International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 7, Issue 9 Ser I (Sep 2018), PP. 25-50

Bioclimatic analysis based on the climate of Greece, in order to minimize energy consumption in buildings

Sofia Giannarou*, Michael Tsatiris**, Kyriaki Kitikidou ***
** Civil engineer, Msc., Candidate PhD , Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, 193 Pantazidou Street, 68 200, Orestiada, Greece*
*** Assistant Professor, Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, 193 Pantazidou Street, 68 200, Orestiada, Greece*
****Associate Professor, Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, 193 Pantazidou Street, 68 200, Orestiada, Greece*
Corresponding Author: Sofia Giannarou

ABSTRACT: *Bioclimatic Design aims to design buildings, based on the local microclimate of the area, by utilizing the energy of the sun and other sources of the environment, as well as the various natural phenomena of the climate. The result is a reduction in energy consumption in the building sector while at the same time providing thermal comfort to building users. In this study, bioclimatic analysis of regions of Greece with different climatic characteristics is performed. According to KENAK 2017, the Prefectures of Greece are classified in four different Climatic Zones A, B, C and D. The bioclimatic analysis is implemented by using the bioclimatic charts of the buildings that were first used by the brothers Victor & Aladar Olgyay. With the help of the required climatic data from the National Meteorological Service, the quantitative and qualitative bioclimatic charts of Victor & Aladar Olgyay are drawn for two Prefectures of each climate zone. From the analysis of the quantitative bioclimatic charts, the average values of the passive needs for solar radiation, shading, wind and humidity for each month and for each climate zone are calculated. The analysis of the qualitative bioclimatic charts, defines passive heating and cooling strategies. The charts of solar, radiant, wind and humidity needs per month are then plotted for each climate zone from which the regression lines are derived and the second degree polynomials equations. These equations serve to quickly calculate the passive thermal and cooling needs for each month and for each climate zone. The results can be used in areas with similar climatic conditions. This study, therefore, can be a guide for building designers. Depending on the climatic zone of each building, they will be aware of the passive heating and cooling strategies they have to implement in order to ensure thermal comfort conditions for the occupants of the buildings.*
KEYWORDS: *bioclimatic chart analysis, passive solar heating, passive cooling, thermal comfort, climate.*

Date of Submission: 24-01-2019 Date of acceptance: 08-02-2019

I. INTRODUCTION

Buildings of households and services, consume large amounts of energy, accounting for about 40% of the total energy that is consumed in Europe, with increasing trends, resulting in large amounts of carbon dioxide emissions [1].

Gorz (1980) had aptly predicted that, the end of our world is coming and if we continue as before, the oceans and the rivers will dry up, the ground will become barren, the air will become unbreathable in the cities, and life will be a privilege for the selected samples of a new race of humans, adapted to the chemical conditions and genetic planning to survive in a new ecological reality, engraved and supported by biologic engineering [2].

Brundtland (1987) on behalf of the World Commission on Environment and Development in a report presented at a meeting in Rio in 1992 introduced the concept of Sustainable Development, which aims to meet the needs of today's generations in a way that does not compromise the ability of generations of the future to meet their own needs [3]. Expanding the above definition in the building sector, the concept of a sustainable or otherwise a building is emerging to cover the needs of today's users, without compromising the future generations to satisfy their own needs [4].

Euthymiopoulos (2017), also refers to the danger of the butterflies disappearing, as during their migratory journey in warmer climates, the change of the climate and the cold and strong rains kill them, at the end of his book writes that, if the butterflies are in danger, the human species may be in danger as well. The society of people, however, is the only one with knowledge and sensitivity to prevent the worst scenario. The butterflies, unfortunately, cannot [5].

So people need to take drastic measures to protect the environment and therefore all living organisms. In the building sector, the over-consumption of energy and the unfavorable environmental impacts have occupied and continue to occupy the building professionals, on a global scale [6]. Thus, in the architectural design of buildings, they follow the principles of bioclimatic architecture. The main objective is to provide thermal comfort inside the buildings and to minimize the additional energy required for heating and cooling [7, 8]. This can be achieved by taking advantage of the favorable climatic conditions prevailing in each area and adapting the architectural design to the prevailing environmental conditions [9].

The term Bioclimatic design of buildings, means the architectural and urban design of buildings and residential complexes which aims at adapting them to the local climate conditions and the natural environment and aims at utilizing the desired environmental parameters in order to minimize their energy needs throughout the year and to reduce the consumption of conventional energy [10].

II. A BRIEF REVIEW OF BIOCLIMATIC CHART ANALYSIS

Since antiquity, people have tried to adapt their homes to climatic conditions, looking for the appropriate building shell to provide them with comfort. The Greek philosopher Socrates, in 400 BC, referred to the ways in which buildings in Athens were constructed, both in shape and in the form they were supposed to have, in order to ensure thermal comfort conditions by exploiting the external climatic conditions, the sun and the wind [11]. This is the "Socratic House" [12]. Then, Vitruvius, in the 1st century BC in his book VI, gave guidelines for designing buildings in areas with different climatic conditions and ensuring health and comfort for people [13].

Later, in the industrial revolution (1760-1860), emphasis was placed on the “form-function” concept of the buildings, while the guarantee of thermal comfort was achieved by the massive use of auxiliary heating and cooling appliances consuming conventional forms of energy and resulting in energy crisis [14].

Heberden (1826), was concerned with the feeling of thermal comfort and said it was not only dependent on air temperature but also on other factors such as humidity and air movement, radiant heat load and occupants clothing [15]. Haldane (1905), later in England, made the first serious study of thermal comfort and referred mainly to the effect of high temperatures [16]. Houghten and Yagloglou (1923), at the ASHVE research laboratories at Pittsburg (American Society of Heating and Ventilating Engineers), set up the comfort zone and drew the comfort lines on the ASHRAE chart [17, 18].

Afterword, the brothers Victor and Aladar Olgyay, from the beginning of the 1950s founded bioclimatic architecture as a science. They created bioclimatic charts and linked the zone of thermal comfort of people with the meteorological data of the region, such as temperature, humidity and air velocity, solar radiation, mean radiant heat and evaporation cooling [19, 20]. They created the quantitative and the qualitative bioclimatic chart for the climate conditions of the United States and people with light clothing and limited activity at an altitude of less than 305m above sea level and 40° latitude [21].

In the 1980s, people became aware of the environmental disaster, so emphasis was placed on the concept of sustainability and the design of bioclimatic buildings [22].

III. THE CONCEPT OF THERMAL COMFORT

The concept of thermal comfort is used to determine the conditions that must prevail in a particular thermal environment so that the person does not feel too hot or too cold [23].

