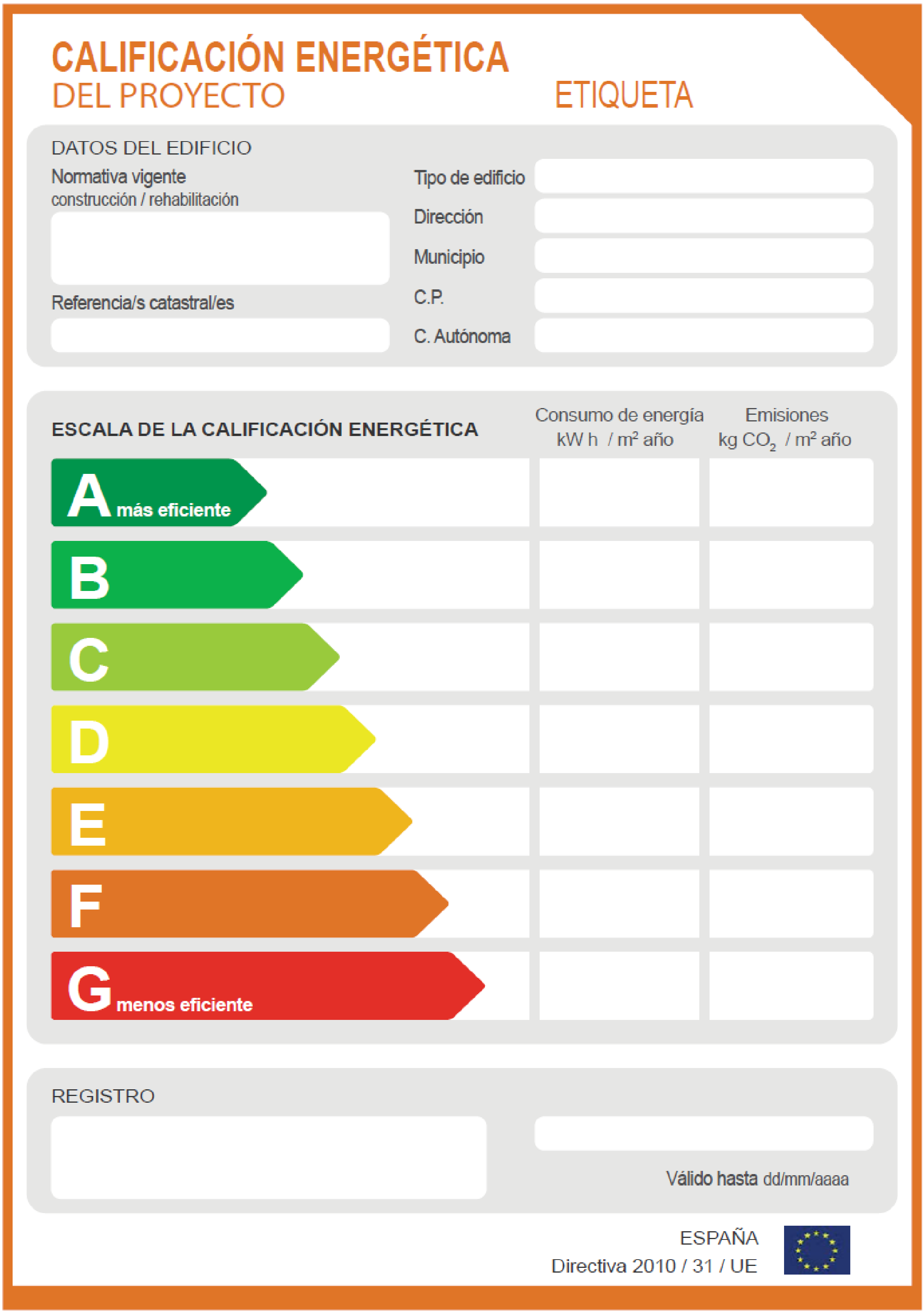
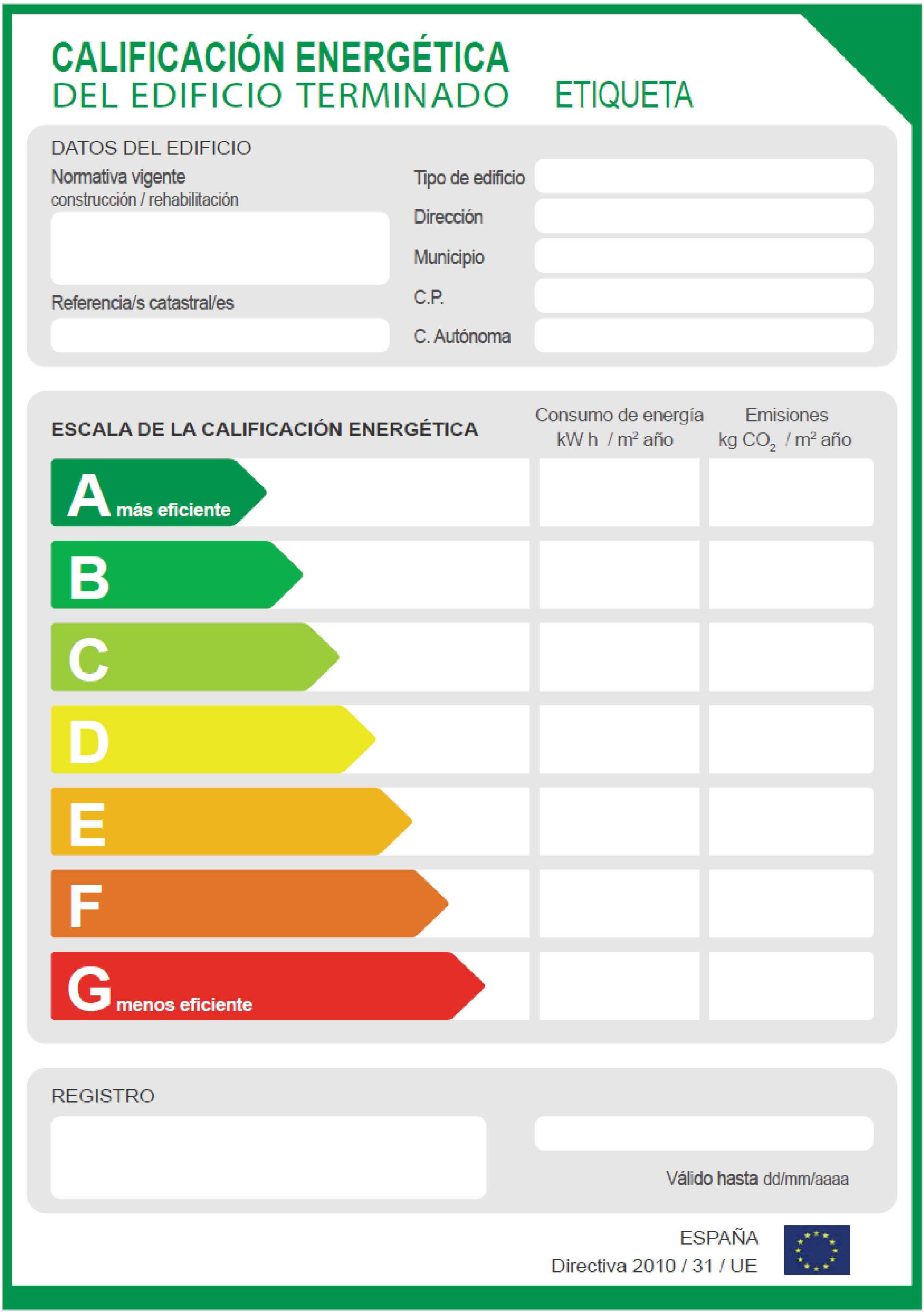
APPENDIX

A. Template of the Spanish EPC Label





CALIFICACIÓN ENERGÉTICA
DEL EDIFICIO TERMINADO ETIQUETA

DATOS DEL EDIFICIO

Normativa vigente
construcción / rehabilitación

Referencia/s catastral/es

Tipo de edificio

Dirección

Municipio

C.P.

C. Autónoma

ESCALA DE LA CALIFICACIÓN ENERGÉTICA

	Consumo de energía kW h / m^2 año	Emisiones kg CO_2 / m^2 año
A más eficiente		
B		
C		
D		
E		
F		
G menos eficiente		

REGISTRO

Válido hasta dd/mm/aaaa

ESPAÑA
Directiva 2010 / 31 / UE

B. Template of the Spanish EPC

CERTIFICADO DE EFICIENCIA ENERGÉTICA DE EDIFICIOS

IDENTIFICACIÓN DEL EDIFICIO O DE LA PARTE QUE SE CERTIFICA:

Nombre del edificio			
Dirección			
Municipio		**Código Postal**	
Provincia		**Comunidad Autónoma**	
Zona climática		**Año construcción**	
Normativa vigente (construcción / rehabilitación)			
Referencia/s catastral/es			

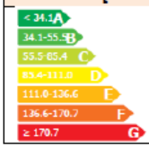
Tipo de edificio o parte del edificio que se certifica:	
☐ Edificio de nueva construcción	☐ Edificio Existente
☐Vivienda ☐Unifamiliar ☐Bloque ☐Bloque completo ☐Vivienda individual	☐Terciario ☐Edificio completo ☐Local

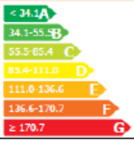
DATOS DEL TÉCNICO CERTIFICADOR:

Nombre y Apellidos		**NIF/NIE**	
Razón social		**NIF**	
Domicilio			
Municipio		**Código Postal**	
Provincia		**Comunidad Autónoma**	
e-mail:		**Teléfono**	
Titulación habilitante según normativa vigente			
Procedimiento reconocido de calificación energética utilizado y versión:			

CALIFICACIÓN ENERGÉTICA OBTENIDA:

CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE [kWh/m2.año]		**EMISIONES DE DIÓXIDO DE CARBONO [kgCO$_2$/m^2·año]**	
(see scale below)		(see scale below)	





El técnico abajo firmante declara responsablemente que ha realizado la certificación energética del edificio o de la parte que se certifica de acuerdo con el procedimiento establecido por la normativa vigente y que son ciertos los datos que figuran en el presente documento, y sus anexos:

Fecha: ___/____/____

Firma del técnico certificador:

Anexo I. *Descripción de las características energéticas del edificio.*
Anexo II. *Calificación energética del edificio.*
Anexo III. *Recomendaciones para la mejora de la eficiencia energética.*
Anexo IV. *Pruebas, comprobaciones e inspecciones realizadas por el técnico certificador.*

Registro del Órgano Territorial Competente:_

Fecha (de generación del documento) XX/XX/XXXX
Ref. Catastral XXXXXXXXXXXXXXXX Página X de X

ANEXO I
DESCRIPCIÓN DE LAS CARACTERÍSTICAS ENERGÉTICAS DEL EDIFICIO

En este apartado se describen las características energéticas del edificio, envolvente térmica, instalaciones, condiciones de funcionamiento y ocupación y demás datos utilizados para obtener la calificación energética del edificio.

1. SUPERFICIE, IMAGEN Y SITUACIÓN

Superficie habitable [m^2]	

Imagen del edificio	Plano de situación
	

2. ENVOLVENTE TÉRMICA

Cerramientos opacos

Nombre	Tipo	Superficie [m^2]	Transmitancia [W/m^2·K]	Modo de obtención

Huecos y lucernarios

Nombre	Tipo	Superficie [m2]	Transmitancia [W/m2·K]	Factor solar	Modo de obtención. Transmitancia	Modo de obtención. Factor solar

3. INSTALACIONES TÉRMICAS

Generadores de calefacción

Nombre	Tipo	Potencia nominal [kW]	Rendimiento Estacional [%]	Tipo de Energía	Modo de obtención
TOTALES		-			

Generadores de refrigeración

Nombre	Tipo	Potencia nominal [kW]	Rendimiento Estacional [%]	Tipo de Energía	Modo de obtención
TOTALES		-			

Instalaciones de Agua Caliente Sanitaria

ANEXO II
CALIFICACIÓN ENERGÉTICA DEL EDIFICIO

Zona climática		**Uso**	

1. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN EMISIONES

INDICADOR GLOBAL		**INDICADORES PARCIALES**			
		CALEFACCIÓN		**ACS**	
		*Emisiones calefacción [kgCO₂/m²·año]*		*Emisiones ACS [kgCO₂/m²·año]*	
		REFRIGERACIÓN		**ILUMINACIÓN**	
Emisiones globales [kgCO₂/m²·año][1]		*Emisiones refrigeración [kgCO₂/m²·año]*		*Emisiones iluminación [kgCO₂/m²·año]*	

La calificación global del edificio se expresa en términos de dióxido de carbono liberado a la atmósfera como consecuencia del consumo energético del mismo.

	kgCO2/m2.año	**kgCO2/año**
Emisiones CO2 por consumo eléctrico		
Emisiones CO2 por otros combustibles		

2. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE

Por energía primara no renovable se entiende la energía consumida por el edificio procedente de fuentes no renovables que no ha sufrido ningún proceso de conversión o transformación.

INDICADOR GLOBAL		**INDICADORES PARCIALES**			
		CALEFACCIÓN		**ACS**	
		*Energía primaria calefacción [kWh/m²·año]*		*Energía primaria ACS [kWh/m²·año]*	
		REFRIGERACIÓN		**ILUMINACIÓN**	
Consumo global de energía primaria no renovable [kWh/m²·año][1]		*Energía primaria refrigeración [kWh/m²·año]*		*Energía primaria iluminación [kWh/m²·año]*	

3. CALIFICACIÓN PARCIAL DE LA DEMANDA ENERGÉTICA DE CALEFACCIÓN Y REFRIGERACIÓN

La demanda energética de calefacción y refrigeración es la energía necesaria para mantener las condiciones internas de confort del edificio.

DEMANDA DE CALEFACCIÓN		**DEMANDA DE REFRIGERACIÓN**	
			
Demanda de calefacción [kWh/m²·año]		*Demanda de refrigeración [kWh/m²·año]*	

[1] El indicador global es resultado de la suma de los indicadores parciales más el valor del indicador para consumos auxiliares, si los hubiera (sólo ed. terciarios, ventilación, bombeo, etc…). La energía eléctrica autoconsumida se descuenta únicamente del indicador global, no así de los valores parciales.

Fecha (de generación del documento) XX/XX/XXXX

Ref. Catastral XXXXXXXXXXXXXXXXX

Página X de X

Demanda diaria de ACS a 60ºC (litros/día)	

Nombre	Tipo	Potencia nominal [kW]	Rendimiento Estacional [%]	Tipo de Energía	Modo de obtención

Sistemas secundarios de calefacción y/o refrigeración (sólo edificios terciarios)

Nombre			
Tipo			
Zona asociada			
Potencia calor [kW]	Potencia frío [kW]	Rendimiento estacional calor [%]	Rendimiento estacional frío [%]
Enfriamiento gratuito	Enfriamiento evaporativo	Recuperación de energía	Control

Torres de refrigeración (sólo edificios terciarios)

Nombre	Tipo	Servicio asociado	Consumo de energía [kWh/año]
TOTALES			

Ventilación y bombeo (sólo edificios terciarios)

Nombre	Tipo	Servicio asociado	Consumo de energía [kWh/año]
TOTALES			

4. INSTALACIÓN DE ILUMINACIÓN (sólo edificios terciarios)

Espacio	Potencia instalada [W/m^2]	VEEI [W/m^2·100lux]	Iluminancia media [lux]	Modo de obtención
TOTALES	-			

5. CONDICIONES DE FUNCIONAMIENTO Y OCUPACIÓN (sólo edificios terciarios)

Espacio	Superficie [m^2]	Perfil de uso

6. ENERGÍAS

Térmica

Nombre	Consumo de Energía Final,cubierto en función del servicio asociado [%]			Demanda de ACS cubierta [%]
	Calefacción	Refrigeración	ACS	
Paneles solares				
Caldera de biomasa				
TOTAL				

Eléctrica

Nombre	Energía eléctrica generada y autoconsumida [kWh/año]
Panel fotovoltaico	
TOTAL	

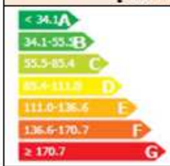
ANEXO III
RECOMENDACIONES PARA LA MEJORA DE LA EFICIENCIA ENERGÉTICA

Denominación

CALIFICACIÓN ENERGÉTICA GLOBAL

CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE [kWh/m2.año]		**EMISIONES DE DIÓXIDO DE CARBONO [kgCO$_2$/m^2·año]**	
			

CALIFICACIONES ENERGÉTICAS PARCIALES

DEMANDA DE CALEFACCIÓN [kWh/m^2·año]		**DEMANDA DE REFRIGERACIÓN [kWh/m^2·año]**	
			

ANÁLISIS TÉCNICO

Indicador	**Calefacción**		**Refrigeración**		**ACS**		**Iluminación**		**Total**	
	Valor	ahorro respecto a la situación original	Valor	ahorro respecto a la situación original	Valor	ahorro respecto a la situación original	Valor	ahorro respecto a la situación original	Valor	ahorro respecto a la situación original
Consumo Energía final [kWh/m^2·año]										
Consumo Energía primaria no renovable [kWh/m^2·año]										
Emisiones de CO$_2$ [kgCO$_2$/m^2·año]										
Demanda [kWh/m^2·año]										

Nota: Los indicadores energéticos anteriores están calculados en base a coeficientes estándar de operación y funcionamiento del edificio, por lo que solo son válidos a efectos de su calificación energética. Para el análisis económico de las medidas de ahorro y eficiencia energética, el técnico certificador deberá utilizar las condiciones reales y datos históricos de consumo del edificio.

