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METHODOLOGY FOR A REGIONAL CARTOGRAPHY FOR THE APPLICATION OF THE BIOCLIMATIC STRATEGIES OF THE GIVONI CHARTER

METODOLOGÍA PARA ELABORAR UNA CARTOGRAFÍA REGIONAL Y APLICAR ESTRATEGIAS BIOCLIMÁTICAS SEGÚN LA CARTA DE GIVONI

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RESUMEN

Se plantea como objetivo de la investigación expuesta la viabilidad de una metodología para cartografiar un territorio concreto, implementando las estrategias bioclimáticas necesarias para alcanzar el confort, según el diagrama de Givoni; herramienta muy útil para el diseño de edificios. Tal metodología se desarrolla en cuatro fases: I, obtención de la información climática; II, análisis de los datos climatológicos; III, selección de estaciones y datos mensuales, aplicación de la carta de Givoni e inicio del proceso de cartografiado; IV, establecimiento de la zonificación, y elaboración de mapas, con carácter mensual. Como resultado del trabajo, se obtiene un conjunto de mapas que indican las estrategias bioclimáticas adecuadas a cada territorio, en periodicidad mensual, para alcanzar el confort en los edificios. La metodología fue validada en un territorio concreto en España, utilizado como caso de estudio. En definitiva, la aportación original de la investigación es precisamente el desarrollo de la mencionada metodología, que permite elaborar una cartografía para un territorio determinado -mapa que convierte en una potente herramienta para el diseño bioclimático- y que, además, es susceptible de ser aplicada a cualquier territorio.

Palabras clave
arquitectura bioclimática, cartografía, climatología, territorio

ABSTRACT

The aim of the research is the feasibility of a methodology to map a specific territory, implementing the bioclimatic strategies necessary to achieve comfort, according to the Givoni diagram, as a very useful tool for building design.The methodology used is developed in four phases: I, obtaining the climatic information; II, analysis of climatological data; III, selection of stations and monthly data, application of Givoni letter and start of the mapping process; IV, establishment of zoning, and mapping, on a monthly basis. As a result of the application of the methodology, a set of maps is obtained that indicate the appropriate bioclimatic strategies for each territory, on a monthly basis, in order to achieve comfort in the buildings. The methodology has been validated in a specific territory in Spain, used as a case study. The original contribution of the research is said methodology that allows to elaborate the cartography for a territory, that becomes a powerful tool for the bioclimatic design, and that is capable of being applied to any territory.

Keywords
bioclimatic architecture, cartography, climatology, territory

INTRODUCTION

BIOCLIMATIC DESIGN ACCORDING TO STRATEGIES OF GIVONI

The bioclimatic design is a tool to reach levels of thermal comfort that has its origin in the study of the relationship of man with the climate. Already at the beginning of the 20th century, Houghten and Yagloglou worked with the concept of climate comfort in their study "Determining lines of equal comfort" (1923), as part of what is now known as ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). This work proposed to locate comfort zones in a psychometric diagram, relating humidity and temperature, based on the effective temperature index. Many investigations were generated from that moment. As evolution to these approaches, the so-called climates, bioclimatic diagrams or bioclimatic charts were established, which are used as tools to determine design strategies of exterior and interior spaces with the aim of achieving thermal comfort. These charts allowed connect climatic conditions of the place with the passive and/or active strategies that are needed to achieve comfort conditions (Givoni, 1969).

In the development of these tools, numerous contributions have been made to analyze the variables involved in these phenomena and the way they do it: Halawa and Van Hoof (2012), Mena, Rodríguez, Castilla y Arahal (2014), Dávila (2015), Larrumbide and Bedoya (2015), Kurbán and Cúnsulo (2017), and Esteves (2018). Most of them focus on the relationships between different thermal variables and human comfort, and their impact on the graphic representation of these relationships.

The most commonly used diagrams, or bioclimatic charts, are those of Olgyay and Givoni, as they are directly applicable to buildings and their surroundings, so that they obtain equally direct recommendations from them. The first quantifies corrections of the bioclimatic parameters to get human comfort in outdoor conditions, without any relation to the architectural object. The second one has the incidents that architecture can produce in the climate and points out the qualities that buildings must have in order to achieve a sense of comfort within them (Couret, Guzmán, Milián, García, and Salazar, 2015; Medina and Escobar, 2019).

The application of Givoni diagram for the bioclimatic design of buildings is in its initial objective. It has been used both in the field of design of concrete construction systems (Balter, Ganem and Discoli, 2016), in specific cases of buildings (Rodríguez, Nájera and Martín, 2018), and in the preparation of bioclimatic architecture manuals for a particular territory (Pérez, Ladrón de Guevara and Boned, 2015). There are also references

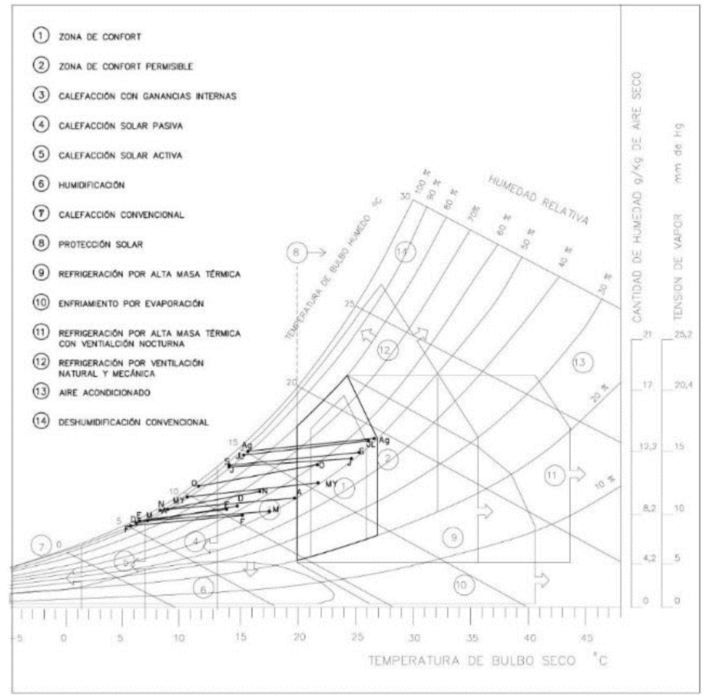

Figure 1. Givoni diagram for the climatic conditions of the data collection period: 2002-2016, at the Lourizán meteorological observatory, Galicia, Spain. Source: Made by the authors.