The definition of thermal comfort can be approached in three different ways [24]:

1. the psychological definition,
2. the thermo physiological definition and
3. the energetic definition

The international standard ISO7730 refers to the definition of the psychological approach to thermal comfort "thermal comfort is defined as a condition of the mind which expresses satisfaction with the thermal environment", which is the sense of satisfaction that people feel during their station in a particular thermal environment [25]. In the American standard ASHRAE 55 (American Society of Heating, Refrigeration and Air Conditioning Engineers), thermal comfort is defined as "that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation". So, in the definition of the sense of satisfaction of the mind in the thermal environment, the concept of subjectivity is added. This is because people are different from each other, both physiologically and psychologically, and the environmental conditions required to ensure thermal comfort are not the same for everyone [26].

Also, according to ASHRAE 55, the factors that affect the feeling of thermal comfort of living organisms are as follows [26]:

1. the metabolic rate,
2. the clothing,
3. the air temperature,
4. the radiation,
5. the speed of the air,
6. the humidity

The thermo physiological approach to thermal comfort suggests that a person's thermal perception is due to the sensitivity of the nerve ends to temperature or temperature change. The nerves are on the skin and reach to the hypothalamus of the brain [27].

Finally, according to the latter type of approach, thermal comfort is related to providing a thermal balance between inputs and outputs of heat to the human body so that body temperature and sweat levels are within the tolerable limits, depending on the metabolic activity [28]. Under normal conditions, the feeling of thermal comfort is the result of proper body function, i.e. a body temperature of 37°C and a skin temperature of 31-34°C [29].

According to the European Standard EN15251, "An energy declaration without a declaration related to the indoor environment makes no sense". Therefore, the indoor environment of buildings (temperature, ventilation and lighting), which is directly related to the health, productivity and comfort of the occupants, determines the measures to be taken in the design of energy-efficient buildings. There is therefore a need to identify all the criteria that determine the good quality of the indoor environment and the thermal comfort conditions when designing buildings with reduced energy consumption [30]. Thus, the thermal comfort requirements inside a building play a key role in designing it [23].

Therefore, securing inside buildings, thermal comfort conditions, has a beneficial effect on the health and well-being of people. That is why it should not be considered as a luxury and privilege of a limited population, but a right of all [31].

IV. THE CLIMATE OF GREECE

Climate is defined as the average of weather conditions, i.e. rainfall, temperature, humidity, sunshine, wind speed, and other weather measurements in an area, over a specific period of time, usually 30 years [32]. The climate of a place depends on geographic location, height above sea level, topography and flora [33].

Greece is located in the southern part of Europe, between the 34th and 42nd parallel of the northern hemisphere, drenched from the Mediterranean Sea. It is characterized by a particularly intense topographic relief, with great altitude differences as there are several mountainous volumes. Also, a large part of the country is bordered by the sea. As a result, the climate is different from place to place [34].

According to the Köppen-Geiger classification system, Greece, for the most part of its surface, has "Warm Mediterranean Climate" [35].

Consequently, according to the National Meteorological Service (HNM), in the largest part of Greek land, the climate can be classified as Mediterranean, i.e. mild winters with rains and snow at the higher altitudes and summers relatively hot and with rare rainfall. Two seasons are distinguished during the year [34]:

• Winter, which lasts from mid-October to the end of March and is characterized by cold and rainy weather, and

• Summer, which lasts from April to mid-October and is characterized by heat and drought.

Greece is also a country that sun is shining almost throughout the year [34]. In the summers, on warm and dry days, there are cool winds called "meltemia". In the mountainous parts of the country the climate is cold. The winters in the lowlands do not experience particularly low temperatures and snow, while in the mountains usually snow [36].

Given that the climatic conditions, play a key role in minimizing conventional energy used for heating, cooling, air conditioning, lighting and hot water production in buildings, and taking into account the different climatic conditions prevailing in the various regions of Greece, at KENAK 2017, which is the current legislative framework for the design of energy-efficient buildings, Greece is subdivided, in the four climatic zones of Table 1 The schematic representation of the climatic zones in the Greek map is given in Fig. 1 [37].

Climatic Zones	Prefectures
Zone A	Heraklion, Chania, Rethymnon, Lasithi, Cyclades, Dodecanese, Samos, Messinia, Laconia, Argolida, Zakynthos, Kefallinia and Ithaca, Kithira and the Saronic Islands (Attica), Arcadia.
Zone B	Attica (excluding Kithira and Saronic islands), Korinthia, Ileia, Achaia, Aitoloakarnania, Fthiotida, Fokida, Viotia, Evia, Magnisia, Lesvos, Chios, Corfu, Lefkada, Thesprotia, Preveza, Arta.
Zone C	Arcadia (mountainous), Evritania, Ioannina, Larissa, Karditsa, Trikala, Pieria, Imathia, Pella, Thessaloniki, Kilkis, Khalkidhiki, Serres (except BA), Kavalla, Xanthi, Rodopi, Evros.
Zone D	Grevena, Kozani, Kastoria, Florina, Serres (NE section), Drama.

Table 1. Integration of the Prefectures of Greece into the climatic zones.
[Source: Energy Performance Regulation of Buildings (KENAK 2017) [37]].