DESCRIPCIÓN DE MEDIDA DE MEJORA
Características técnicas de la medida (modelo de equipos, materiales, parámetros característicos) *(Según anexo …)*
Coste estimado de la medida
Otros datos de interés

Fecha (de generación del documento) XX/XX/XXXX
Ref. Catastral XXXXXXXXXXXXXXXXX

Página X de X

ANEXO IV
PRUEBAS, COMPROBACIONES E INSPECCIONES REALIZADAS POR EL TÉCNICO CERTIFICADOR

Se describen a continuación las pruebas, comprobaciones e inspecciones llevadas a cabo por el técnico certificador durante el proceso de toma de datos y de calificación de la eficiencia energética del edificio, con la finalidad de establecer la conformidad de la información de partida contenida en el certificado de eficiencia energética.

Fecha de realización de la visita del técnico certificador	

C. Template of the Austrian EPC

Muster Energieausweis Wohngebäude (WG) Seite 1

Energieausweis für Wohngebäude

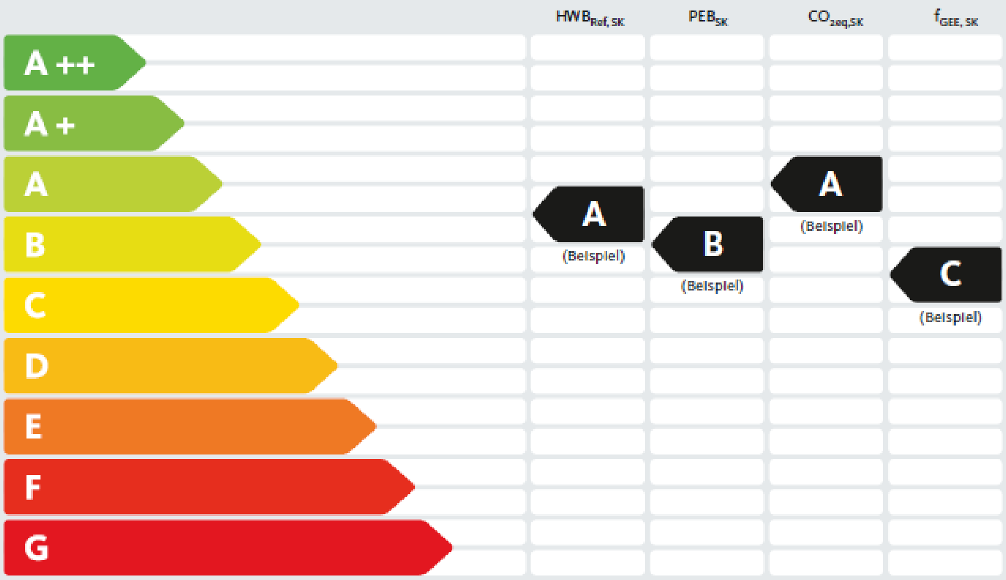
OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe: April 2019

Logo

BEZEICHNUNG		**Umsetzungsstand**	Planung, Bestand, Ist-Zustand
Gebäude(-teil)		Baujahr	
Nutzungsprofil		Letzte Veränderung	
Straße		Katastralgemeinde	
PLZ/Ort		KG-Nr.	
Grundstücksnr.		Seehöhe	

SPEZIFISCHER REFERENZ-HEIZWÄRMEBEDARF, PRIMÄRENERGIEBEDARF, KOHLENDIOXIDEMISSIONEN und GESAMTENERGIEEFFIZIENZ-FAKTOR jeweils unter STANDORTKLIMA-(SK)-Bedingungen



HWB_{Ref}: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

RK: Das **Referenzklima** ist ein virtuelles Klima. Es dient zur Ermittlung von Energiekennzahlen.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f_{GEE}: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus einerseits dem Endenergiebedarf abzüglich allfälliger Endenergieerträge und zuzüglich des dafür notwendigen Hilfsenergiebedarfs und andererseits einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren ($PEB_{ern.}$) und einen nicht erneuerbaren ($PEB_{n.ern.}$) Anteil auf.

CO_2eq: Gesamte dem Endenergiebedarf zuzurechnenden **äquivalenten Kohlendioxidemissionen** (Treibhausgase), einschließlich jener für Vorketten.

SK: Das **Standortklima** ist das reale Klima am Gebäudestandort. Dieses Klimamodell wurde auf Basis der Primärdaten (1970 bis 1999) der Zentralanstalt für Meteorologie und Geodynamik für die Jahre 1978 bis 2007 gegenüber der Vorfassung aktualisiert.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der OIB-Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU vom 19. Mai 2010 über die Gesamtenergieeffizienz von Gebäuden bzw. 2018/844/EU vom 30. Mai 2018 und des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist für Strom: 2013-09 – 2018-08, und es wurden übliche Allokationsregeln unterstellt. 1

Seite 2 für Wohngebäude (WG)

Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK — OIB-Richtlinie 6 Ausgabe: April 2019 — Logo

GEBÄUDEKENNDATEN — EA-Art:

Brutto-Grundfläche (BGF)	#.###,# m²	Heiztage	### d	Art der Lüftung	#########
Bezugsfläche (BF)	#.###,# m²	Heizgradtage	#.### Kd	Solarthermie	## m²
Brutto-Volumen (V_B)	#.###,# m³	Klimaregion	#########	Photovoltaik	#,# kWp
Gebäude-Hüllfläche (A)	#.###,# m²	Norm-Außentemperatur	#,# °C	Stromspeicher	#.###,# kWh
Kompaktheit (A/V)	#,## 1/m	Soll-Innentemperatur	#,# °C	WW-WB-System (primär)	#########
charakteristische Länge (ℓ_c)	#,## m	mittlerer U-Wert	#,## W/m²K	WW-WB-System (sekundär, opt.)	#########
Teil-BGF	#.###,# m²	LEK_T-Wert	#,##	RH-WB-System (primär)	#########
Teil-BF	#.###,# m²	Bauweise	#########	RH-WB-System (sekundär, opt.)	#########
Teil-V_B	#.###,# m³				

WÄRME- UND ENERGIEBEDARF (Referenzklima) — Nachweis über #####

	Ergebnisse			Anforderungen	
Referenz-Heizwärmebedarf	$HWB_{Ref,RK}$ =	###,# kWh/m²a	entspricht / entspricht nicht	$HWB_{Ref,RK,zul}$ =	###,# kWh/m²a
Heizwärmebedarf	HWB_{RK} =	###,# kWh/m²a			
Endenergiebedarf	EEB_{RK} =	###,# kWh/m²a	entspricht / entspricht nicht	$EEB_{RK,zul}$ =	###,# kWh/m²a
Gesamtenergieeffizienz-Faktor	$f_{GEE,RK}$ =	#,##	entspricht / entspricht nicht	$f_{GEE,RK,zul}$ =	#,##
Erneuerbarer Anteil		#########	entspricht / entspricht nicht	Punkt 5.2.3 a, b oder c	

WÄRME- UND ENERGIEBEDARF (Standortklima)

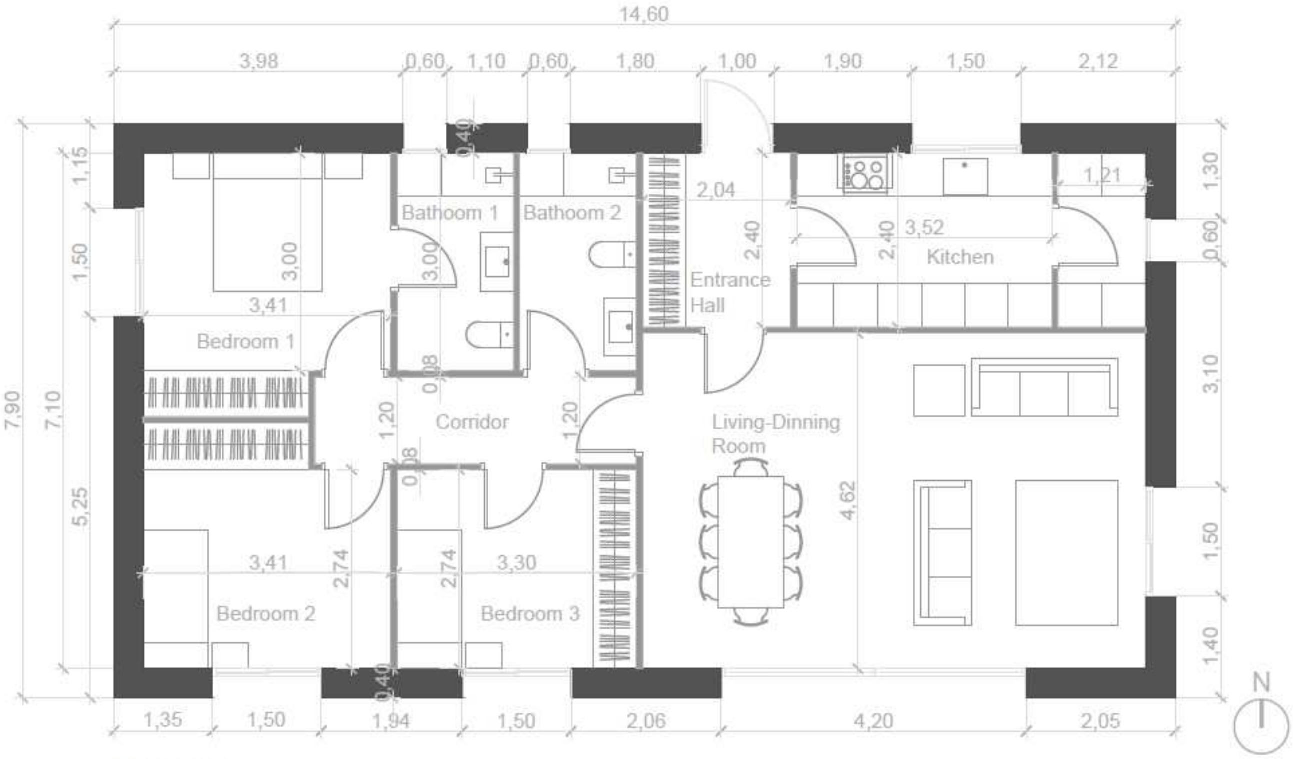
Referenz-Heizwärmebedarf	$Q_{h,Ref,SK}$ =	###.### kWh/a	$HWB_{Ref,SK}$ =	###,# kWh/m²a
Heizwärmebedarf	$Q_{h,SK}$ =	###.### kWh/a	HWB_{SK} =	###,# kWh/m²a
Warmwasserwärmebedarf	Q_{tw} =	###.### kWh/a	WWWB =	###,# kWh/m²a
Heizenergiebedarf	$Q_{H,Ref,SK}$ =	###.### kWh/a	HEB_{SK} =	###,# kWh/m²a
Energieaufwandszahl Warmwasser			$e_{AWZ,WW}$ =	#,##
Energieaufwandszahl Raumheizung			$e_{AWZ,RH}$ =	#,##
Energieaufwandszahl Heizen			$e_{AWZ,H}$ =	#,##
Haushaltsstrombedarf	Q_{HHSB} =	###.### kWh/a	HHSB =	###,# kWh/m²a
Endenergiebedarf	$Q_{EEB,SK}$ =	###.### kWh/a	EEB_{SK} =	###,# kWh/m²a
Primärenergiebedarf	$Q_{PEB,SK}$ =	###.### kWh/a	PEB_{SK} =	###,# kWh/m²a
Primärenergiebedarf nicht erneuerbar	$Q_{PEBn.ern.,SK}$ =	###.### kWh/a	$PEB_{n.ern.,SK}$ =	###,# kWh/m²a
Primärenergiebedarf erneuerbar	$Q_{PEBern.,SK}$ =	###.### kWh/a	$PEB_{ern.,SK}$ =	###,# kWh/m²a
äquivalente Kohlendioxidemissionen	$Q_{CO2eq,SK}$ =	###.### kg/a	$CO_{2eq,SK}$ =	###,# kg/m²a
Gesamtenergieeffizienz-Faktor			$f_{GEE,SK}$ =	#,#
Photovoltaik-Export	$Q_{PVE,SK}$ =	###.### kWh/a	$PVE_{EXPORT,SK}$ =	###,# kWh/m²a

ERSTELLT

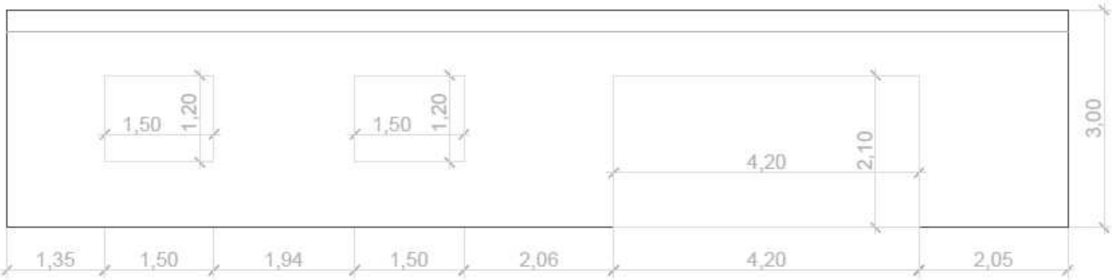
GWR-Zahl		ErstellerIn	
Ausstellungsdatum		Unterschrift	
Gültigkeitsdatum			
Geschäftszahl			

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von den hier angegebenen abweichen. 2

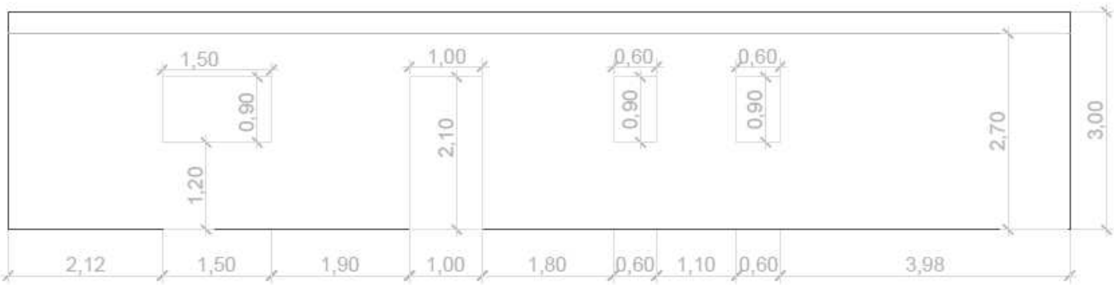
D. Test Case Study House Floorplan and Elevations