for Japan (Ooka, 2002), China (Gou, Li, Zhao, Nik and Scartezzini, 2015) and even Latin America (Echeverría, García, Celis and Saelzer, 2019).

The bioclimatic chart of Givoni is based on the Thermal Stress Index (TSI) to delimit the wellness zone, and its application is very suitable in hot climates of arid regions. This method takes into account the characteristics of the construction as modifiers of conditions of the outside climate and recommends the well-being inside buildings.

Givoni (1969) proposes a bioclimatic chart in which dry bulb temperatures are represented in the abscissa axis, while in the axis of the ordinates, the partial tension of water vapor contained in the air, the curved, psychometric lines represent the relative humidity (Figure 1). The wet bulb temperature is located above the maximum humidity line (100%).

The representation of the annual climate can be done with the average conditions of each month. The diagram delimits several zones whose characteristics of temperature and humidity indicate the desirability of using certain design strategies in the building.

Each of these zones can be seen in Figure 1. The heating strategies are successive, while, in the cooling strategies, there is an overlap and, therefore, a range of possibilities with which the comfort area can be reached.

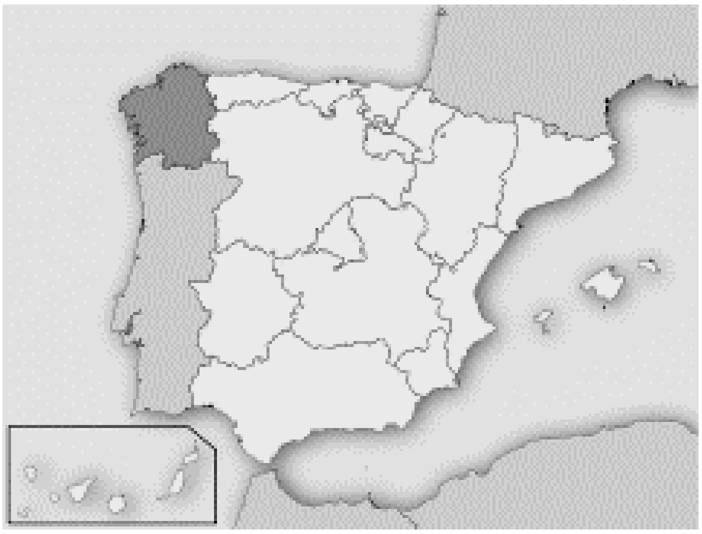

Figure 2. Geographical location of Galicia in the Iberian Peninsula (darker color). Source: National Geographic Institute (www.ign.es).

Indications obtained in the diagram are indicative, and not exclusive. The designer has information of systems that are effective in that place and in the analyzed time. It is from that information that the designer makes the right decisions. Usually, it is advisable to adopt combined measures that allow the best use of the equipment installed in different climatic situations. This leads to true reductions in energy consumption, in addition to the optimization of the consumption of conventional air conditioning equipment to be installed.

It should also be kept in mind that the adoption of corrective strategies for conditions considered insufficient, favors and reduces the use of conventional systems. Thus, if conventional heating is needed, good passive behavior will decrease the amount of energy spent on it. (Da Casa, 2000).

The problem arises when in order to apply this tool to the design process, the precondition is to have weather data corresponding to the location of the building to integrate them into the Givoni diagram and, thus, to know the bioclimatic strategies necessary to correct discomfort parameters. The most common difficulty is precisely obtaining specific location information that is reliable. In many cases it does not exist, which forces complex research processes (Corral, García and Romero, 2018); in other cases, climate data files for simulation are very general and simplified (in order to facilitate their management), without taking into account specific factors such as local overheating or microclimates, nor the effects of climate change (Luciani, Velasco and Hudson, 2018).

In short, the difficulty of using this tool globally, in any territory, to achieve the benefits of sustainable design is presented. Given this, and as starting point for the investigation, the need to answer the following questions is considered: Is it possible to have generalizable climatological data for immediate use? Is it possible to generate an application model from Givoni diagrams? Is it possible to extract from them a basic interpretation of a territorial nature? And, most importantly, is it possible to map all this?

Obtaining answers to these questions is the basis of the objective of this research, which proposes to develop an optimal methodology to develop a "regional bioclimatic cartography" of a specific territory, usable by any technician in the design of buildings, where to have the necessary information to adopt the most appropriate criteria and strategies, based on Givoni bioclimatic chart.

Among the studies related to the subject, we can mention those that address the cartographic representation of bioclimates (Marco, Sariñena, López, MS and López, ML, 2016) or of parameters, such as solar radiation (Díaz, Montero and Mazorra-Aguiar , 2018). There are also some attempts to graph the climatic zoning reference of the Technical Building Code of Spain. There is no reference to the generation of specific cartographies referring to bioclimatic design strategies, beyond a methodological proposal set forth by Da Casa (2000).

The development and application of these strategies facilitates the achievement of SDG, as well as that of all energy efficiency regulations, both those of consumption reduction, and those of increasing the optimization of buildings from their own design. Having this new tool (using the available resources, without having to make an investment, in the case of a public initiative), generates great interest, given the profitability of its approach and its high potential for benefits of a particular territory.