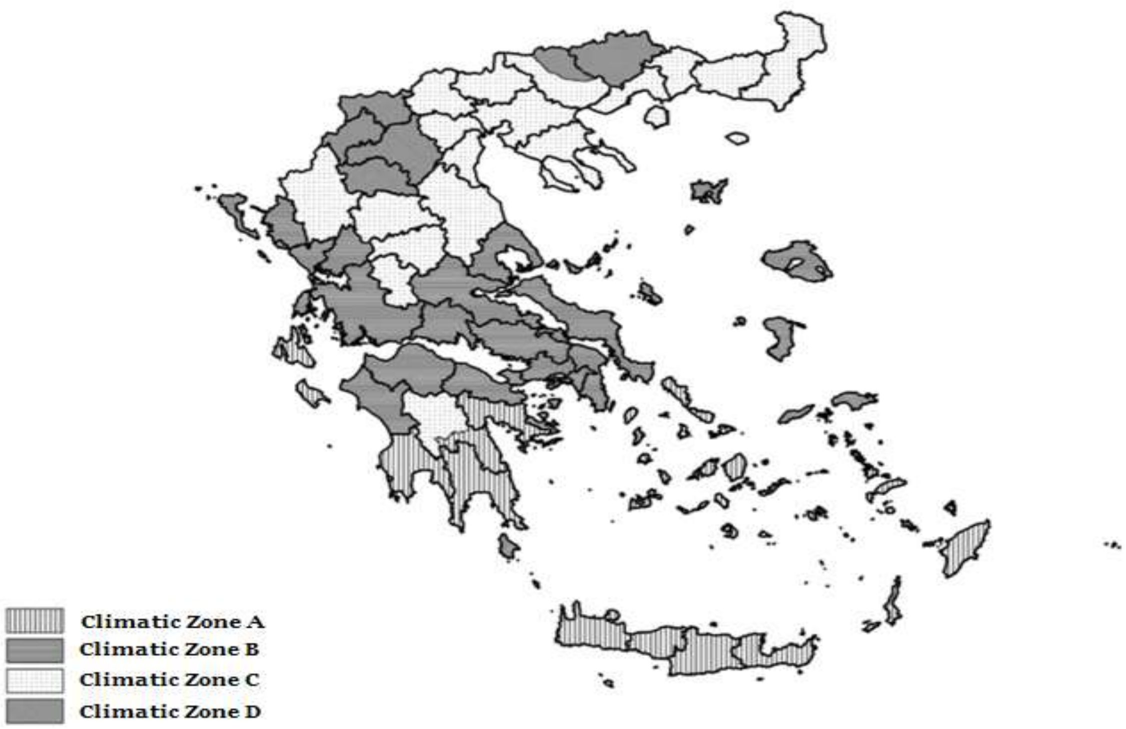

Fig. 1. Map of Greece with climate zones
[Source: Energy Performance Regulation of Buildings (KENAK 2017) [37]]

V. THE OLGYAY BIOCLIMATIC CHARTS

In the present study, the bioclimatic analysis is carried out by applying the method of the Olgyay brothers.

Bioclimatic charts or otherwise bioclimatic diagrams aim at correlating the local climatic conditions prevailing in each area with the feeling of thermal comfort of the occupants. They are presented in a psychometric diagram, where temperature and humidity are combined at every moment with human comfort. Thus, building design guidelines are defined to maximize comfort inside without the use of mechanical means. In all these charts, the 'comfort zone' is defined which is the range of climatic conditions in which the majority of people feel thermal comfort [38].

The bioclimatic charts of the Olgyay brothers were redesigned and adapted to the climatic conditions of Cyprus by Katafygiotou and Serghides (2014), so they apply to regions of the temperate north zone, where there is little difference between indoor and outdoor climatic conditions, for light clothing and sedative activity [19, 20], [39]. Similar climatic conditions prevail in Greece.

Other assumptions made for the design of bioclimatic maps are as follows:

- Heat transfer to the body of people is affected by clothing. For this reason, the thermal resistance of clothes was determined in clo units. The thermal resistance of a clo ($0,155 m^2K/W$) corresponds to suit clothing [29]. In the bioclimatic analysis, thermal resistance of clothes was considered 0.4 clo for

summer clothing and 0.8 clo for winter clothing [26, 40]
- The values of solar radiation in the bioclimatic diagram were determined for the mean altitude of the sun 52°. The data came from the Cyprus Meteorological Service [20].

VI. CLIMATIC PARAMETERS FOR THE CLIMATIC ZONES A, B, C AND D

According to Table 1 the climatic parameters of the following regions per climatic zone are sought:
Zone A: Messinia and Heraklion,
Zone B: Ileia and Aitoloakarnania,
Zone C: Evros and Larissa,
Zone D: Drama and Kastoria.

These prefectures represent all the others of each zone, as they are characterized by similar climatic conditions [37, 41]. The measurements of the Hellenic National Meteorological Service (HNMC) were used [42]. The averages of the mean maximum and minimum monthly temperatures in °C, as well as the mean maximum and minimum monthly relative humidity values in %, were calculated (Table 2).

- Climatic Zone A

For the prefecture of Messinia, the measurements of the meteorological station in Kalamata with latitude 37° 04', longitude 22° 00', and altitude 11.1m were used [41].

For the prefecture of Heraklion, the measurements of the meteorological station in the area of Timbaki with latitude 35° 00', longitude 24° 46', and altitude of 6.7m and the measurements of the meteorological station in the area of Heraklion with latitude 35° 20', longitude 25° 11', and altitude 39.3m were used [41].

- Climatic Zone B

For the prefecture of Ileia, the measurements of the meteorological station in Andravida with latitude 37° 55', longitude 21° 17', and altitude 15.1m were used [41].

For the prefecture of Aitoloakarnania the measurements of the meteorological station in the area of Agrinio with latitude 38° 37', longitude 21° 23', and altitude 25.0m were used [41].

- Climate Zone C

For the Prefecture of Evros, the measurements of the meteorological station in Alexandroupolis with latitude 40° 51', longitude 25° 56', and altitude 3.5m were used.
For the prefecture of Larissa, the measurements of the meteorological station in the city of Larissa with latitude 39° 39', longitude 22° 27', and altitude 73.6m [41].

- Climate Zone D.

For the Prefecture of Drama, the measurements of the meteorological station in Drama with latitude 41° 09', longitude 24° 09', and altitude 104.0m and for the meteorological station in Doxato, with latitude 41° 09', longitude 24° 23', and altitude 100.0m [41].
For the prefecture of Kastoria, the measurements of the meteorological station in Kastoria with latitude 40° 27', longitude 21° 17' and altitude 660.9 m [41].

VII. BIOCLIMATIC CHART ANALYSIS IN A, B, C AND D CLIMATIC ZONES

The values of the monthly average temperature in °C and the corresponding values of the mean monthly relative humidity in % (Table 2), are identified in a x/y-coordinate system with relative humidity (RH) in % as x-axis and the dry bulb temperature (T) at °C as y-axis [38, 43].
These are the quantitative and the qualitative bioclimatic charts where the following points are highlighted:
- Point 1: Maximum monthly relative humidity with minimum monthly air temperature.
- Point 2: Minimum monthly relative humidity with maximum monthly air temperature.

The line formed by the union of the two-points is the mapping of the external conditions for each month. Each month, is imprinted in a different color (Table 3).