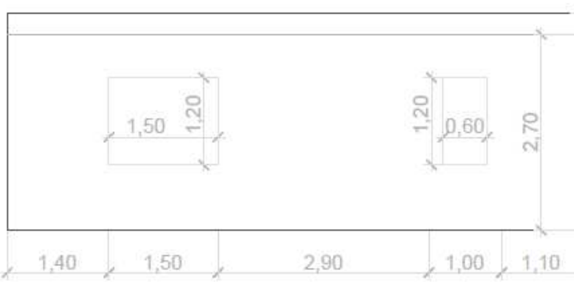
Floorplan

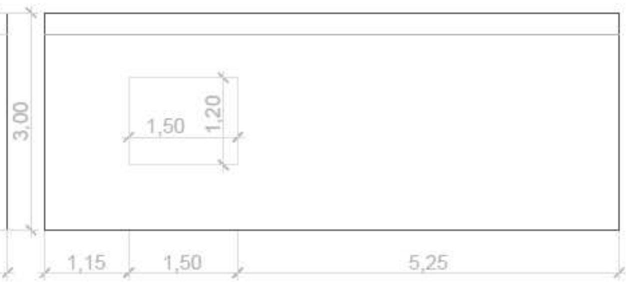


South Elevation



North Elevation





East Elevation

West Elevation

E. Summary Table of Construction Techniques

	Selected Techniques	F. Manzano-Agugliaro et al.	Donald Watson
3	**Heating Internal Gains**	**Heating Internal Gains**	**Heating Internal Gains**
	People	People	X
	Lighting	Lighting	
	Equipment	Equipment	
4	**Passive Solar Heating**	**Passive Solar Heating**	**Passive Solar Heating**
	Awning	Awning	A. Direct gain Systems
	Radiation through openings	Radiation through openings	- Windows
	Capacitative flooring	Capacitative flooring	- Clestory
	Roof pond	Roof pond	- Horizontal Skylight
	Glazed gallery	Glazed gallery	B. Indirect gain systems
	Adjoined greenhouse	Adjoined greenhouse	Thermal storage walls
	Trombe Wall	Trombe Wall	1. Sunspace
	Roof openings	Roof openings	2. Trombe Wall
			3. Water wall
			Roof Pond
			Isolated gain systems
			Greenhouse system
			Solarium/Sunspace system
5	**Active Solar Heating**	**Active Solar Heating**	**Active Solar Heating**
	Low temperature solar thermal cells	Low temperature solar thermal cells	Solar collection air systems
	Photovoltaic cells	Photovoltaic cells	Liquid collection air systems
6	**Humidification**	**Humidification**	**Humidification**
	Exterior vegetation	Exterior vegetation	
	Interior vegetation	Interior vegetation	
	Accumulated water	Accumulated water	
	Water buried pipes	Water buried pipes	
7		**Conventional heating**	**Conventional heating**
8	**Solar protection**	**Solar protection**	**Solar protection**
	Exterior Shading devices	Decidious vegetation	Exterior Shading devices
	Decidious vegetation	Pergola with decidious vegetation	Horizontal projections
	Pergola with decidious vegetation	Porch	Vertical projections
	Horizontal projections	Sunblind and store	Eggcrate Shading devices
	Vertical projections	horizontal slats	Sunscreens
	Eggcrate Shading devices		Shutters
	Sunscreens		Roller Blinds/Shades
	Shutters		Awnings
	Roller Blinds/Shades		Glazing
	Awnings		Multiple Glazing
	Glazing		Heat-Absorbing Glass
	Multiple Glazing		Reflective Glass
	Heat-Absorbing Glass		Glass Blocks
	Reflective Glass		Window Tilt
	Glass Blocks		Interior Shading devices
	Window Tilt		Insulating Shutters
	Interior Shading devices		Opaque Shades
	Insulating Shutters		Film Shades
	Opaque Shades		Draperies
	Draperies		Venetian Blinds/Interior Louvers
	Venetian Blinds/Interior Louvers		
	Façade Protecion		
	Reflective materials or colors		
9	**Cooling through a high thermal mass**	**Cooling through a high thermal mass**	**Cooling through a high thermal mass**
	Capacitative materials idealy with shading protection (i.e. patio)	Capacitative materials idealy with shading protection (i.e. patio)	Underground Construction
10	**Evaporative Cooling**	**Evaporative Cooling**	**Evaporative Cooling**
	Exterior vegetation	Exterior vegetation	Swamp coolers
	water ponds or fountains	water ponds or fountains	Fountain courts
	buried water pipes	buried water pipes	Atrium pools
	patios with vegetation & water	patios with vegetation & water	Roof sprays
	vegetative cover	vegetative cover	
	exterior water spraying	exterior water spraying	
	indoor water spraying	indoor water spraying	
11	**Cooling High Thermal Mass With Night Cooling**	**Cooling High Thermal Mass With Night Cooling**	**Cooling High Thermal Mass With Night Cooling**
	Capacitative material with phase difference	Capacitative material with phase difference	night sky radiation
12	**Cooling Natural and Mechanical Ventilation**	**Cooling Natural and Mechanical Ventilation**	**Cooling Natural and Mechanical Ventilation**
	Cross ventilation	Cross ventilation	Natural Ventilation
	chimeny effect	chimeny effect	Induced Ventilation
	solar chamber	solar chamber	Night Ventilation
	subterranean ventilation	subterranean ventilation	
	wind tower	wind tower	
	evaporative tower	evaporative tower	
	vertical spaces	vertical spaces	
	patios	patios	
13	**Air Conditioned**	**Air Conditioned**	**Air Conditioned**
14	**Conventional Dry**	**Conventional Dry**	**Conventional Dry**
	Absorbent salts	Absorbent salts	
	saline cells	saline cells	

Table 30 Bioclimatic Construction Techniques in Reviewed Literature

F. Assigned Constructions in Vienna

EXTERIOR WALL **U-Value 0.198 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Exterior	-	-	-	-
Silicate plaster with additional synthetic resin	0.005	ç	0.8	-
Insulation EPS-W20	0.14	19.5	0.038	1.45
Bricks 17cm to 38cm	0.3	775	0.26	1.0
Gypsum plaster	0.15	1300	0.57	1.0
Interior	-	-	-	-

ROOF **U-Value 0,102 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Exterior	-	-	-	-
Ballast	0.06	1800	0.7	1.0
Waterproofing layer	0.0078	1100	0.23	1.26
Vapour control layer	0.0016	980	0.5	1.26
Insulation EPS-W20	0.36	19.5	0.038	1.45
Aluminium-bitumen sheet	0.0014	1100	0.23	1.26
Vapour control layer	0.0018	980	0.5	1.26
Concrete	0.2	2300	2.3	1.0
Plaster finish	0.0030	1300	0.8	0.9
Interior	-	-	-	-

SLAB **U-Value 0,141 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Interior	-	-	-	-
Woodfloor	0.01	740	0.16	1.6
Cement screed	0.05	1800	1.1	1.08
Polyethylen Waterproofing-Vapour layer	0.0001	980	0.5	1.26
Glasswool	0.03	80	0.035	1.03
Concrete	0.2	2300	2.3	1.00
Polyethylen Waterproofing-Vapour layer	0.0004	980	0.5	1.26
Glasswool foam board	0.24	115	0.041	0.84
Polymerbitumen layer	0.01	1100	0.23	1.26
Row Concrete	0.05	2000	1.35	1.00
Fabric sheet	0.0003	500	0.17	0
Gravel	0.15	1800	0.7	1.00
Exterior	-	-	-	-

INTERIOR WALL **U-Value 0,573 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Exterior	-	-	-	-
Plasterboard	0.015	900	0.21	1.05
Mineralwool insulation	0.05	15	0.043	1.03
Airgap	0.025	1	0.138	1.008
Plasterboard	0.015	900	0.21	1.05
Interior	-	-	-	-

OPENINGS

Material	U-Value	G-Value
Windows Triple Glazing	1.11	0.48
Entrance Door	1.82	0.75

G. Assigned Constructions in Seville

EXTERIOR WALL **U-Value 0.168 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Exterior	-	-	-	-
Silicate system paint facada	0.003	1810	1.8	0.8
Mortar	0.005	1400	0.44	0.8
Insulation	0.14	120	0.036	0.8
Mortar	0.005	1400	0.44	0.8
Bricks	0.250	800	0.297	1.0
Mineral Wool Insulation	0.04	50	0.035	0.8
Plasterboard	0.015	960	0.25	1.0
Interior	-	-	-	-

ROOF **U-Value 0.157 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Exterior	-	-	-	-
Ceramic Roof tile	0.02	2000	1.0	0.8
Insulation	0.14	120	0.039	0.8
Concrete Beam filling	0.25	1330	1.316	1.0
Insulation	0.1	50	0.04	0.8
Plasterboard	0.015	960	0.25	1.0
Interior	-	-	-	-

SLAB **U-Value 0.537 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Interior	-	-	-	-
Ceramic Tile	0.015	2000	1.0	0.8
Mortar	0.005	1400	0.44	0.8
Rigid plasterboard	0.02	1200	0.202	1.0
Insulation	0.06	120	0.039	0.8
Ceramic Beam Filling	0.35	1169	1.75	1.0
Exterior	-	-	-	-

INTERIOR WALL **U-Value 0,573 W/m2K**

Material	Thickness [m]	Density [kg/m^3]	Lambda λ [W/mK]	Specific heat [kJ/kgK]
Exterior	-	-	-	-
Plasterboard	0.015	900	0.21	1.05
Mineralwool insulation	0.05	15	0.043	1.03
Airgap	0.025	1	0.138	1.008
Plasterboard	0.015	900	0.21	1.05
Interior	-	-	-	-

OPENINGS

Material	U-Value	G-Value
Windows Triple Glazing	0.6	0.27
Entrance Door	0.99	0.28

H. Weather Conditions in Vienna

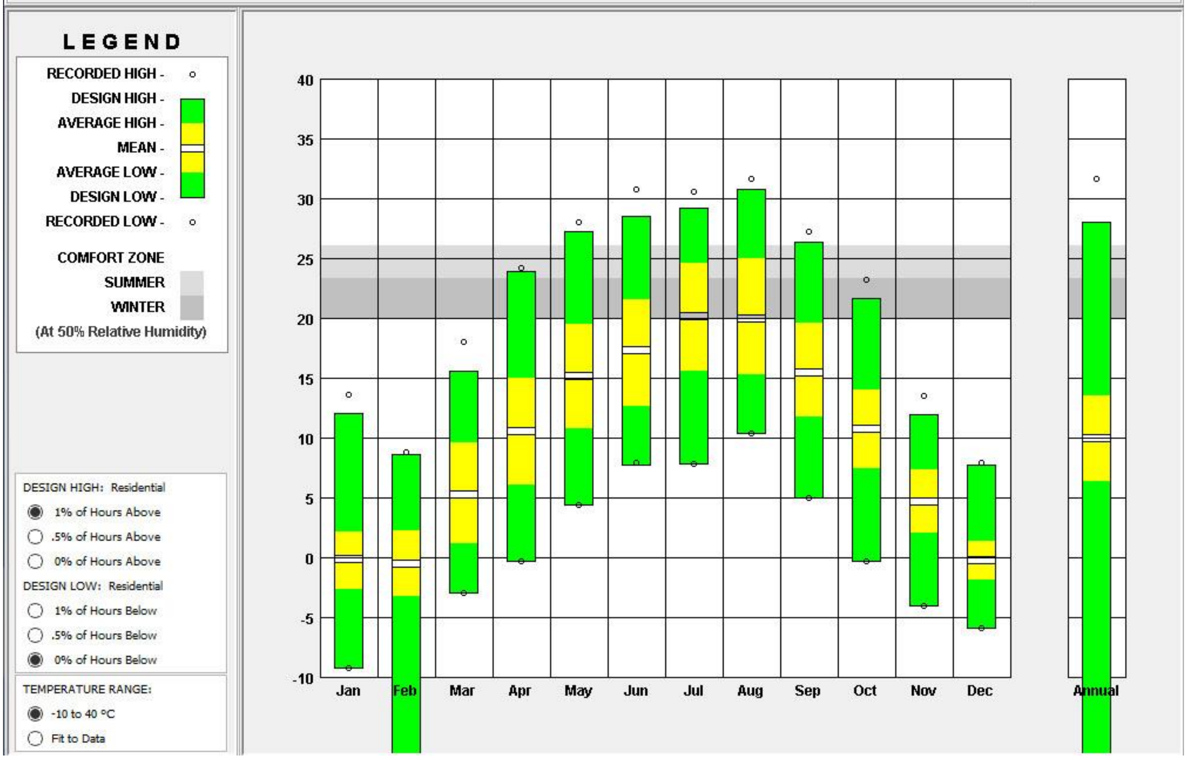
WEATHER DATA SUMMA...

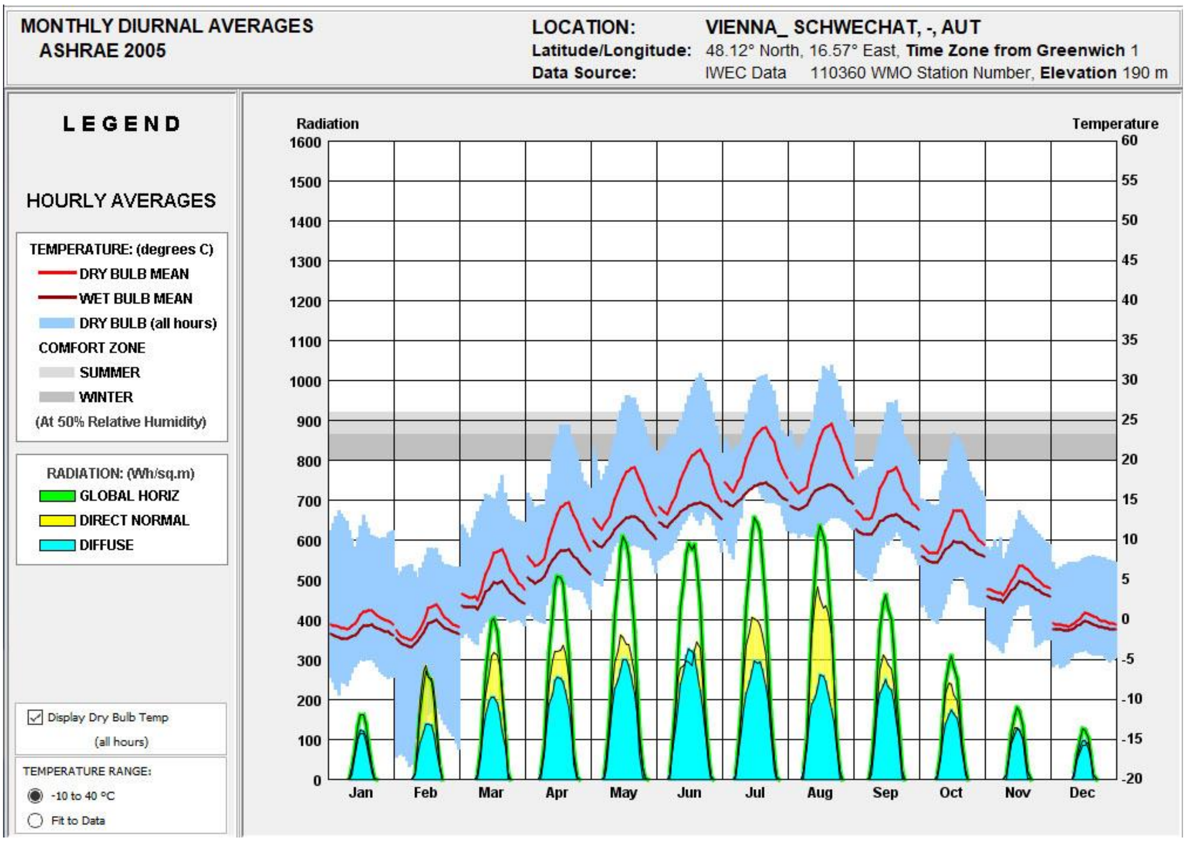
LOCATION: **VIENNA_ SCHWECHAT, -, AUT**
Latitude/Longitude: 48.12° North, 16.57° East, **Time Zone from Greenwich** 1
Data Source: IWEC Data 110360 WMO Station Number, **Elevation** 190 m