METHODOLOGY

In the investigation process a clear, particular and complete methodology has been established for the elaboration of this type of cartography. In order to verify its feasibility, an example applied to a specific territory was used as a validation system, as a pilot experience. The selected territory was the Autonomous Community of Galicia, in Spain (Figure 2).

In this context, four main phases are established:

- Phase I. Obtaining updated climate information available from the field of study.
- Phase II. Analysis of climatological data.
- Phase III. Implementation of stations and monthly

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data according to Givoni bioclimatic strategies. Start of the cartography process.

- Phase IV. Zoning, and establishment of "maps" of bioclimatic strategies of Givoni, on a monthly basis.

Next, each of these stages is deepened.

PHASE I. OBTAINING UPDATED CLIMATE INFORMATION AVAILABLE FROM THE FIELD OF STUDY.

To obtain specific climatic data from the study area, a network of meteorological observatories was available with the required data (at least, average, maximum and minimum temperature, and average, maximum and minimum relative humidity). The established source of information was the network of meteorological observatories of Xunta de Galicia (www.meteogalicia.es), which has a total of 101 observatories distributed throughout its geography (Figure 3).

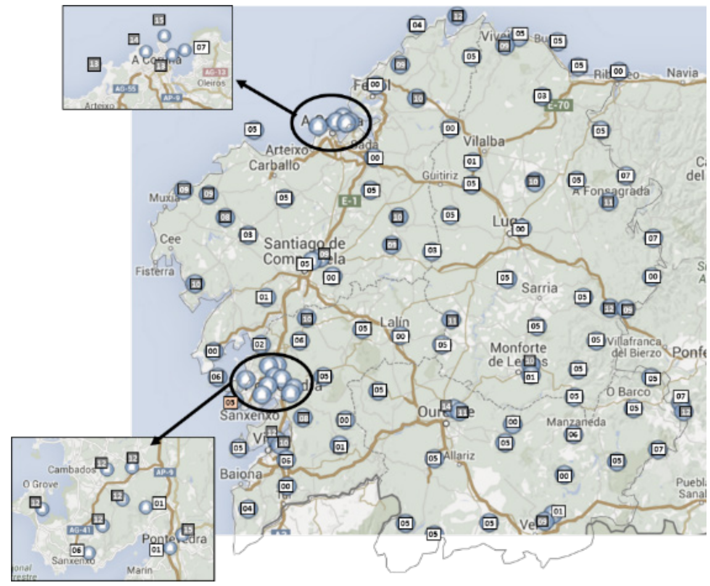

Figure 3. Meteorological stations available from Galicia with date of implementation. Source: Made by the authors based on images extracted from www.meteogalicia.es.

Regarding the minimum period of meteorological data to be collected, it was suggested that this should be sufficient to be referents of the real climate (usually considered 30 years). However, the extension and digitalization of the observatories does not allow such amount to be reached in most cases, which must be taken into account.

To this we must add the potential effect of the current climate change situation, in which the existence of a slight increase in temperature can be accepted as a model (Solanki, Schüssler and Fligge, 2000; Solanki, Usoskin, Kromer, Schüssler and Beer, 2004), especially in winter, and a shift in winter rainfall towards spring, which leads to an increase in oceanity and temperance (not a tropicalization). It affects existing facilities in buildings (Sánchez, Rubio, Marrero, Guevara and Canivell, 2017), as well as other areas (Enríquez, Díaz, Martín and Santos, 2017). This directly affects the application of passive design strategies (Rubio, 2015).

For all the above, it is estimated as acceptable reference a time range around 15 years (representative period of the change). In cases where shorter periods were available, the data were checked in terms of their consistency with the rest of the observatories and they were used in a complementary manner.

In the case of Galicia, the first implementation observatories are from 2000, which implies a period of more than 15 years. In addition, all the observatories consulted have the precise data for the application of the methodology considered in this work.

Thus, 55 observatories distributed homogeneously in the territory were selected, giving priority to older ones. Such selection was made in two phases: 33 observatories in the first one and another 22 in the second one (Table 1). Data of climatic parameters necessary for the elaboration of the bioclimatic chart of Givoni of the entire available period of each observatory were collected on a monthly basis, that is, monthly data on maximum temperature, minimum temperature, average maximum temperature, and average of the minimum, as well as data of the average, maximum and minimum relative humidity.

In order for the geographical distribution of observatories to be consulted to be homogeneous, the selection process was carried out, as already indicated, in two phases: in the first, the highest priority (33 observatories) were chosen, and the second was complemented with 22 other observatories, in order to have as complete coverage as possible of the territory of analysis.

In order to verify if the completeness of the study was valid, with 55 observatories tested, it is worth mentioning that, in 2010, the "Technical guide of external climatic conditions of the project", prepared by the Spanish Technical Association of Air Conditioning and Refrigeration (ATECYR, by its initials in Spanish) for the Institute for Diversification and Energy Saving (IDEA, by its initials in Spanish), is based on data from only 6 Meteorological Stations to determine the climate in Galicia. The objective of this study was to promote efficiency in the final use of energy in buildings. From that background, the number of study points is validated.