Month			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Climatic Zone A														
Prefecture of Messinia														
Point 1	max RH(%)	X1	91,9	91,9	92,2	92,3	91,1	88,7	86,4	84,8	88,3	91,0	91,5	91,5
	min T(°C)	Y1	5,4	6,2	7,0	9,1	12,5	16,6	19,0	19,6	17,2	13,3	10,0	6,4
Point 2	min RH(%)	X2	54,3	51,1	48,3	43,4	40,1	37,5	34,4	33,3	39,9	46,9	51,2	53,3
	max T(°C)	Y2	15,1	16,0	17,8	21,3	25,2	29,5	32,3	32,9	29,3	24,6	20,8	16,8
Prefecture of Heraklion														
Point 1	max RH(%)	X1	89,2	88,6	88,9	87,1	86,0	83,1	78,3	75,1	82,6	84,8	86,8	87,4
	min T(°C)	Y1	9,1	9,3	9,7	12,1	15,3	19,2	22,1	22,2	20,0	17,6	14,5	11,1
Point 2	min RH(%)	X2	53,3	50,9	50,4	45,4	45,4	46,5	42,9	42,2	45,0	52,6	55,9	56,7
	max T(°C)	Y2	15,9	16,7	17,9	21,1	24,4	28,0	31,0	31,3	28,7	24,4	21,3	17,2
Climatic Zone B														
Prefecture of Ileia														
Point 1	max RH(%)	X1	90,0	89,3	90,6	90,4	89,0	89,4	87,1	85,9	88,0	90,1	90,5	90,1
	min T(°C)	Y1	6,0	6,5	7,4	10,1	13,5	17,1	19,6	19,8	17,8	13,7	10,2	6,9
Point 2	min RH(%)	X2	55,7	53,2	51,1	46,6	41,6	39,7	39,5	35,2	41,2	49,0	53,0	54,7
	max T(°C)	Y2	14,3	15,1	17,0	20,6	24,6	28,6	31,3	32,3	28,6	23,8	19,9	15,8
Prefecture of Ileia														
Point 1	max RH(%)	X1	92,1	90,7	92,1	93,1	88,0	79,8	76,7	76,2	86,0	91,8	88,0	95,9
	min T(°C)	Y1	3,0	4,6	5,9	8,2	12,0	16,4	19,1	18,7	15,9	11,9	7,7	4,7
Point 2	min RH(%)	X2	55,0	60,2	53,8	57,9	41,8	34,5	29,8	27,8	33,8	50,2	52,6	62,4
	max T(°C)	Y2	13,7	14,4	18,7	21,2	25,6	32,3	35,8	35,9	31,9	24,0	20,3	15,0
Climatic Zone C														
Prefecture of Evros														
Point 1	max RH(%)	X1	91,7	90,0	90,1	88,9	88,3	85,3	76,6	76,8	83,9	89,3	90,3	89,8
	min T(°C)	Y1	1,5	3,6	5,2	8,2	12,8	17,3	20,1	20,5	16,3	10,9	7,5	3,5
Point 2	min RH(%)	X2	64,0	59,7	55,0	48,4	45,4	42,5	34,4	32,7	39,9	52,4	60,2	61,7
	max T(°C)	Y2	8,9	11,2	13,7	18,6	24,1	28,4	32,3	32,9	27,6	20,9	16,2	11,4
Prefecture of Larissa														
Point 1	max RH(%)	X1	94,8	94,9	94,9	93,6	91,1	83,5	74,8	76,7	87,6	92,7	96,7	96,2
	min T(°C)	Y1	0,9	2,9	4,4	7,6	12,2	16,9	19,6	19,3	15,8	10,9	6,3	1,9
Point 2	min RH(%)	X2	58,7	53,1	47,5	39,1	31,3	26,5	24,7	26,4	34,0	44,7	55,6	57,9
	max T(°C)	Y2	10,3	13,1	16,1	21,2	26,8	31,3	34,4	34,0	29,2	22,3	17,2	11,8
Climatic Zone D														
Prefecture of Drama														
Point 1	max RH(%)	X1	96,6	96,1	95,6	95,2	94,4	94,9	90,8	90,3	94,7	96,1	96,9	96,9
	min T(°C)	Y1	1,8	2,9	5,5	9,0	14,0	18,2	20,4	20,3	16,0	11,3	6,8	2,5
Point 2	min RH(%)	X2	32,3	27,9	24,6	22,6	24,8	24,1	23,4	24,4	25,8	29,0	32,9	33,1
	max T(°C)	Y2	9,3	11,8	15,5	20,1	25,7	30,0	32,5	32,7	27,7	21,4	15,6	9,9

Prefecture of Kastoria														
Point 1	max RH(%)	X1	99,8	99,3	99,3	98,3	98,1	95,4	94,9	94,6	98,2	99,2	99,7	99,6
	min T(°C)	Y1	-2,0	-1,0	1,7	5,1	9,2	12,8	15,1	14,8	11,2	7,3	3,0	-0,9
Point 2	min RH(%)	X2	35,3	23,8	15,8	18,4	21,8	20,3	16,2	17,2	22,1	25,9	31,1	33,7
	max T(°C)	Y2	6,7	9,2	13,4	17,8	22,7	27,7	30,8	30,8	25,1	19,2	13,6	8,1

Table 2. Mean maximum and minimum monthly temperature in °C and mean maximum and minimum relative humidity in % for A, B, C, D climate zones of Greece.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Table 3. Color display of months in qualitative and quantitative Bioclimatic Charts [46].

- Climatic Zone A

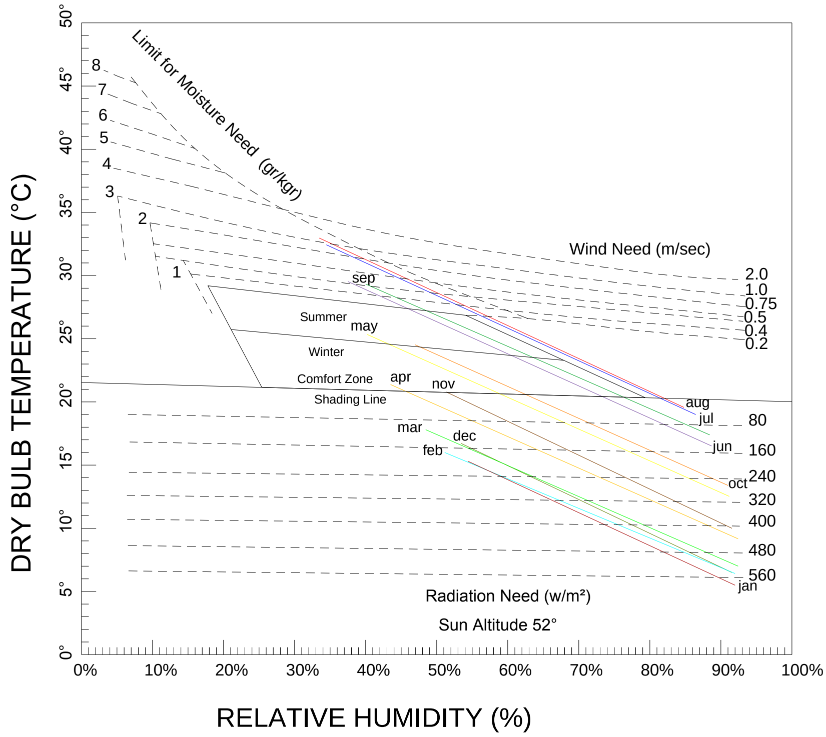

Fig. 2. Quantitative Bioclimatic chart of Messinia. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