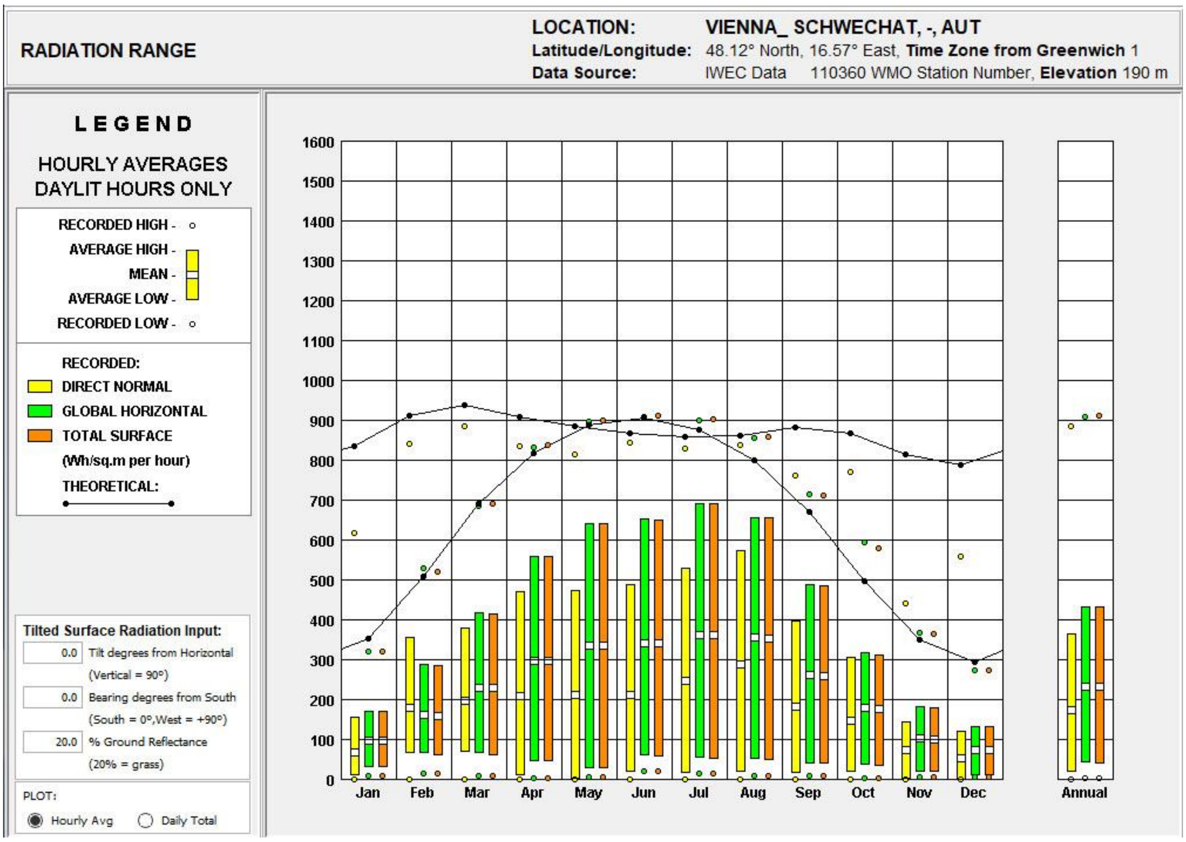
MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	96	162	230	296	334	341	361	355	262	179	102	74	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	68	180	197	208	212	211	247	287	181	146	74	53	Wh/sq.m
Diffuse Radiation (Avg Hourly)	76	92	132	163	184	192	185	163	156	111	76	59	Wh/sq.m
Global Horiz Radiation (Max Hourly)	320	530	686	833	897	909	900	855	715	594	369	275	Wh/sq.m
Direct Normal Radiation (Max Hourly)	617	840	886	836	816	845	829	838	762	770	440	558	Wh/sq.m
Diffuse Radiation (Max Hourly)	195	245	359	419	431	485	428	405	366	292	211	153	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	836	1597	2686	4011	5023	5383	5573	4994	3239	1915	925	611	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	583	1777	2269	2838	3201	3345	3806	4053	2232	1563	673	443	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	662	906	1552	2201	2766	3032	2854	2289	1943	1186	693	490	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	10654	17615	25218	32519	36843	37842	40011	39080	28904	19756	11276	8239	lux
Direct Normal Illumination (Avg Hourly)	5731	16524	18846	20380	20662	20339	23729	27630	17300	13606	6514	4374	lux
Dry Bulb Temperature (Avg Monthly)	0	0	5	10	15	17	20	19	15	10	4	0	degrees C
Dew Point Temperature (Avg Monthly)	-3	-3	0	2	8	10	13	12	9	6	1	-1	degrees C
Relative Humidity (Avg Monthly)	75	78	70	60	64	67	65	65	67	75	82	87	percent
Wind Direction (Monthly Mode)	130	130	0	280	280	280	330	290	140	140	130	120	degrees
Wind Speed (Avg Monthly)	6	3	4	4	3	3	3	3	4	5	3	3	m/s
Ground Temperature (Avg Monthly of 3 Depths)	6	4	2	2	5	8	12	15	16	15	13	10	degrees C

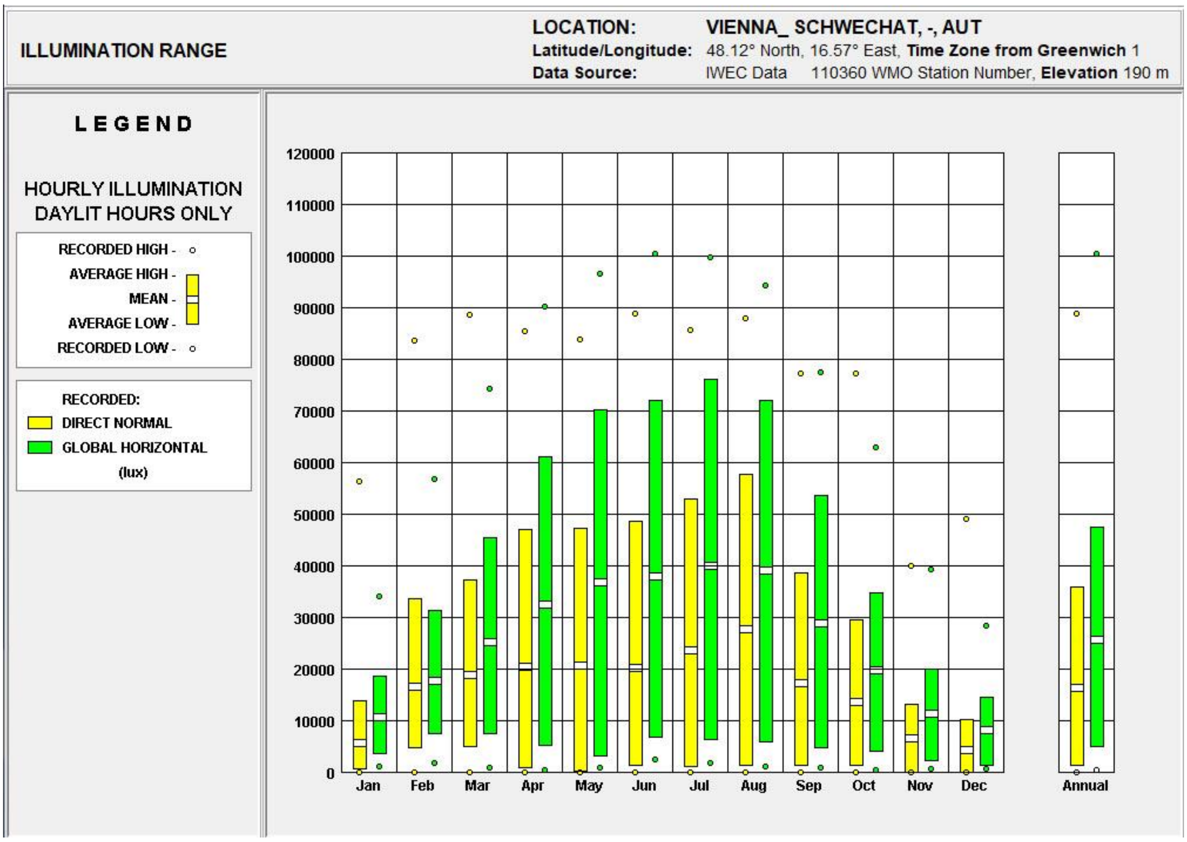
TEMPERATURE RANGE
ASHRAE 2005

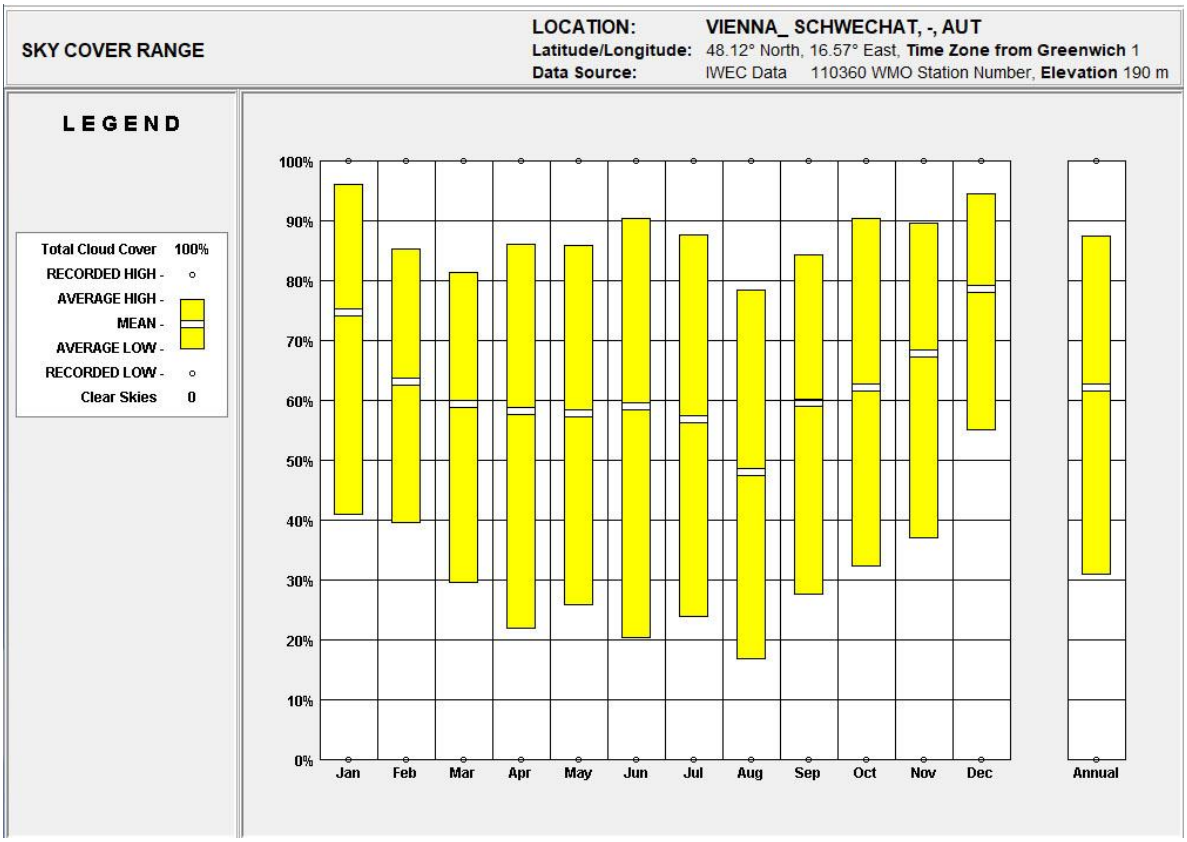
LOCATION: **VIENNA_ SCHWECHAT, -, AUT**
Latitude/Longitude: 48.12° North, 16.57° East, **Time Zone from Greenwich** 1
Data Source: IWEC Data 110360 WMO Station Number, **Elevation** 190 m

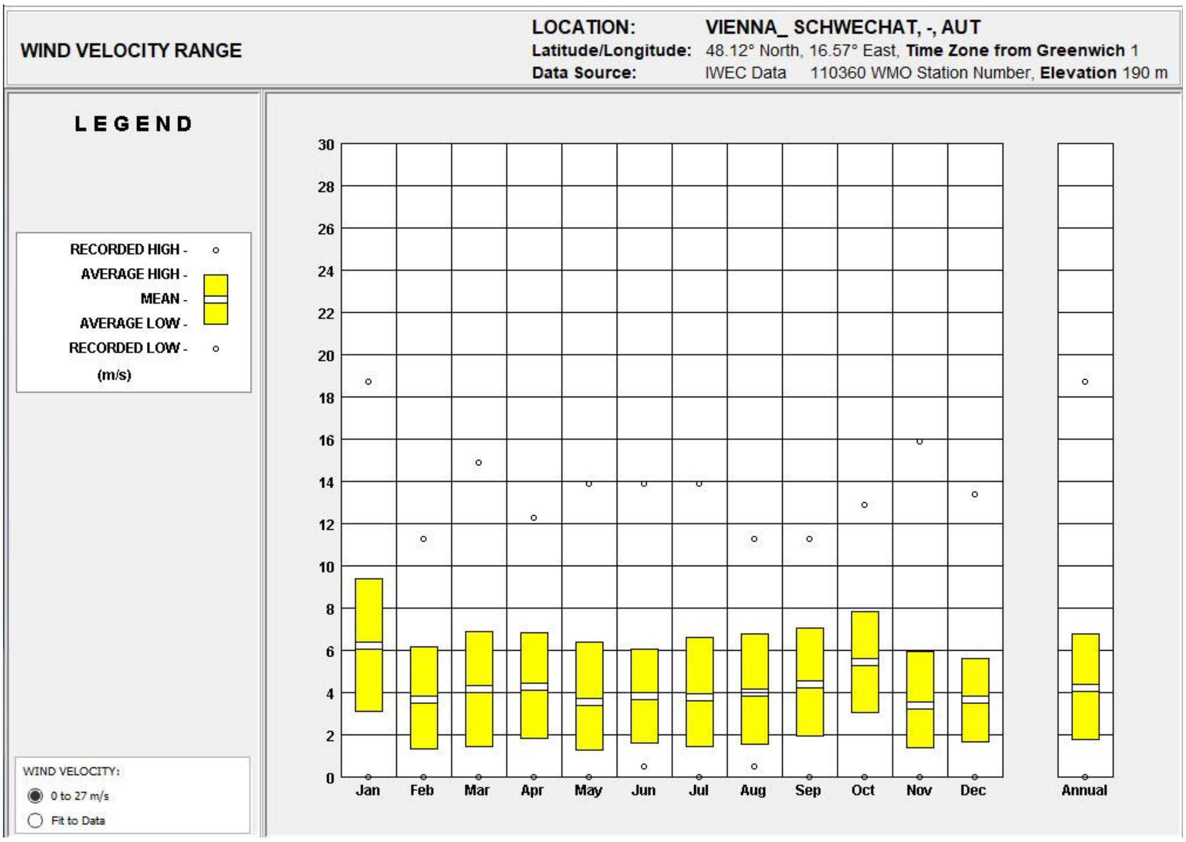


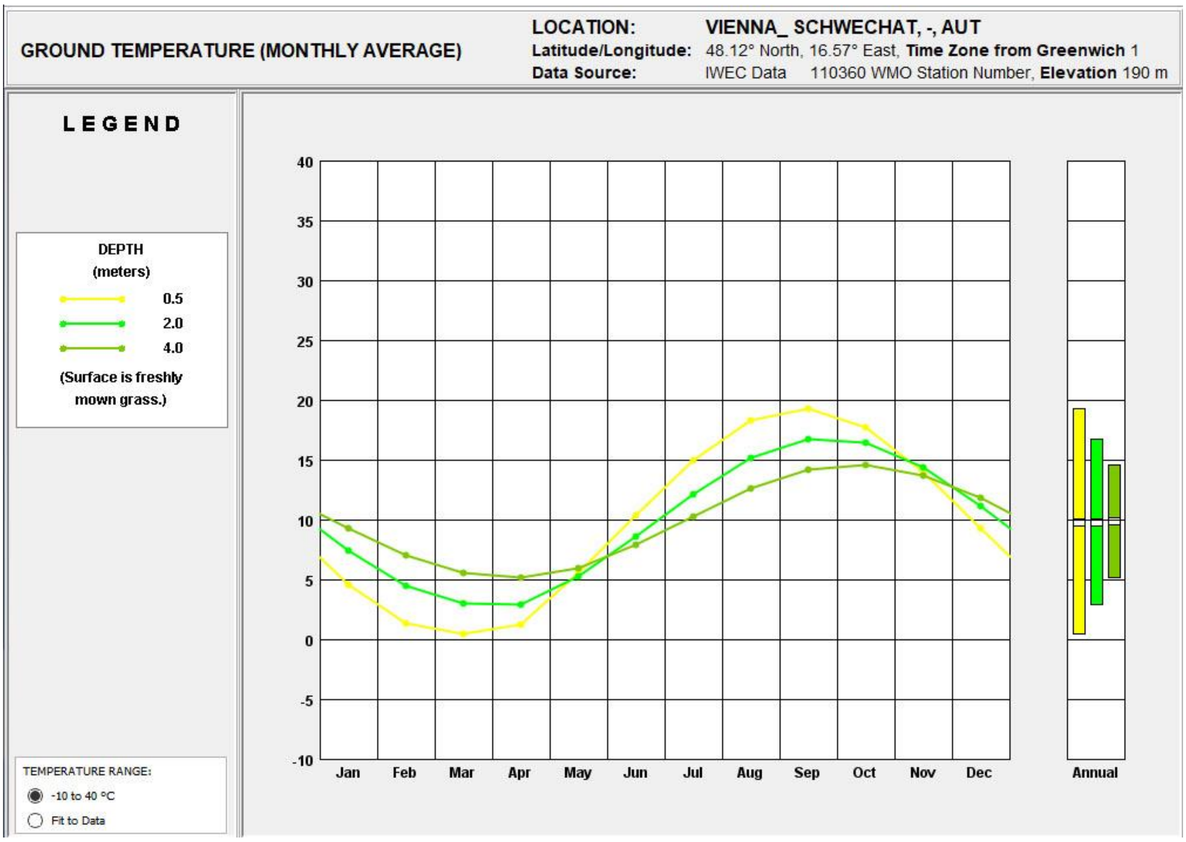

MONTHLY DIURNAL AVERAGES
ASHRAE 2005
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
HOURLY AVERAGES
TEMPERATURE: (degrees C)
DRY BULB MEAN
WET BULB MEAN
DRY BULB (all hours)
COMFORT ZONE
SUMMER
WINTER
(At 50% Relative Humidity)
RADIATION: (Wh/sq.m)
GLOBAL HORIZ
DIRECT NORMAL
DIFFUSE
Display Dry Bulb Temp (all hours)
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
Radiation
Temperature
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