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OBSERVATORIOS PRINCIPALES CONSULTADOS (1ª fase)					OBSERVATORIOS CONSULTADOS en 2ª fase				
Nº clave	Denominación	Provincia	Municipio	Año implantación	Nº clave	Denominación	Provincia	Municipio	Año implantación
1	Castro Vicaludo	Pontevedra	Oia	2004	A	A Pontenova	Lugo	A Pontenova	2005
2	Monte Aloia	Pontevedra	Tui	2000	B	O Xipro	Lugo	A Fonsagrada	2007
3	Queimadelos	Pontevedra	Mondariz	2001	C	Ventosa	Lugo	Navia de Suarna	2007
4	Entrimo	Ourense	Entrimo	2005	D	Caldas de Reis	Pontevedra	Caldas de Reis	2006
5	Gandarela	Ourense	Celanova	2005	E	Pereira	Pontevedra	Forcarei	2005
6	Baltar	Ourense	Baltar	2005	F	Mouriscade	Pontevedra	Lalín	2000
7	O Invernadeiro	Ourense	Vilariño de Conso	2000	G	Ourense	Ourense	Ourense	2011
8	Xares	Ourense	A Veiga	2007	H	Marroxo	Lugo	Monforte	2001
9	Lourizán	Pontevedra	Pontevedra	2001	I	Serra do Eixe	Ourense	O Barco de Valdeorras	2005
10	Amiudal	Ourense	Avión	2005	J	Cabeza de Manzaneda	Ourense	Manzaneda	2006
11	Alto do Rodicio	Ourense	Maceda	2000	K	Viana do Bolo	Ourense	Viana do bolo	2005
12	San Xoán de Río	Ourense	San Xoán de Río	2005	L	Fornelos de Montes	Pontevedra	Fornelos de monte	2000
13	As Petarelas	Ourense	Rubias	2005	M	Penedo do Galo	Lugo	Viveiro	2005
14	Corrubedo	A Coruña	Ribeira	2000	N	Portomarín	Lugo	Portomarín	2005
15	Muralla	A Coruña	Lousame	2001	O	Abradelo	Lugo	Samos	2005
16	Sergude	A Coruña	Boqueixon	2000	P	Verín-Vilamaior	Ourense	Verin	2001
17	Serra do Faro	Pontevedra	Rodeiro	2005	Q	Corón	Pontevedra	Vilanova de Arousa	2002
18	Bóveda	Lugo	Bóveda	2005	R	Rebordelo	Pontevedra	Cotobade	2005
19	Courel	Lugo	Folgoso	2005	S	Ons	Pontevedra	Bueu	2005
20	Fontecada	A Coruña	Santa Comba	2003	T	Illas Cíes	Pontevedra	Vigo	2005
21	Río do Sol	A Coruña	Coristanco	2005	U	Camariñas	A Coruña	Camariñas	2009
22	Melide	A Coruña	Melide	2003	V	Lira	A Coruña	Carnota	2010
23	Campus Lugo	Lugo	Lugo	2000					
24	Ancares	Lugo	Cervantes	2000					
25	Malpica	A Coruña	Malpica	2005					
26	Mabegondo	A Coruña	Abegondo	2000					
27	Guitiriz	Lugo	Guitiriz	2000					
28	Pol	Lugo	Pol	2005					
29	CIS Ferrol	A Coruña	Ferrol	2000					
30	Punta Candieira	A Coruña	Cedeira	2004					
31	Serra da Faladoira	A Coruña	Ortigueira	2005					
32	Fragavella	Lugo	Abadín	2003					
33	Pedro Murias	Lugo	Ribadeo	2000					

Table 1. List of observatories selected in the study (the year of implementation is indicated). Source: Made by the authors.

PHASE II. ANALYSIS OF CLIMATOLOGICAL DATA

Once all the climatological information was collected, it was considered as the first step to proceed to the homogenization of data obtained from each observatory, according to existing models (Arava, 2014; Cartaya, Zurita and Montalvo, 2016). In this way, individualized tables of each of the observatories were acquired with monthly data (throughout the available period) of maximum and minimum temperature, average maximum and minimum, and relative average, maximum and minimum humidity. This information allowed the analysis of its evolution and the comparative analysis with extreme temperatures. It should be noted that data that responded to situations of equipment failures or deficiencies in the acquisition of these were filtered.

The average data per month of each parameter were entered in the Givoni climate graph, and with the result, the bioclimatic strategies were established on a monthly basis, both for cooling and heating in the required months.

As it is known, Givoni strategies for heating are progressive as the temperature data decreases. This makes possible to use spreadsheets as a tool to present the resulting monthly data, being able to define the limit heating strategy that allows achieve comfort, for each month and in each zone.

With respect to refrigeration strategies, the application is not as direct, since strategies overlap, and its evolution is not as clear as in terms of heating, depending not only on the variation of the temperature, but on the relationship with environmental relative humidity. In this type of strategies, the direct application of Givoni diagram is required to establish results. It is necessary to see that in most of the occasions several strategies will be available, which can even be adopted simultaneously (Guzmán, Cano and Roset, 2019).

With the data obtained, tables and diagrams corresponding to each observatory were prepared, in which the type of strategy required to achieve comfort conditions in each month, corresponding to heating and cooling independently, was indicated.