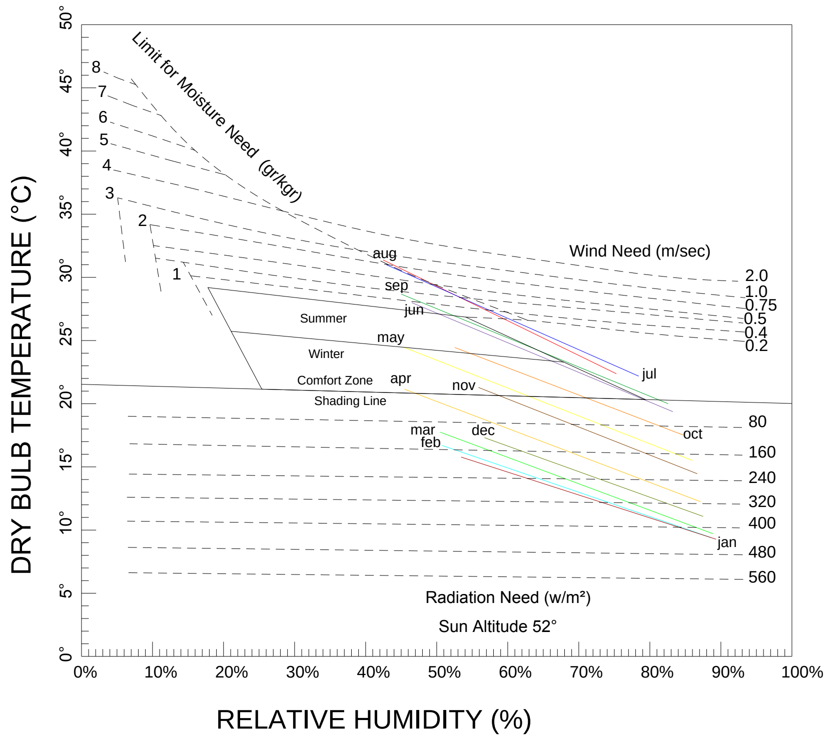

Fig. 3. Quantitative Bioclimatic chart of Heraklion. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

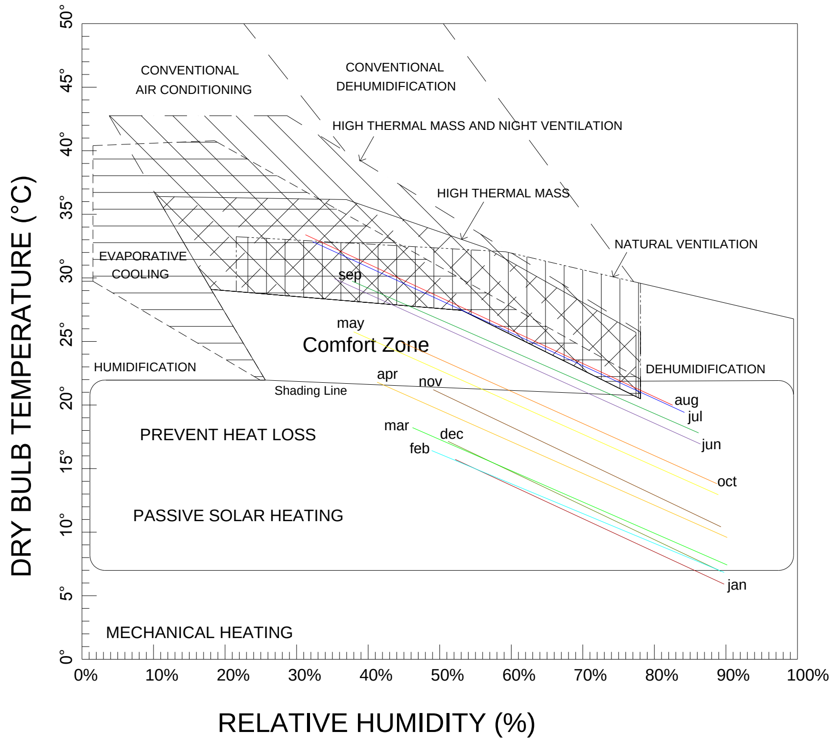

Fig. 4. Qualitative Bioclimatic chart of Messinia. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

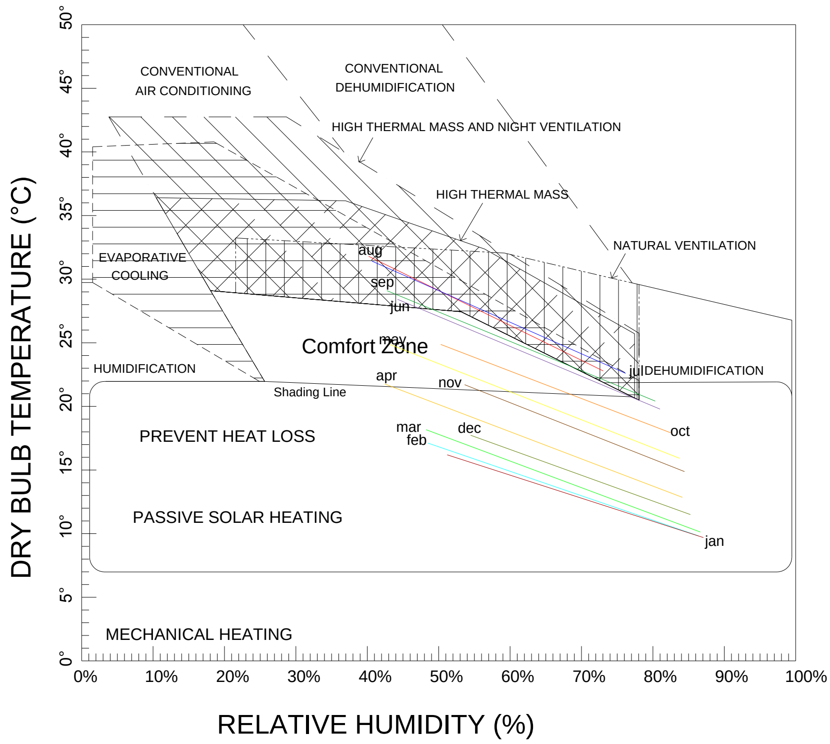

Fig. 5. Qualitative Bioclimatic chart of Heraklion. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

Month	Radiation needs (W/m^2)			Shading needs (%)			Wind needs (m/sec)			Moisture needs (gr/Kgr)		
	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**
Jan	560	440	**500**	0	0	0	0	0	0	0	0	0
Feb	550	430	**490**	0	0	0	0	0	0	0	0	0
Mar	520	420	**470**	0	0	0	0	0	0	0	0	0
Apr	440	320	**380**	0	0	0	0	0	0	0	0	0
May	300	180	**240**	37	43	**40**	0	0	0	0	0	0
Jun	140	40	**90**	70	89	**79,5**	0,5	0,4	**0,45**	1,0	0,5	**0,75**
Jul	50	0	**25**	90	100	**95**	1,0	0,85	**0,93**	3,0	2,5	**2,75**
Aug	30	0	**15**	95	100	**97,5**	1,2	0,85	**1,03**	3,2	2,5	**2,85**
Sept	110	10	**60**	69	97	**83**	0,5	0,5	**0,50**	1,0	1,0	**1,00**
Oct	260	100	**180**	35	58	**46,5**	0	0	0	0	0	0
Nov	410	220	**315**	0	0	0	0	0	0	0	0	0
Dec	550	360	**455**	0	0	0	0	0	0	0	0	0

Table 4. Recording of maximum passive needs, derived from the analysis of quantitative bioclimatic charts of Messinia and Heraklion. Exporting medium term for Climate Zone A.