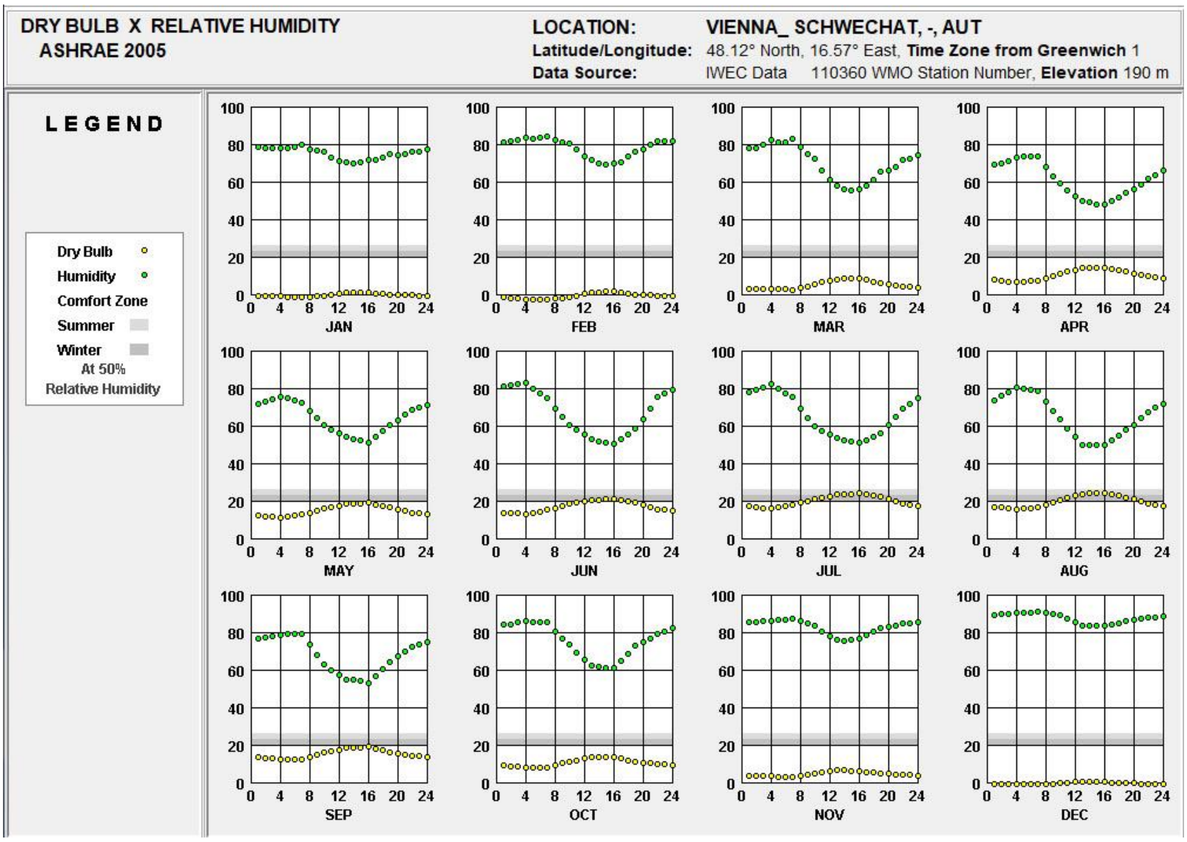

RADIATION RANGE
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
HOURLY AVERAGES
DAYLIT HOURS ONLY
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
RECORDED:
DIRECT NORMAL
GLOBAL HORIZONTAL
TOTAL SURFACE
(Wh/sq.m per hour)
THEORETICAL:
Tilted Surface Radiation Input:
0.0 Tilt degrees from Horizontal (Vertical = 90°)
0.0 Bearing degrees from South (South = 0°,West = +90°)
20.0 % Ground Reflectance (20% = grass)
PLOT:
Hourly Avg
Daily Total
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Annual

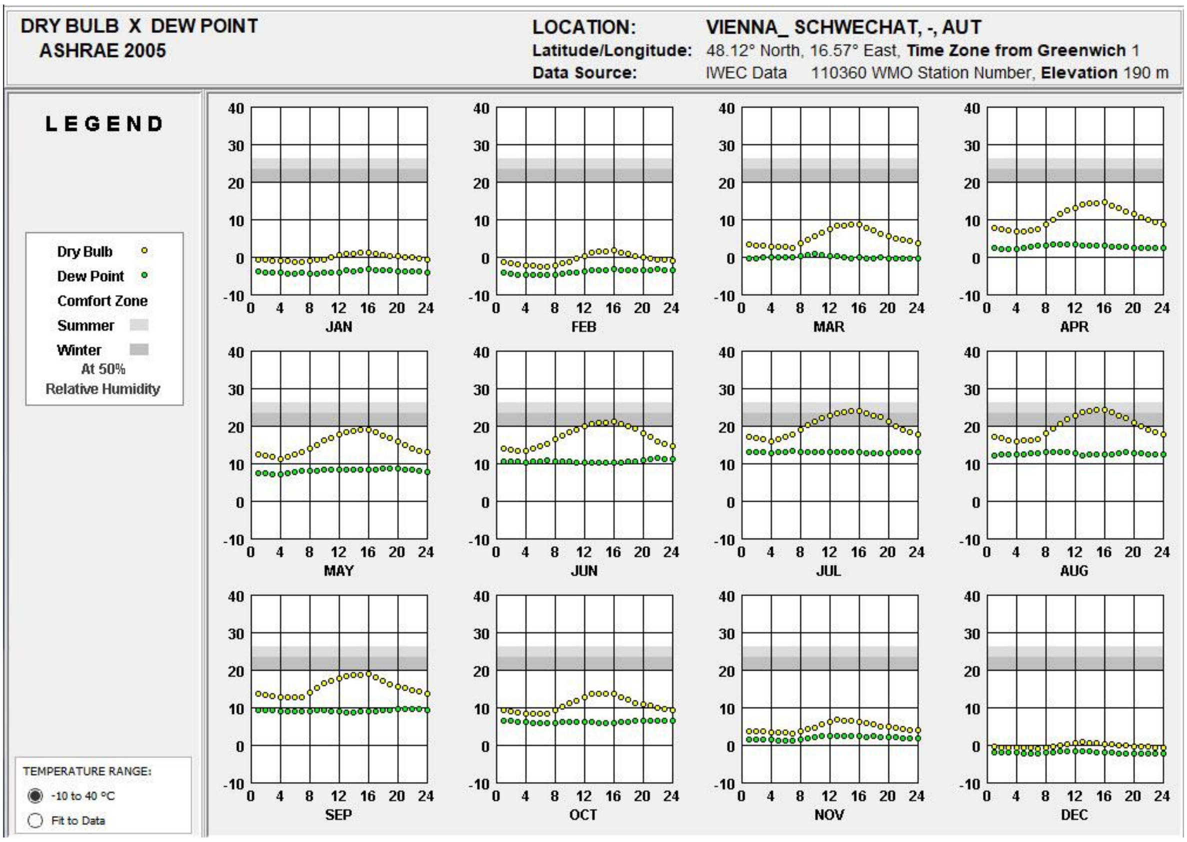

ILLUMINATION RANGE
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
HOURLY ILLUMINATION
DAYLIT HOURS ONLY
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
RECORDED:
DIRECT NORMAL
GLOBAL HORIZONTAL
(lux)
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual

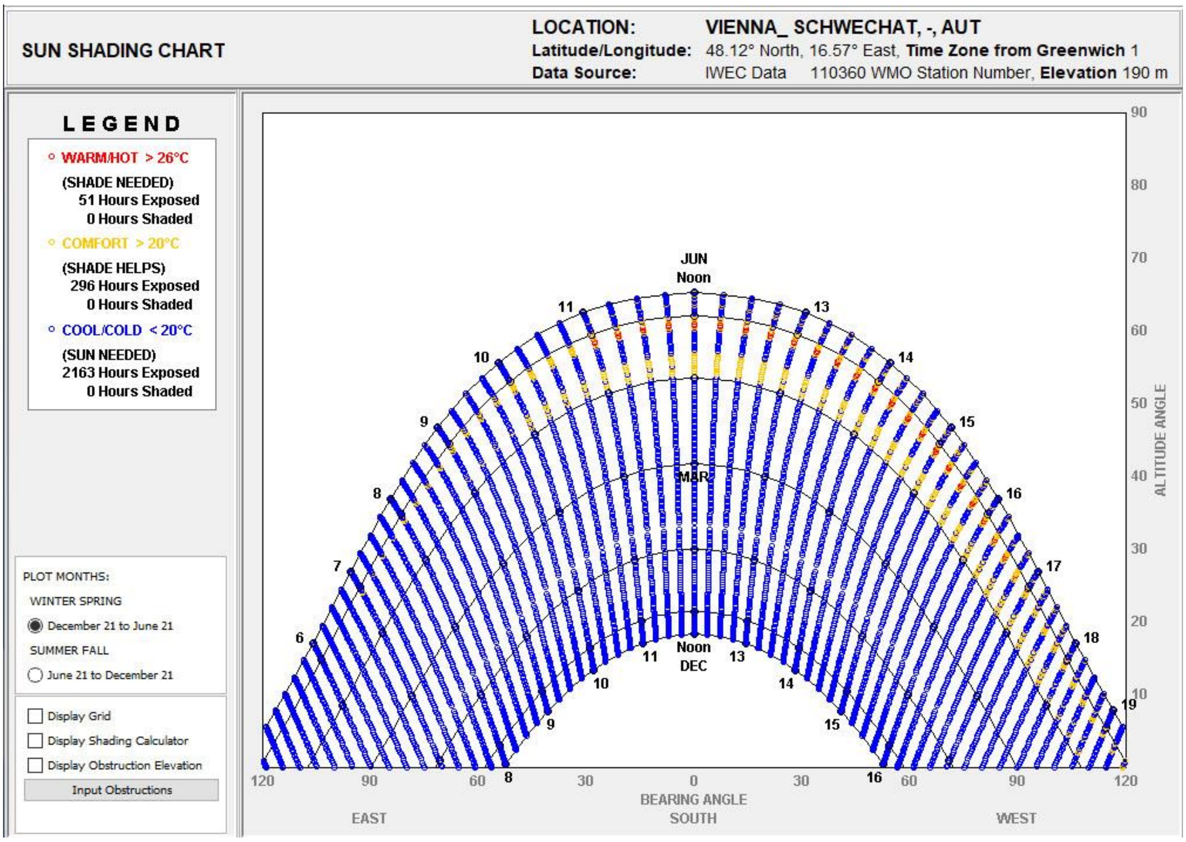

SKY COVER RANGE
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
Total Cloud Cover 100%
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
Clear Skies 0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual

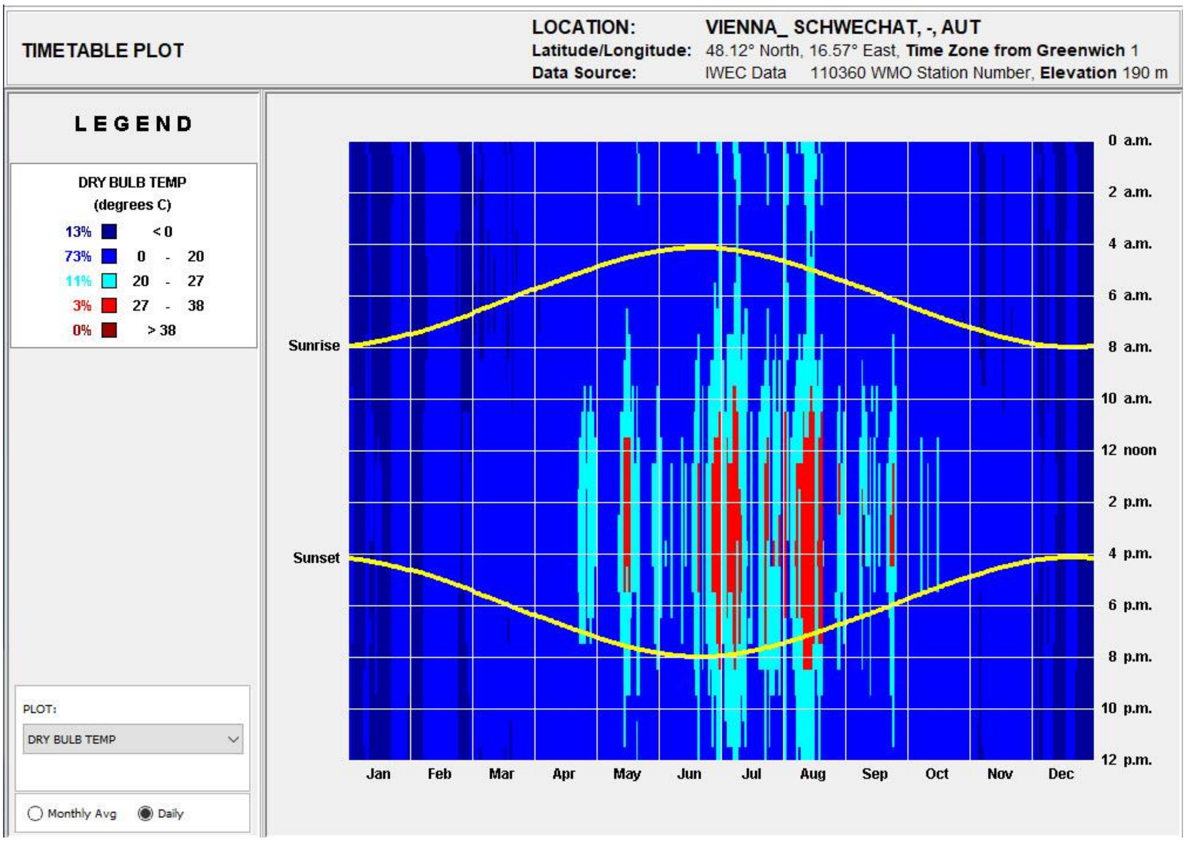

WIND VELOCITY RANGE
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
(m/s)
WIND VELOCITY:
0 to 27 m/s
Fit to Data
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual

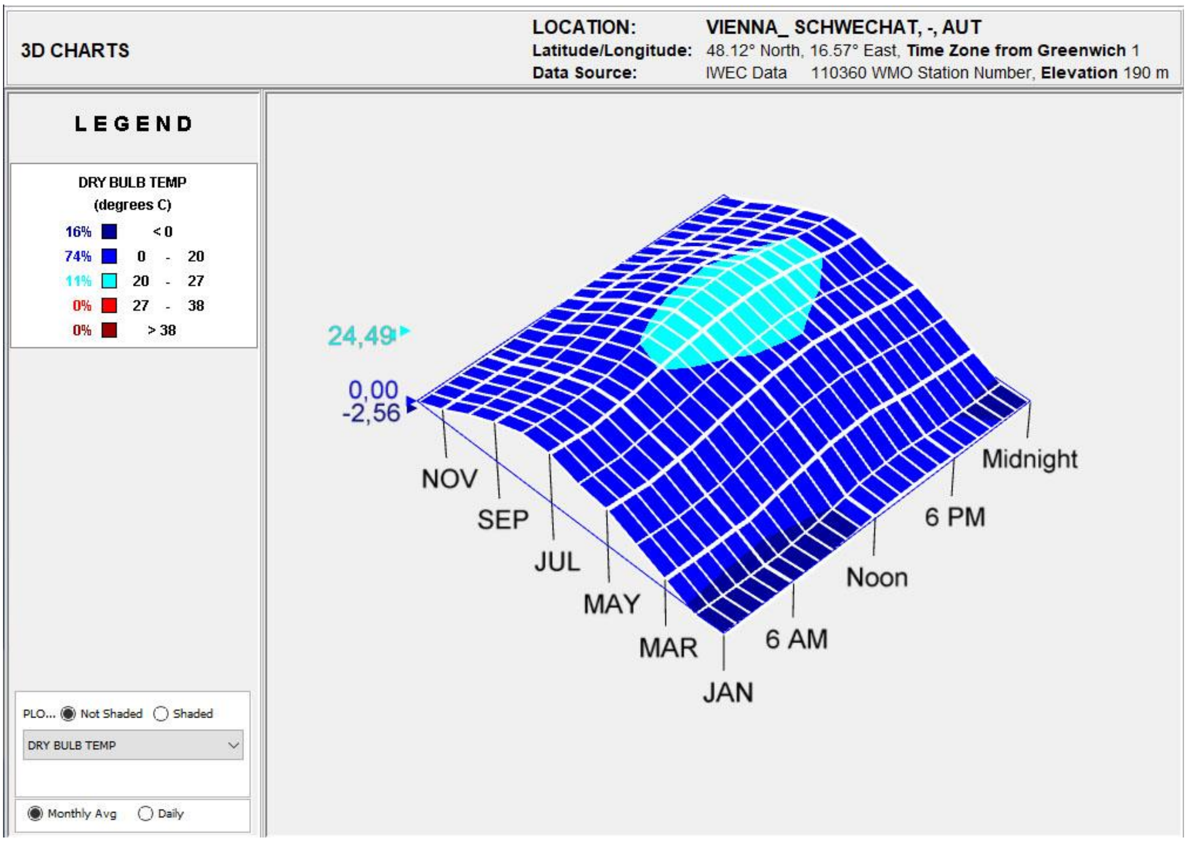

GROUND TEMPERATURE (MONTHLY AVERAGE)
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
DEPTH
(meters)
0.5
2.0
4.0
(Surface is freshly mown grass.)
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
40
35
30
25
20
15
10
5
0
-5
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual


DRY BULB X RELATIVE HUMIDITY
ASHRAE 2005
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
Dry Bulb
Humidity
Comfort Zone
Summer
Winter
At 50% Relative Humidity
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


DRY BULB X DEW POINT
ASHRAE 2005
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
Dry Bulb
Dew Point
Comfort Zone
Summer
Winter
At 50% Relative Humidity
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


SUN SHADING CHART
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
WARM/HOT > 26°C
(SHADE NEEDED)
51 Hours Exposed
0 Hours Shaded
COMFORT > 20°C
(SHADE HELPS)
296 Hours Exposed
0 Hours Shaded
COOL/COLD < 20°C
(SUN NEEDED)
2163 Hours Exposed
0 Hours Shaded
PLOT MONTHS:
WINTER SPRING
December 21 to June 21
SUMMER FALL
June 21 to December 21
Display Grid
Display Shading Calculator
Display Obstruction Elevation
Input Obstructions
JUN
Noon
MAR
Noon
DEC
ALTITUDE ANGLE
BEARING ANGLE
SOUTH
EAST
WEST


TIMETABLE PLOT
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
DRY BULB TEMP
(degrees C)
13% < 0
73% 0 - 20
11% 20 - 27
3% 27 - 38
0% > 38
PLOT:
DRY BULB TEMP
Monthly Avg
Daily
Sunrise
Sunset
0 a.m.
2 a.m.
4 a.m.
6 a.m.
8 a.m.
10 a.m.
12 noon
2 p.m.
4 p.m.
6 p.m.
8 p.m.
10 p.m.
12 p.m.
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


3D CHARTS
LOCATION: VIENNA_ SCHWECHAT, -, AUT
Latitude/Longitude: 48.12° North, 16.57° East, Time Zone from Greenwich 1
Data Source: IWEC Data 110360 WMO Station Number, Elevation 190 m
LEGEND
DRY BULB TEMP
(degrees C)
16% < 0
74% 0 - 20
11% 20 - 27
0% 27 - 38
0% > 38
PLO... Not Shaded Shaded
DRY BULB TEMP
Monthly Avg Daily
24,49
0,00
-2,56
NOV
SEP
JUL
MAY
MAR
JAN
6 AM
Noon
6 PM
Midnight

I. Weather Conditions in Seville

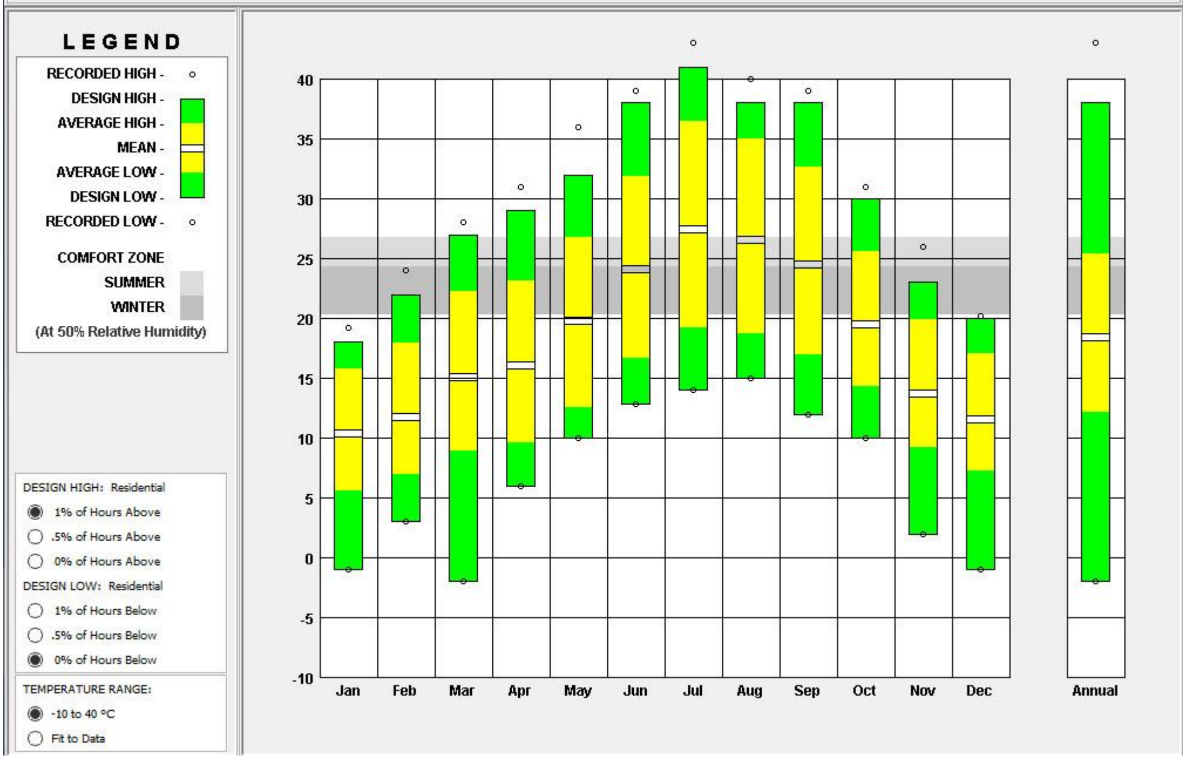
WEATHER DATA SUMMARY

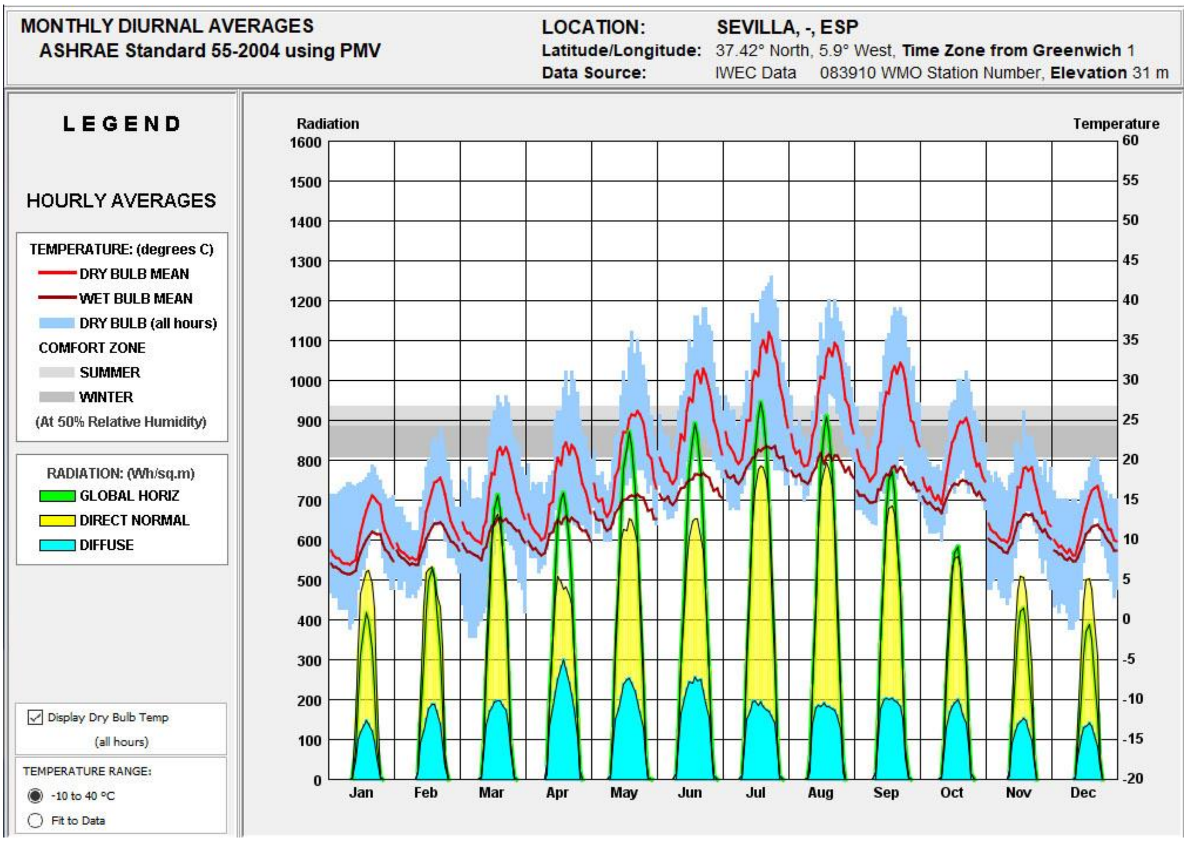
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, **Time Zone from Greenwich** 1
Data Source: IWEC Data 083910 WMO Station Number, **Elevation** 31 m

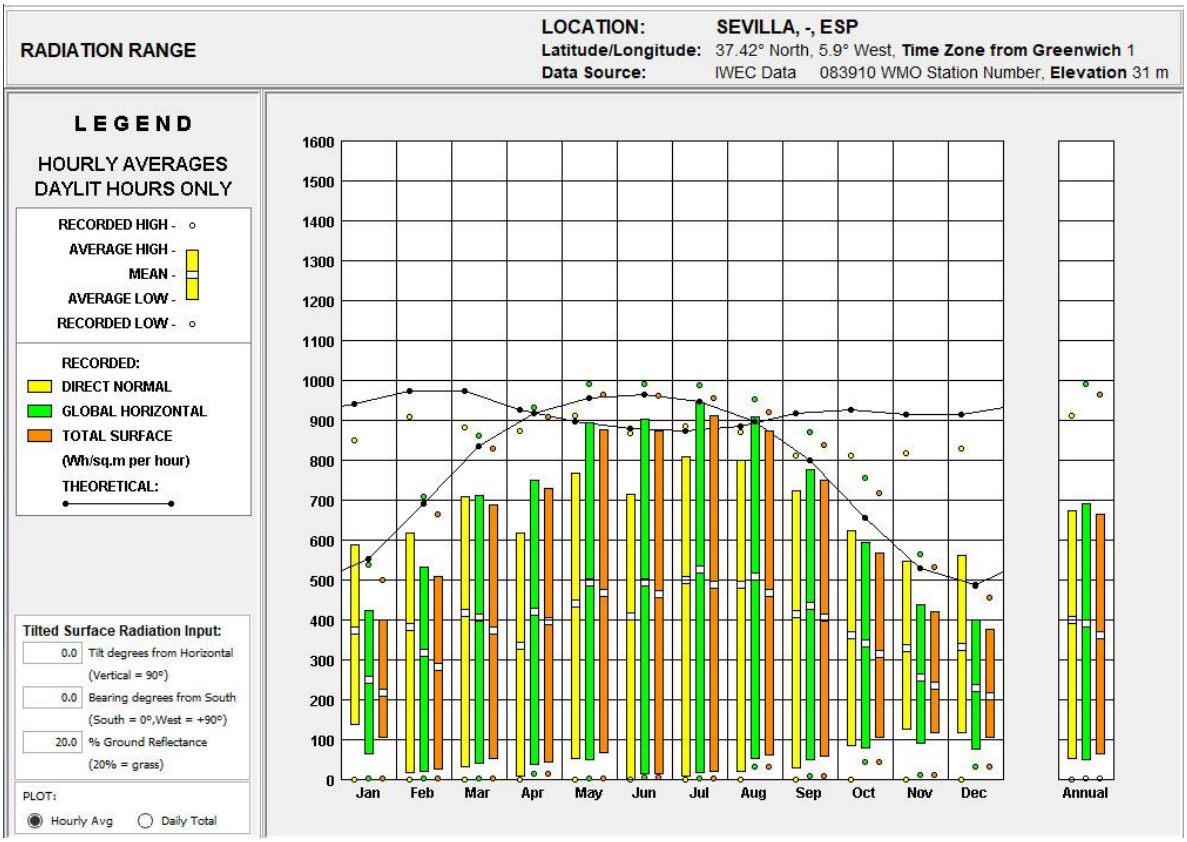
MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	249	318	406	419	494	493	526	508	436	340	255	229	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	374	381	416	336	440	408	499	488	415	361	330	333	Wh/sq.m
Diffuse Radiation (Avg Hourly)	98	128	145	186	169	178	146	147	156	138	108	98	Wh/sq.m
Global Horiz Radiation (Max Hourly)	537	709	862	931	991	992	988	953	870	756	564	486	Wh/sq.m
Direct Normal Radiation (Max Hourly)	851	909	882	873	913	868	885	871	813	813	818	828	Wh/sq.m
Diffuse Radiation (Max Hourly)	288	353	404	654	480	472	457	453	387	394	289	240	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2423	3365	4810	5430	6937	7179	7517	6818	5349	3737	2541	2169	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	3621	4028	4941	4337	6181	5932	7117	6550	5089	3960	3264	3151	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	964	1360	1714	2433	2378	2590	2093	1975	1907	1525	1081	930	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	26838	34366	43817	45560	53446	53922	57730	55480	47612	37047	27606	24617	lux
Direct Normal Illumination (Avg Hourly)	33988	35830	40573	32908	42969	39834	49020	47786	39849	33949	30606	29820	lux
Dry Bulb Temperature (Avg Monthly)	10	11	15	16	19	24	27	26	24	19	13	11	degrees C
Dew Point Temperature (Avg Monthly)	5	7	6	6	9	11	15	14	12	13	8	7	degrees C
Relative Humidity (Avg Monthly)	74	76	59	56	55	50	53	53	50	69	72	77	percent
Wind Direction (Monthly Mode)	50	40	90	270	240	230	230	230	230	40	60	50	degrees
Wind Speed (Avg Monthly)	2	2	2	2	3	2	2	2	2	2	3	2	m/s
Ground Temperature (Avg Monthly of 3 Depths)	18	15	13	12	12	14	17	20	22	24	23	21	degrees C