Metodología para elaborar una cartografía regional y aplicar estrategias bioclimáticas según la carta de givoni
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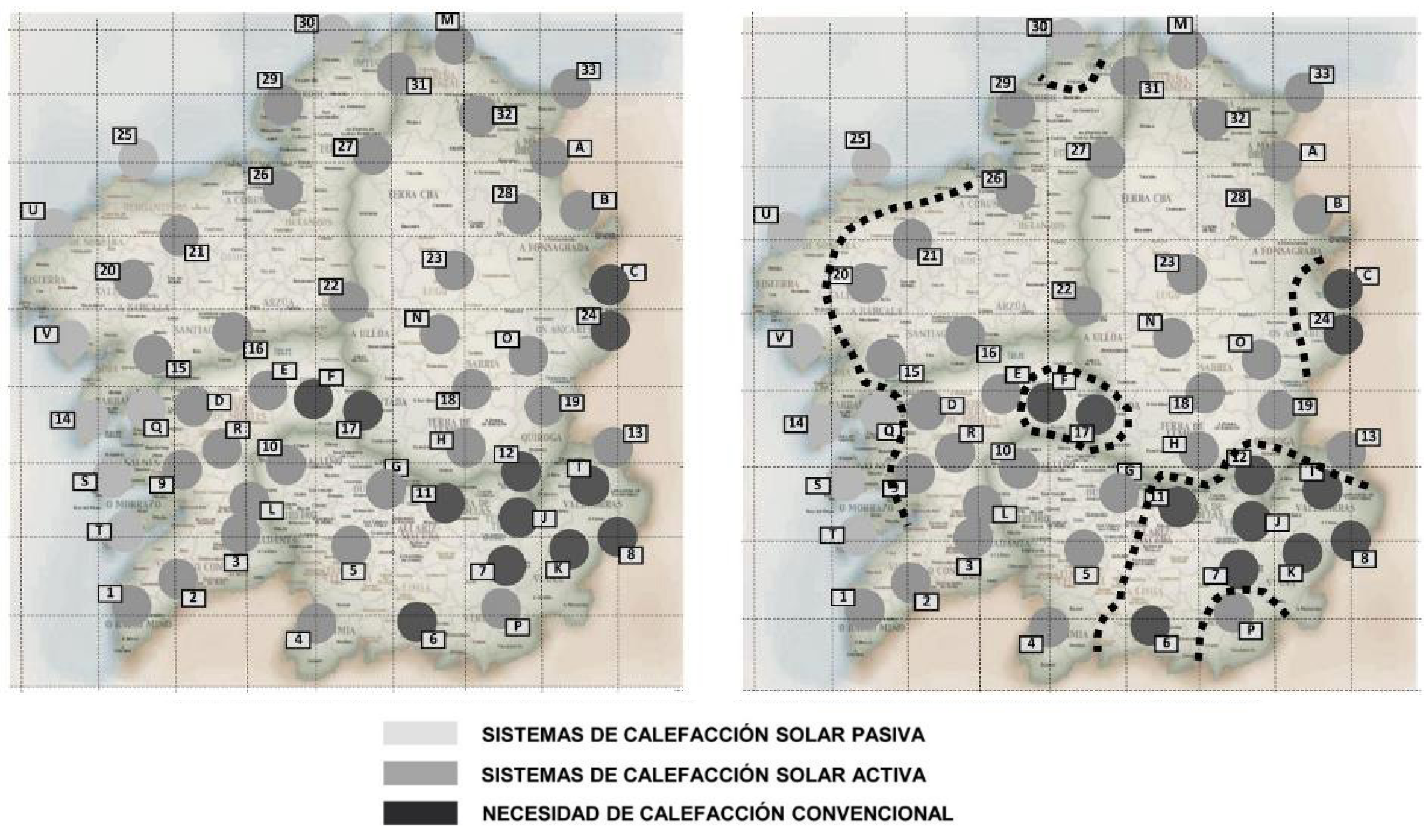

Figure 4. Illustrative example of the initial cartography process corresponding to heating needs of the month of February. Source. Made by authors.

PHASE III. IMPLEMENTATION OF STATIONS AND MONTHLY DATA ACCORDING TO GIVONI BIOCLIMATIC STRATEGIES. START OF THE CARTOGRAPHY PROCESS.

The first step of this phase was the transfer the territory into a map, of the data obtained individually in each observatory. It was captured graphically with color code according to the different strategy necessary for each month in the geographical location of each observatory. In this way, one map was available per month, with all the points selected and coded. Maps for heating and cooling strategies were independently produced.

The second step was to carry out a first analysis in order to verify the existence of uniqueness zones by contrast between results. Complementary analyzes of new observatories were carried out to complement the information and to better define the complexity of boundary zones. Then, the existence of areas of similar behavior could be observed.

In the third step of this phase, the zonal grouping of observatories was carried out whose data imply the use of similar design strategies. Initial limits of each of the territorial areas that had a similar behavior were established graphically.

It is good to point out, as illustration Figure 4 shows, on the left, a positioning of data and, on the right, the first zonal delimitation.

PHASE IV. ZONING AND ESTABLISHMENT OF "MAPS" OF BIOCLIMATIC STRATEGIES OF GIVONI, ON A MONTHLY BASIS.

Once the first outline of monthly maps with the results in the form of data points was established, results in the delimitation between areas of different characterization were analyzed. It was possible to observe the divergences or disagreements, and the areas of doubtful delimitation, or areas where some initially inconsistent behavior was observed.

At that time, the need to expand the number of observatories to be studied was determined, incorporating those indicated in Table 1, as the 2nd phase. In cases where reliable data from an observatory in that area were not available, interpolation was carried out, based on the effective distance and taking into account the difference in altitude and latitude between observatories. In some specific areas the orographic factor and the local wind regime were introduced.

After modifying and adjusting the initial delimitations, the zoning mapping was obtained, on a monthly basis,