- Climatic Zone B

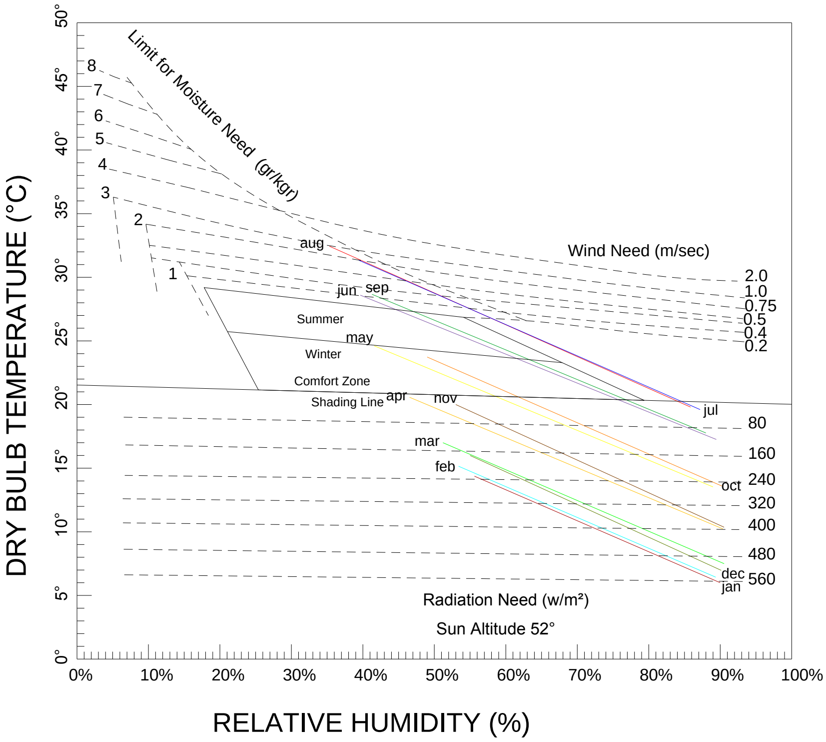

Fig. 6. Quantitative Bioclimatic chart of Ileia. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

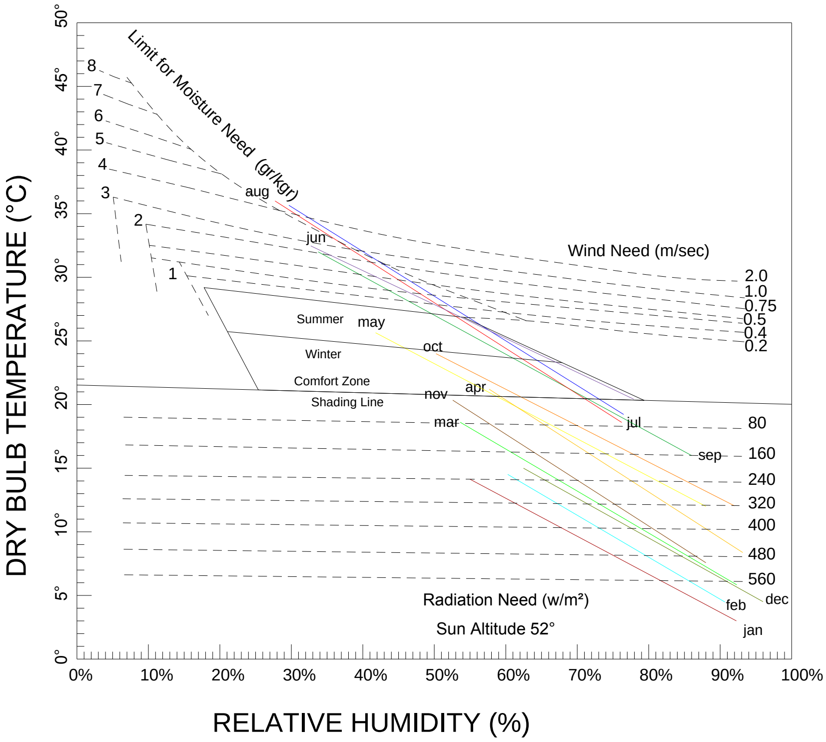

Fig. 7. Quantitative Bioclimatic chart of Aitoloakarnania. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

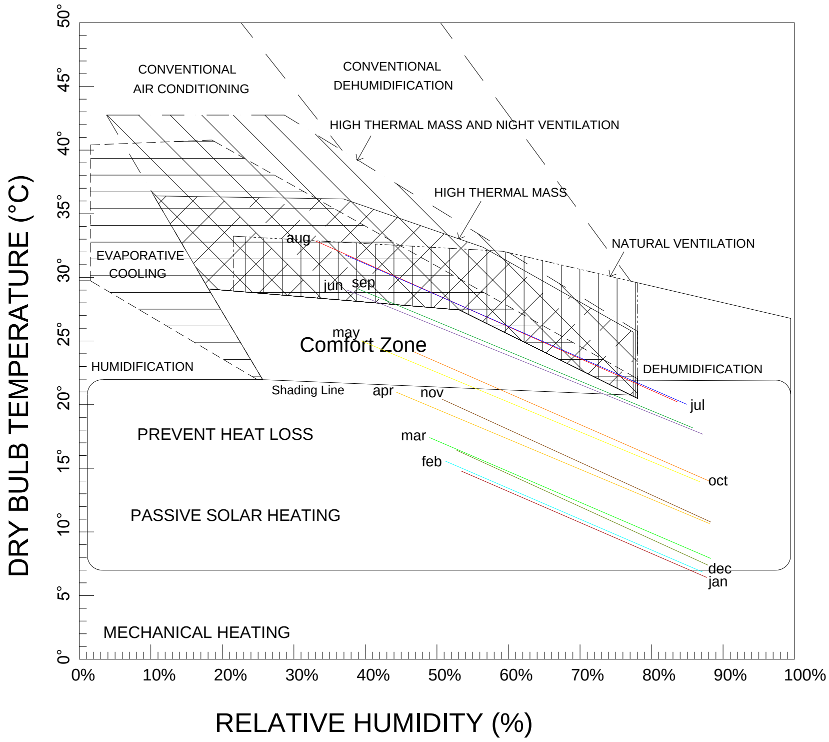

Fig. 8. Qualitative Bioclimatic chart of Ileia. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