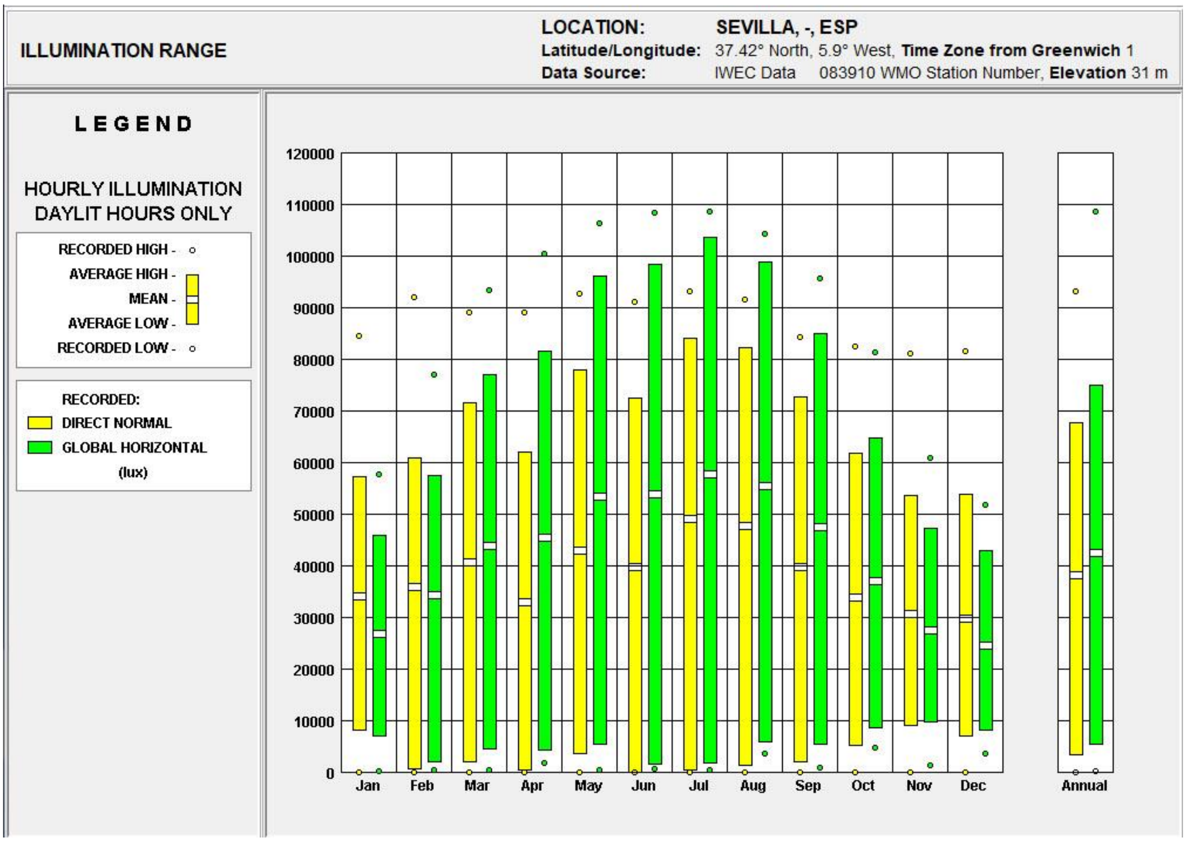
TEMPERATURE RANGE
ASHRAE Standard 55-2004 using PMV

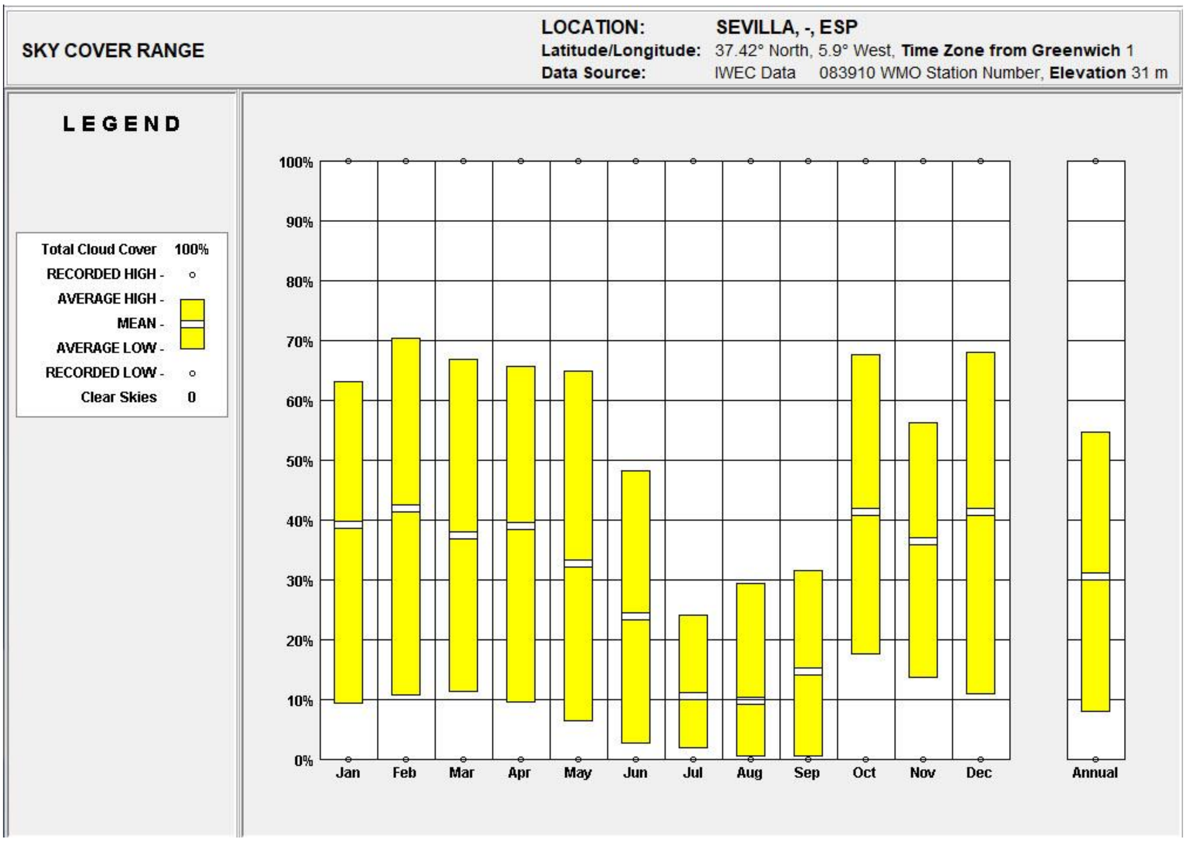
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, **Time Zone from Greenwich** 1
Data Source: IWEC Data 083910 WMO Station Number, **Elevation** 31 m

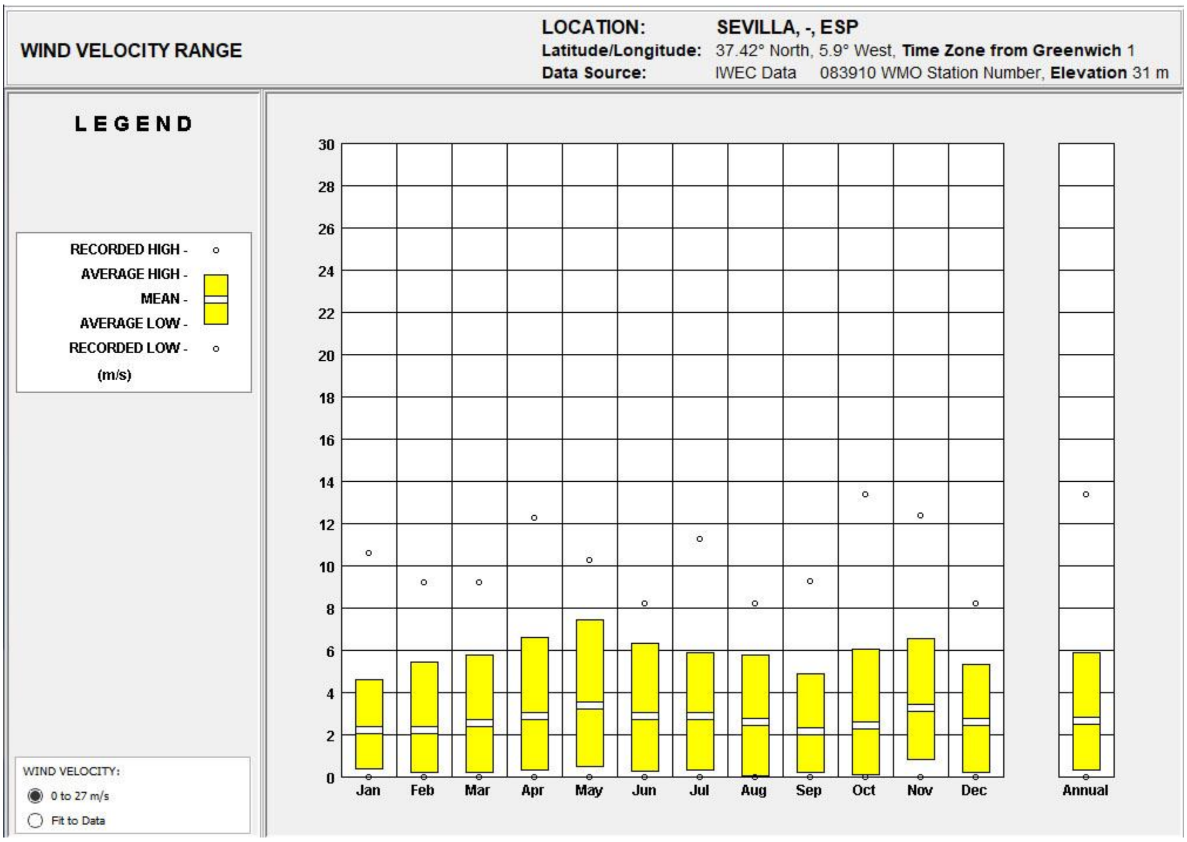


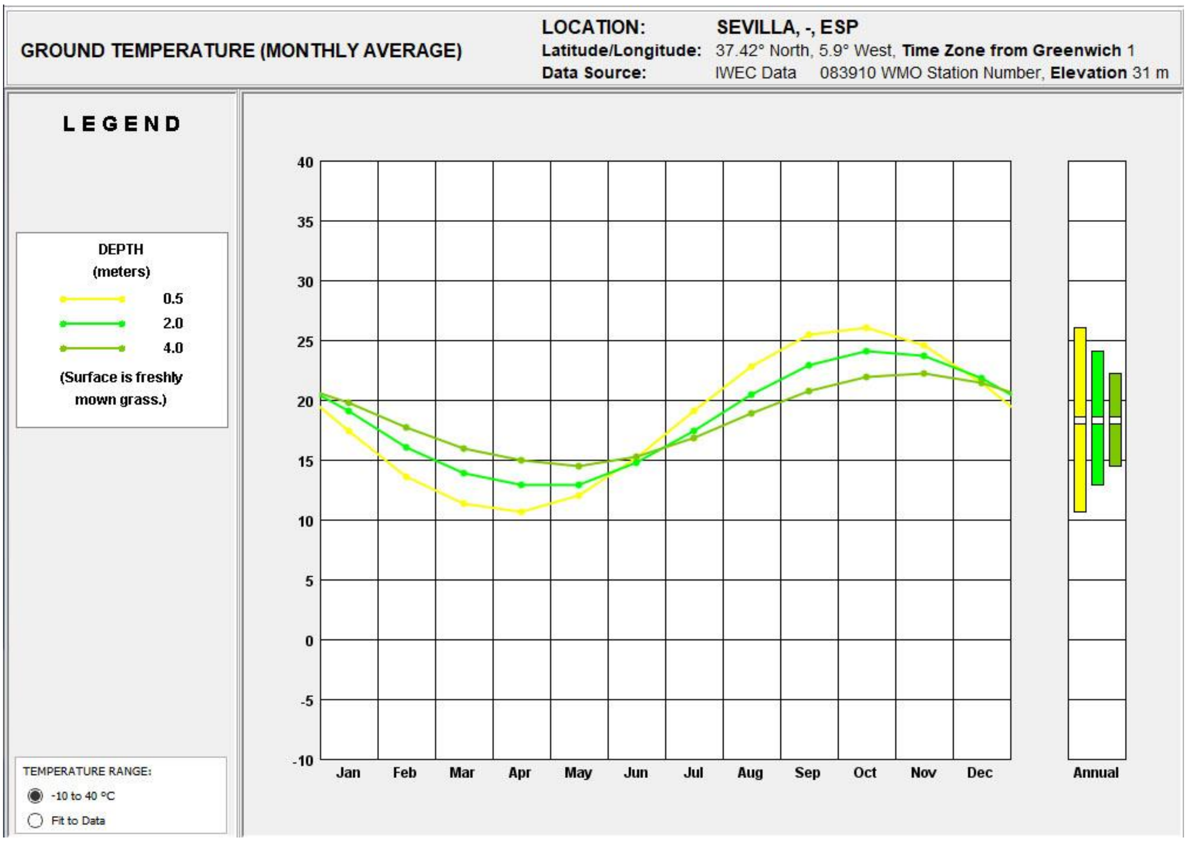

MONTHLY DIURNAL AVERAGES
ASHRAE Standard 55-2004 using PMV
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
HOURLY AVERAGES
TEMPERATURE: (degrees C)
DRY BULB MEAN
WET BULB MEAN
DRY BULB (all hours)
COMFORT ZONE
SUMMER
WINTER
(At 50% Relative Humidity)
RADIATION: (Wh/sq.m)
GLOBAL HORIZ
DIRECT NORMAL
DIFFUSE
Display Dry Bulb Temp (all hours)
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
Radiation
Temperature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

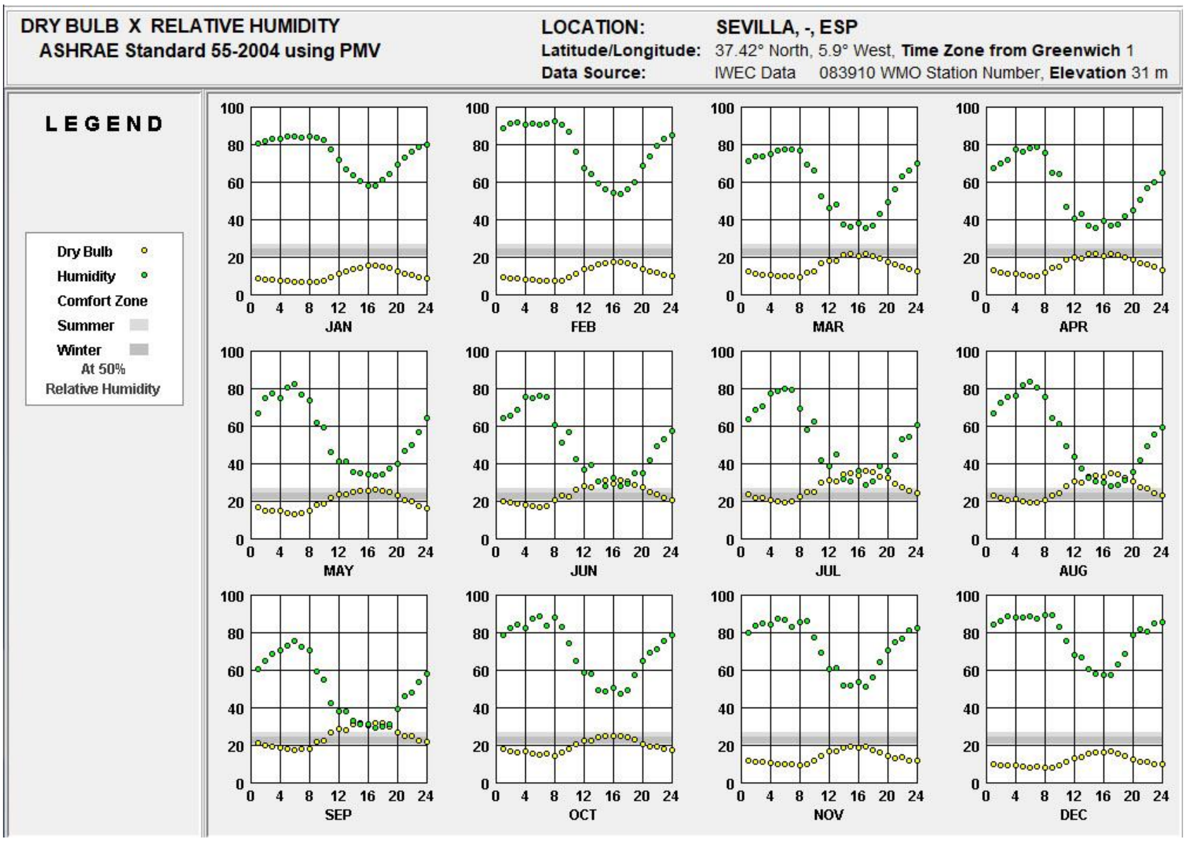

RADIATION RANGE
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
HOURLY AVERAGES
DAYLIT HOURS ONLY
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
RECORDED:
DIRECT NORMAL
GLOBAL HORIZONTAL
TOTAL SURFACE
(Wh/sq.m per hour)
THEORETICAL:
Tilted Surface Radiation Input:
0.0 Tilt degrees from Horizontal
(Vertical = 90°)
0.0 Bearing degrees from South
(South = 0°,West = +90°)
20.0 % Ground Reflectance
(20% = grass)
PLOT:
Hourly Avg
Daily Total
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual

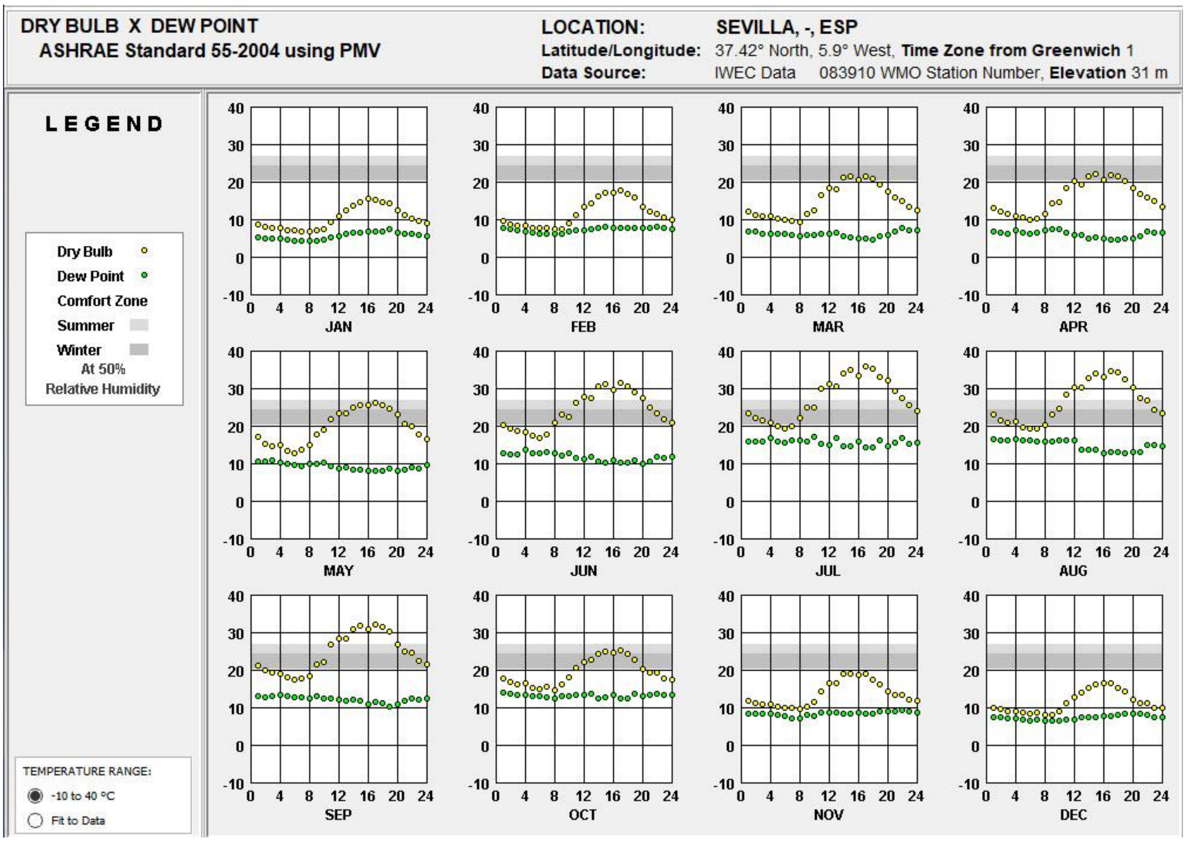

ILLUMINATION RANGE
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
HOURLY ILLUMINATION
DAYLIT HOURS ONLY
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
RECORDED:
DIRECT NORMAL
GLOBAL HORIZONTAL
(lux)
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Annual

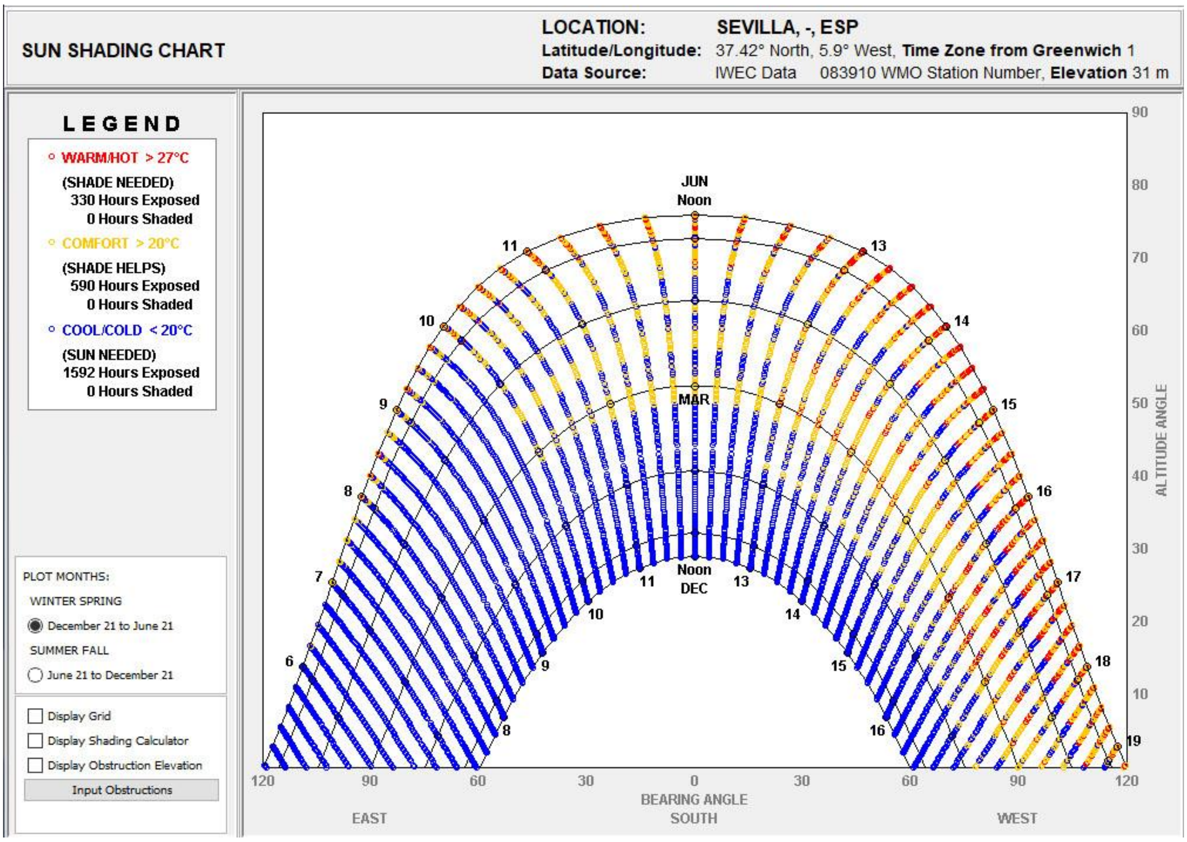

SKY COVER RANGE
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
Total Cloud Cover 100%
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
Clear Skies 0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Annual

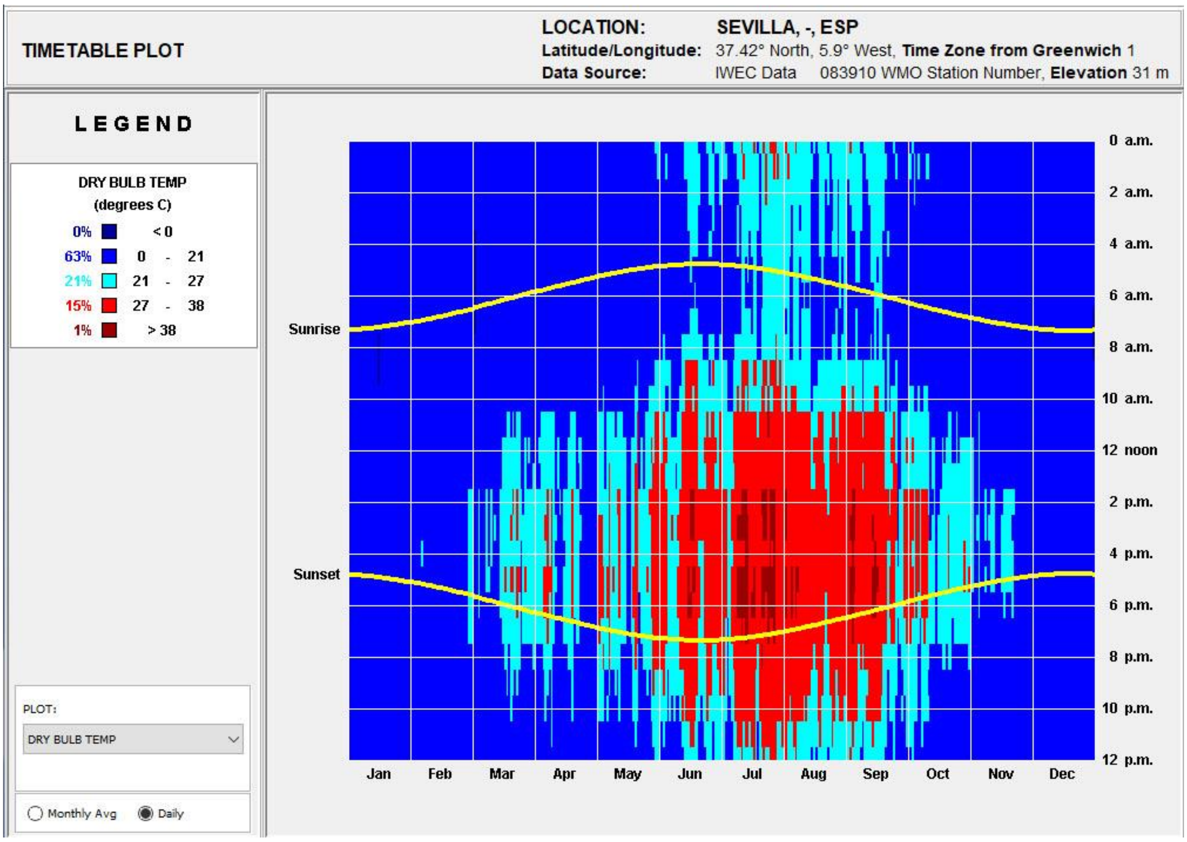

WIND VELOCITY RANGE
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
RECORDED HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
RECORDED LOW -
(m/s)
WIND VELOCITY:
0 to 27 m/s
Fit to Data
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual

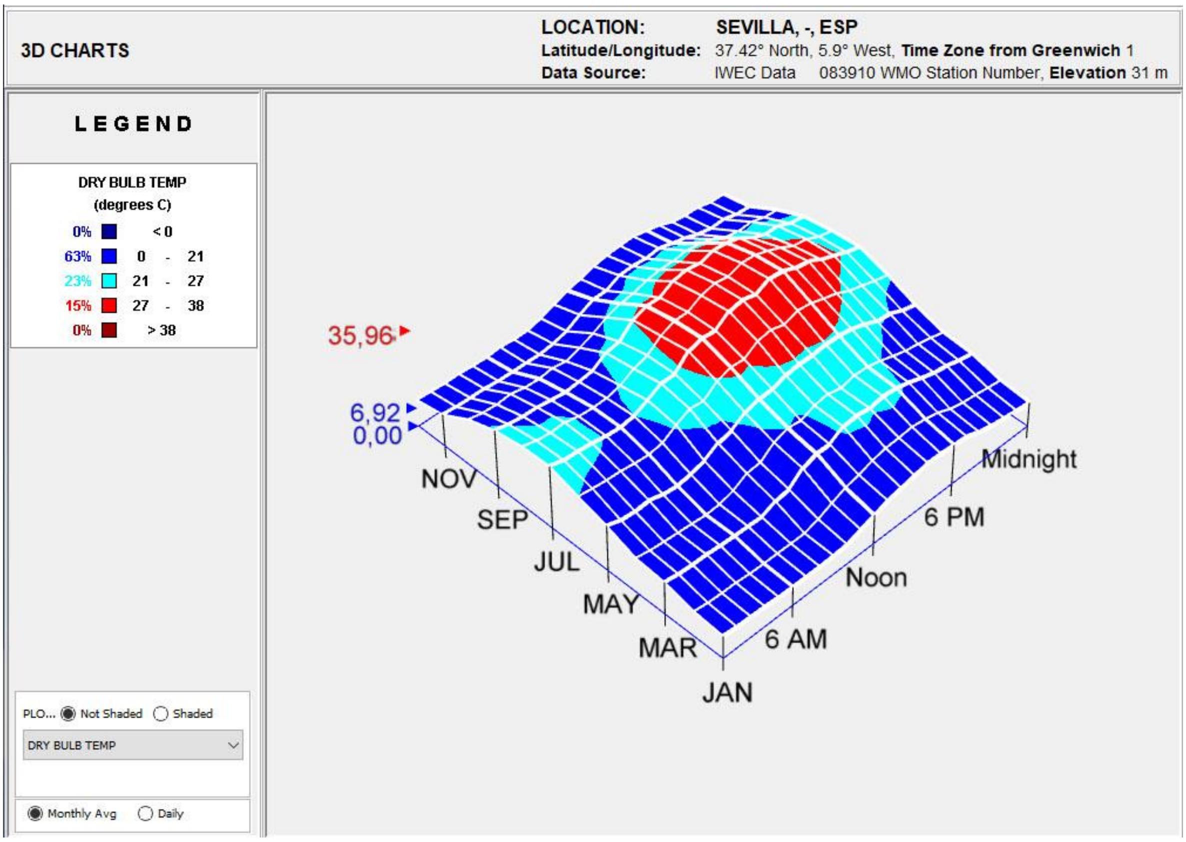

GROUND TEMPERATURE (MONTHLY AVERAGE)
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
DEPTH
(meters)
0.5
2.0
4.0
(Surface is freshly mown grass.)
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
40
35
30
25
20
15
10
5
0
-5
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual


DRY BULB X RELATIVE HUMIDITY
ASHRAE Standard 55-2004 using PMV
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
Dry Bulb
Humidity
Comfort Zone
Summer
Winter
At 50% Relative Humidity
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


DRY BULB X DEW POINT
ASHRAE Standard 55-2004 using PMV
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
Dry Bulb
Dew Point
Comfort Zone
Summer
Winter
At 50% Relative Humidity
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


SUN SHADING CHART
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
WARM/HOT > 27°C
(SHADE NEEDED)
330 Hours Exposed
0 Hours Shaded
COMFORT > 20°C
(SHADE HELPS)
590 Hours Exposed
0 Hours Shaded
COOL/COLD < 20°C
(SUN NEEDED)
1592 Hours Exposed
0 Hours Shaded
PLOT MONTHS:
WINTER SPRING
December 21 to June 21
SUMMER FALL
June 21 to December 21
Display Grid
Display Shading Calculator
Display Obstruction Elevation
Input Obstructions
JUN
Noon
MAR
Noon
DEC
ALTITUDE ANGLE
BEARING ANGLE
EAST
SOUTH
WEST


TIMETABLE PLOT
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
DRY BULB TEMP
(degrees C)
0% < 0
63% 0 - 21
21% 21 - 27
15% 27 - 38
1% > 38
PLOT:
DRY BULB TEMP
Monthly Avg
Daily
Sunrise
Sunset
0 a.m.
2 a.m.
4 a.m.
6 a.m.
8 a.m.
10 a.m.
12 noon
2 p.m.
4 p.m.
6 p.m.
8 p.m.
10 p.m.
12 p.m.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


3D CHARTS
LOCATION: SEVILLA, -, ESP
Latitude/Longitude: 37.42° North, 5.9° West, Time Zone from Greenwich 1
Data Source: IWEC Data 083910 WMO Station Number, Elevation 31 m
LEGEND
DRY BULB TEMP
(degrees C)
0% < 0
63% 0 - 21
23% 21 - 27
15% 27 - 38
0% > 38
PLO... Not Shaded Shaded
DRY BULB TEMP
Monthly Avg Daily
35,96
6,92
0,00
NOV
SEP
JUL
MAY
MAR
JAN
6 AM
Noon
6 PM
Midnight