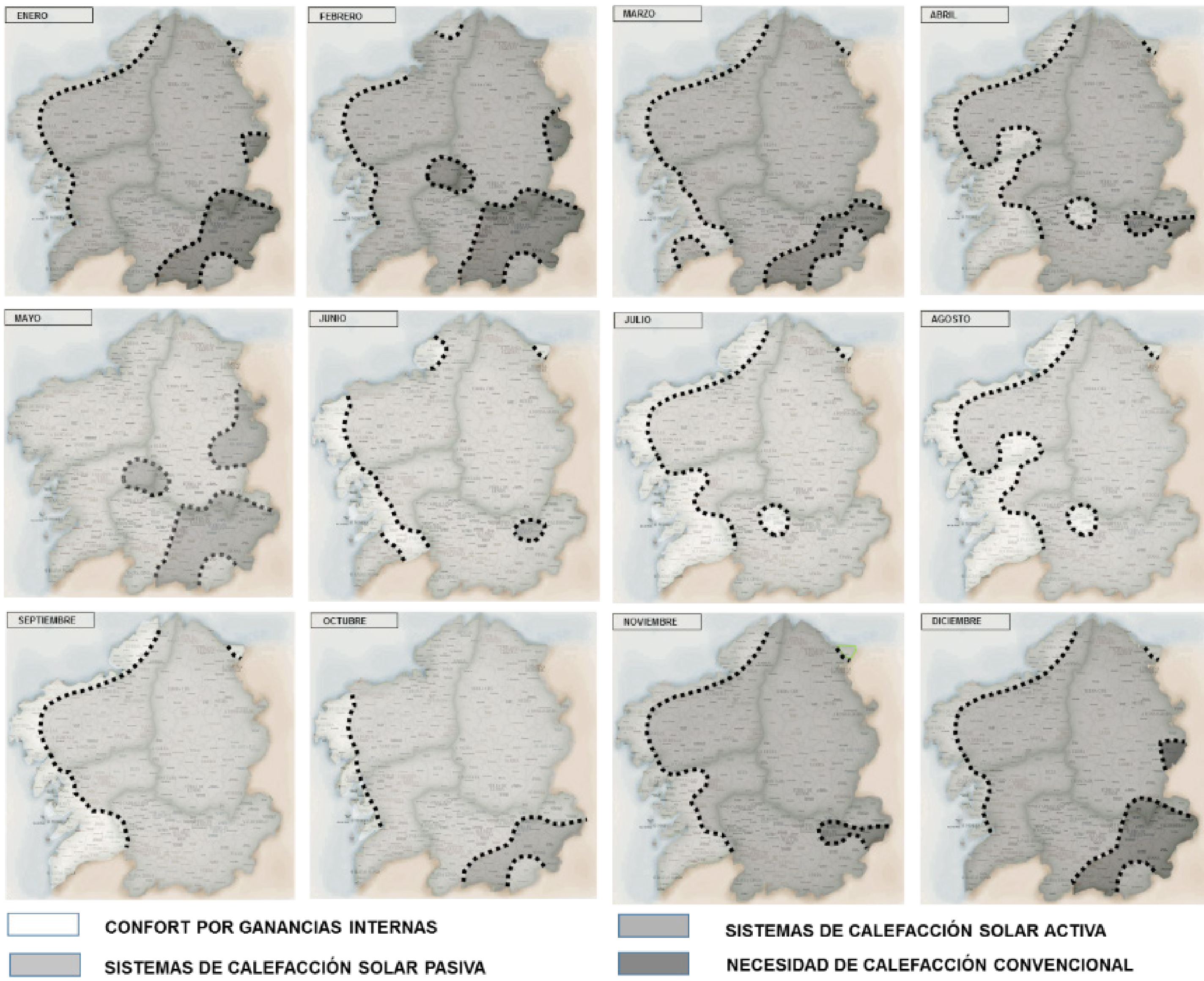

Figure 5. Cartography of bioclimatic strategies for heating in Galicia for each month of the year, according to Givoni. Source: Made by the authors.

of heating strategies and those required for cooling (independently), according to Givoni, with a view to achieving thermal comfort in the studied territory.

Regarding heating strategies, the work generated 12 maps, one per month, since the analysis of the data showed the need to adopt heating strategies throughout the year. Thus, in each month the differentiable zones with different coding were indicated.

The consideration of extreme situations was not taken into account at this stage, notwithstanding that this may be included in subsequent studies. However, such situations should not be considered as the basis of the design, since they would involve excessive oversizing that could generate irregular situations.

Regarding refrigeration strategies, it was in a similar way, showing maps in each of the months in which this type of needs were presented. For the purpose of the investigation, it was proposed to establish as many groups of strategies as they were, according to overlaps of the distribution of the Givoni diagram itself.

It was decided to consider the extreme situations in the case of refrigeration, since these data could be useful as a complement for the information of average parameters, insofar they give indications of extreme states of discomfort.