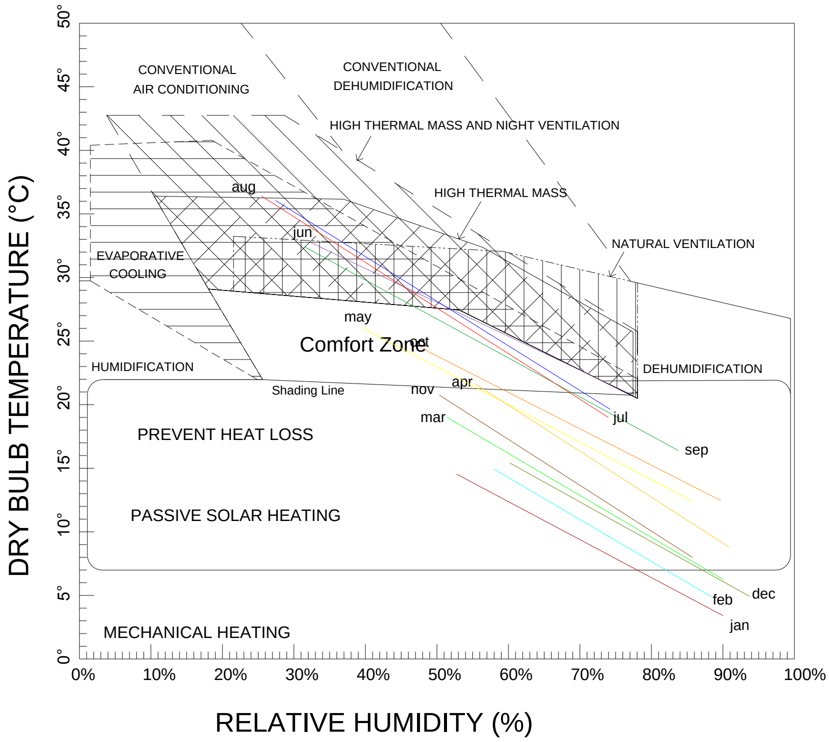

Fig. 9. Qualitative Bioclimatic chart of Aitoloakarnania. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

Month	Radiation needs (W/m^2)			Shading needs (%)			Wind needs (m/sec)			Moisture needs (gr/Kgr)		
	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**
Jan	560	560	**560**	0	0	0	0	0	0	0	0	0
Feb	550	560	**555**	0	0	0	0	0	0	0	0	0
Mar	500	560	**530**	0	0	0	0	0	0	0	0	0
Apr	400	480	**440**	0	0	0	0	0	0	0	0	0
May	260	320	**290**	36	37	**36,5**	0	0	0	0	0	0
Jun	120	0	**60**	72	100	**86**	0,4	1,0	**0,7**	0,5	3,0	**1,75**
Jul	30	40	**35**	95	93	**94**	0,75	2,0	**1,38**	2,0	4,0	**3**
Aug	20	70	**45**	96	89	**92,5**	1,0	2,0	**1,5**	3,0	4,0	**3,5**
Sept	100	160	**130**	76	72	**74**	0,4	0,75	**0,58**	0,5	2,0	**1,25**
Oct	250	320	**285**	31	28	**29,5**	0	0	0	0	0	0
Nov	400	500	**450**	0	0	0	0	0	0	0	0	0
Dec	530	560	**545**	0	0	0	0	0	0	0	0	0

Table 5. Recording of maximum passive needs, derived from the analysis of quantitative bioclimatic charts of Ileia and Aitoloakarnania. Exporting medium term for Climate Zone B.

- Climatic Zone C

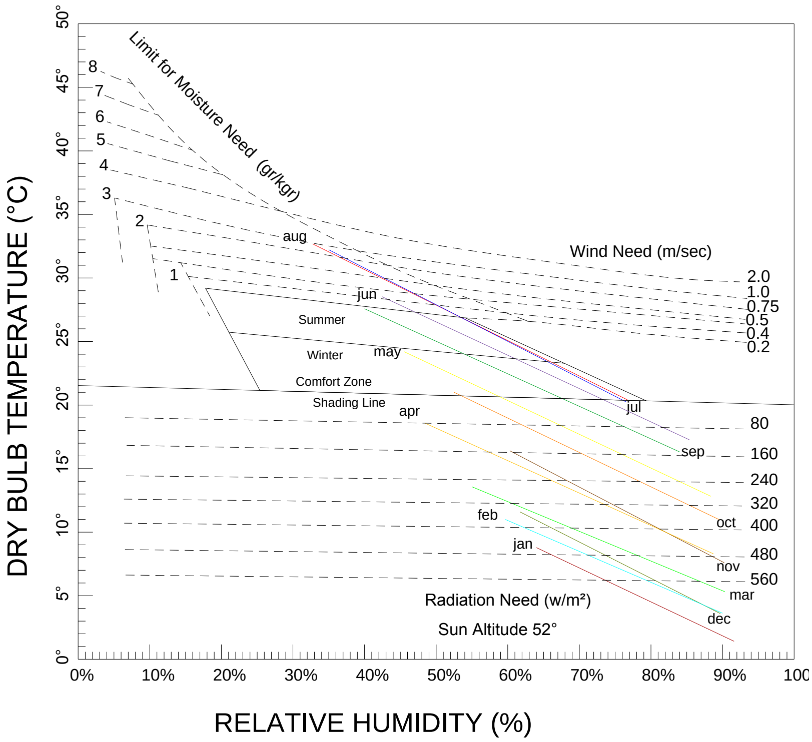

Fig. 10. Quantitative Bioclimatic chart of Evros. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