RESULTS AND DISCUSSION

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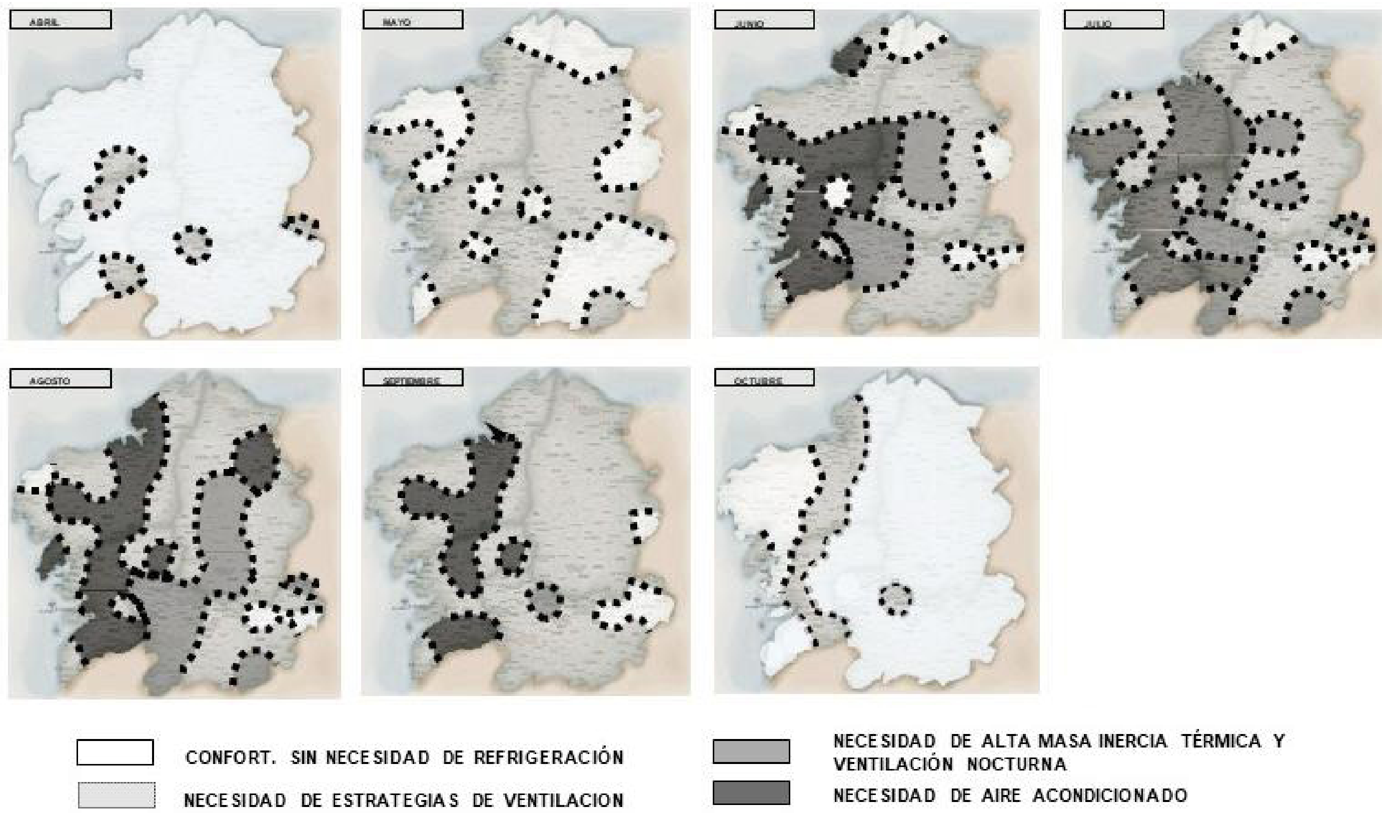

Figure 6. Cartography of bioclimatic strategies for refrigeration in Galicia for maximum temperature from April to October according to Givoni. Source: Made by the authors.

As a result of the application of the proposed methodology, the viability of mapping the needs of air conditioning strategies of a territory was verified. Indeed, 12 maps were obtained, one per month, for heating strategies (Figure 5).

In the case of refrigeration strategies, when applying the data of temperature (maximum and minimum) and average relative humidity (maximum and minimum), a particular circumstance was presented, and it is usual that several strategies are feasible, which can be used individually or simultaneously. But the analysis of the evolution of these strategies was not as clear here as those corresponding to the heating requirements, mainly due to the non-progressive nature of the strategies in the Givoni diagram. This complicated the coding, as there was a greater diversification of points. However, it was proved in practice that in the end diversification is not so wide for each climate.

On the other hand, it was observed that only in 5 dispersed observatories any need for refrigeration is indicated in any month, leaving practically the entire territory in a state of comfort (remember that with the average monthly data).

Given this uniqueness, it was considered interesting to know the mapping of the refrigeration needs in a situation of maximum temperatures, so that the information on the process of adopting bioclimatic strategies in the design could be complemented. When applying the method in these circumstances, refrigeration strategies were dated from April to October, obtaining 7 maps (Figure 6).

Given these results, it is pertinent to present the discussion carried out, which focused on answering the questions related to three main aspects: the reliability of the result obtained, the applicability of the presented cartography, and the ability to extrapolate this methodology to other territories.

DISCUSSION POINT 1: RELIABILITY OF THE RESULT OBTAINED.

When answering the question "Is the information obtained reliable?" It becomes essential to think of the definition of "reliability" itself. If by such term is understood the degree of consistency, stability and absence of errors in the data and its use, must be based on the origin of the used data. The source of climatic data is of all reliability. It is a network of meteorological observatories of a public administration, Xunta de Galicia of public access in digital form (www.meteogalicia.es). The applied data respond to the reality of each location, which were collected continuously and digitally.

The use of a 15-year data collection period allows for a real climate consideration to be established, taking into

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account the evolution produced and the impact of climate change. Therefore, results based on the use of such data can be considered reliable.

The degree of accuracy of the resulting maps responds to the average nature of the weather parameters used, being adjusted for any of the applications for which they can be used. The adjustment made in the delimitation between zones responds to this character with the interpolation between observatories, but taking into account the effective distance between them, the difference in altitude, and even the intermediate orography of the area. In this way, it can be considered to have obtained a balanced and reliable accuracy.

However, if reliability is understood as the "probability of a good functioning of something" (definition of the Royal Spanish Academy), it should be indicated that the consistency check of the maps obtained has been performed, with the climatic delimitation of the Spanish Regulations of the Technical Building Code (Da Casa, Echeverría y Celis, 2017), with a positive result. However, it is clear that each of these zoning responds to different objectives and that the zoning resulting from the methodology applied, not being limited to "reference climates" of the Spanish Standard, conforms to the local reality, expanding coverage of options for bioclimatic design. Therefore, a reliable result can also be considered from this perspective.

DISCUSSION POINT 2: APPLICABILITY OF THE CARTOGRAPHY PRESENTED.

A second issue to discuss about the result obtained is whether the cartography obtained has any other applicability beyond reflecting the design strategies necessary to achieve comfort each month, according to Givoni. Through the analysis carried out in the research process, several applications of great potential have been evidenced.

The first of them is to consider this cartography as a bioclimatic design manual of the mapped region. Any technician or promoter, with the location of the territory on the map, directly obtains the information related to the design strategies necessary to adopt in order to achieve comfort in each of the months. All this, directly, without having to search and interpret the specific climatic data (in many territories this search is very complex for a particular technician).

With the determination of the strategies revealed on the maps, together with the specific conditions of the environment, the designer can establish his own design criteria, appropriate to the territory, the project or the requirements of the use or of the developer himself. Thus, the emergence of efficient and optimized design proposals is encouraged.

A second application consists of the knowledge of the evolution of the needs of the own strategies in the own territory. By observing all the maps together, you can see the evolution of the areas corresponding to each strategy throughout the year.

From the individual analysis by strategies, in the case applied, it is clear which areas are in comfort, not requiring any strategy even in a situation of limit temperature. It can also be noted that, in more than half of the territory, it would not be necessary to have air conditioning systems at any time of the year.

From the analysis of the evolution of strategies in the year, the possibility of generating an annual climatic zoning is determined, adjusted to the physical reality of each territory (Da Casa et al., 2017), and thereby establish coherence with the applicable regulations (if applicable, as in Spain, with the Technical Building Code). The areas of specific singularity can be located, which would allow particular adjustments to the regulations to avoid the appearance of anomalous behaviors, as they do not conform to the general regulatory characteristics.

A third application is its configuration as a tool of great potential for territory research. On the one hand, it allows comparative analysis of the areas obtained, but also of other factors, such as those dependent on human intervention, among which we can mention:

- The location of human population.
- The territorial communication channels.
- The popular and vernacular architecture of the territory
- The study of the needs according to the uses of the territory.

On the other hand, it allows investigating, through comparative analysis, the relationship with the conditions imposed by the characteristics of the territory. Thus, for example, this method opens doors to the study of:

- Geology of the territory; with the objective of having knowledge of materials of each defined area and its possible application in the construction framework, as well as conditions that the nature of land imposes, affecting directly the local microclimate.
- The orographic, topographic and morphological aspects, given conditions of variability between coast and high mountains, and between different altitudes.
- Hydrology, within this field of study, since it influences the degree of environmental humidity. The presence of water (surface or underground) may involve a sensitive variation of the strategies.
- The vegetation of the territory and its variation. The modifications that the vegetation incorporates into the local microclimate are determined by its size and type. Among them, the main ones will be the contribution of humidity, and a relative climatic smoothness, as well as the ability to provide shadows and wind protection.
- The incidence of wind in the territory. Variations of slope, or mountains aspect, and existing obstructions can alter

the parameters obtained in meteorological observatories. Factors that affect the changes of speed, direction and frequency of the prevailing winds affect the needs of ventilation, wind protection or the combination of both, necessary to achieve comfort.

- The incidence of solar radiation and the incidence values per month. It is possible to determine the collection capacity in the less favorable months and the need for its protection in the months that record maximum values.

DISCUSSION POINT 3: ABILITY TO EXTRAPOLATE THE METHODOLOGY USED TO OTHER TERRITORIES.

The last point of discussion raised asks whether the proposed methodology has the capacity to be extrapolated in order to be applied to another territory. Well, after the development of the investigation you can deduce its easy application to any territory, regardless of its extension.

For a correct use of this methodology it is, however, essential to be aware of its limitations. You have to keep in mind that:

- The first condition is to have sufficient meteorological observatories with the required data, with a homogeneous geographical distribution. The distant geographical arrangement between observatories may obviate some intermediate situations. The greater the number of observatories, the accuracy of the resulting cartography improves.
- When using climatic data that express monthly averages, extreme situations are not contemplated (these could be recorded, however, at the stage of data preparation). Information obtained as an acting instruction cannot be treated. The cartography thus obtained provides an idea of order and magnitude of the strategies in the geographical area of study, being able to differentiate the general behavior of various identified areas.
- The limits of the zones obtained, by constituting data clusters, may have a certain degree of inaccuracy. In case of doubt, a more in-depth analysis of the characteristics of the environment should be made.

They are aspects that are proposed to improve the progression of the research project that is the result of this work. In that sense, it is worth noting that, for public administrations of each territory, the cost of obtaining this data is minimal, since access to such information is generally available. These benefits are multiplied, in the case of territories where there is no specific regulation for energy efficiency or where there are no reference climates.

The cartography presented facilitates, finally, its potential application as a bioclimatic design manual, for which a final recommendation is worth. The process would begin with the location of the territory on the map. The information related to design strategies to be adopted is thus obtained directly to achieve comfort in each of the months of the year. Results obtained must be considered as an approximation to the real situation, so it must be the designer who establishes the design criteria and makes the decisions he deems appropriate, always taking into account the rest of the parameters (the territory, the object of the project, or the requirements of the use or of the developer itself).

CONCLUSIONS

The main contribution of the research carried out and exposed here is the methodology to elaborate a regional cartography, whose purpose is to apply bioclimatic strategies to achieve adequate levels of thermal comfort, following the bioclimatic chart of Givoni.

In the development of the work, the methodology in question has been validated through its application to a specific territory in Spain (the Autonomous Community of Galicia), as a result of obtaining a set of monthly maps, where necessary intervention strategies are established, under bioclimatic parameters, which must be adopted in order to achieve thermal comfort in buildings, in such territory and in such period.

The mapping produced in this way becomes a powerful tool for bioclimatic design in the studied territory. Consequently, the possibilities of developing bioclimatic architecture are evident. The tool, in effect, constitutes an open field full of possibilities to be inserted in the usual projection of architectural design systems. The development and application of these strategies contributes to achieving SDG, as well as all energy efficiency regulations, both in terms of reducing consumption and increasing the thermal optimization of buildings from their own design.

The systematics described here is likely to be applied to any territory deemed necessary, beyond the extent of it. With this, it is also possible to have a tool to increase knowledge of the mapped territory itself.

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