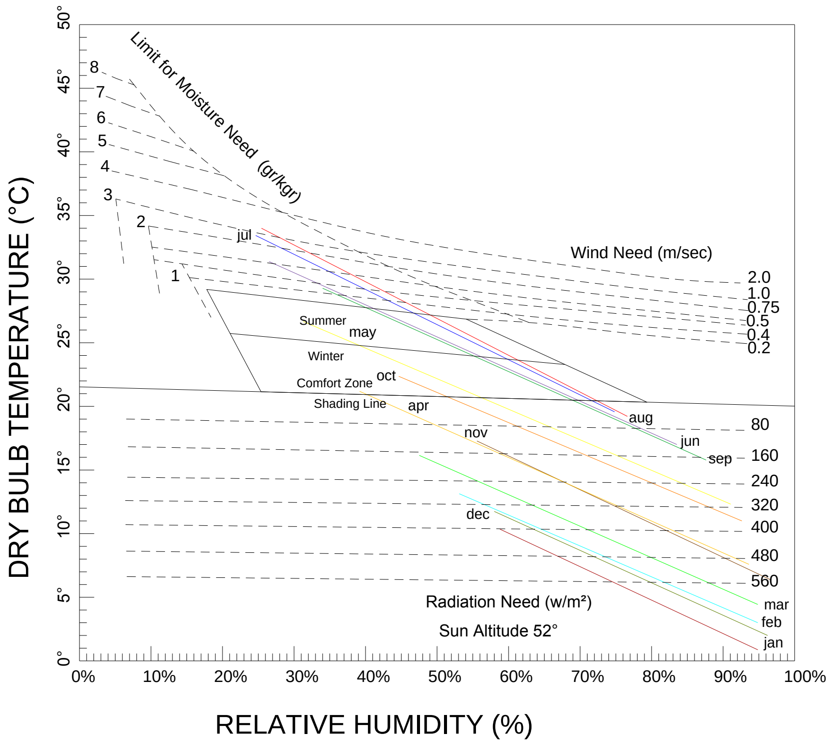

Fig. 11. Quantitative Bioclimatic chart of Larissa. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

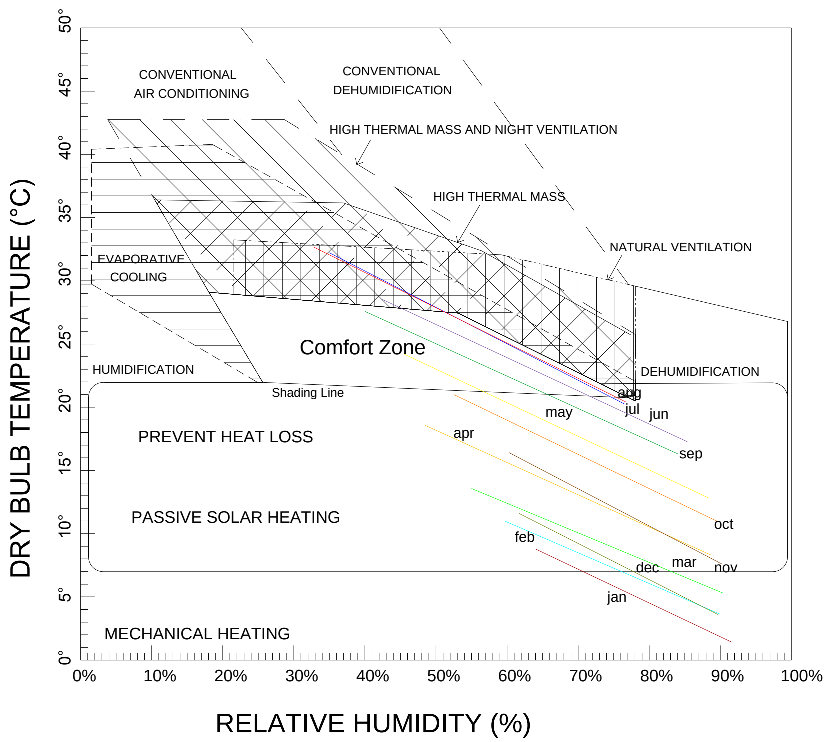

Fig. 12. Qualitative Bioclimatic chart of Evros. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

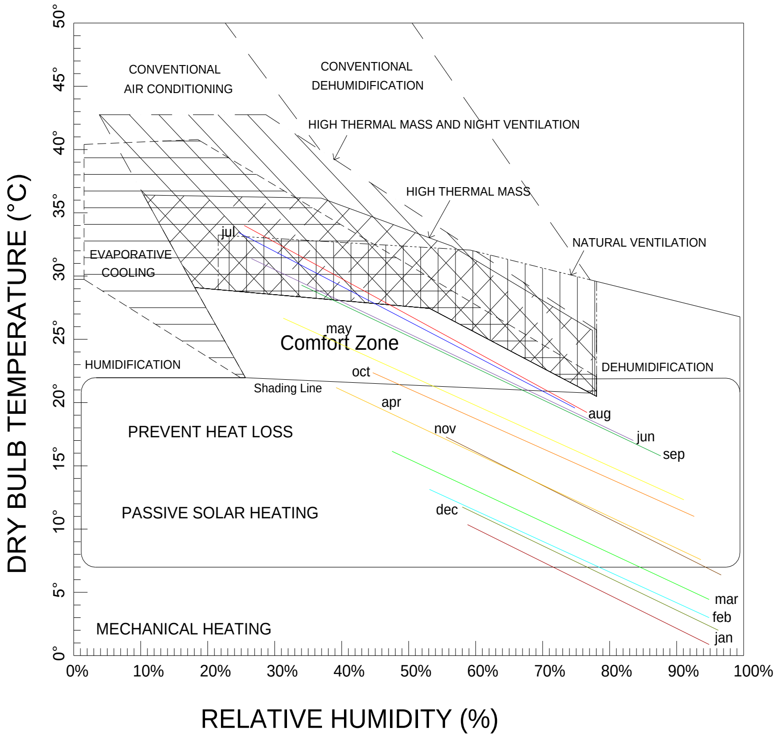

Fig. 13. Qualitative Bioclimatic chart of Larissa. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

Month	**Radiation needs (W/m²)**			**Shading needs (%)**			**Wind needs (m/sec)**			**Moisture needs (gr/Kgr)**		
	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**
Jan	560	560	**560**	0	0	0	0	0	0	0	0	0
Feb	560	560	**560**	0	0	0	0	0	0	0	0	0
Mar	560	560	**560**	0	0	0	0	0	0	0	0	0
Apr	480	500	**490**	0	0	0	0	0	0	0	0	0
May	300	320	**310**	31	41	**36**	0	0	0	0	0	0
Jun	130	120	**125**	72	76	**74**	0,4	0,5	**0,45**	0,5	1,5	**1,0**
Jul	0	40	**20**	100	94	**97**	0,9	1,0	**0,95**	2,5	3,0	**2,75**
Aug	0	60	**30**	100	92	**96**	1,0	1,2	**1,1**	3,0	3,2	**3,1**
Sept	150	170	**160**	63	65	**64**	0	0,45	**0,23**	0	0,7	**0,35**
Oct	380	360	**370**	0	14	**7**	0	0	0	0	0	0
Nov	500	560	**530**	0	0	0	0	0	0	0	0	0
Dec	560	560	**560**	0	0	0	0	0	0	0	0	0

Table 6. Recording of maximum passive needs, derived from the analysis of quantitative bioclimatic charts of Evros and Larissa. Exporting medium term for Climate Zone C.

- Climatic Zone D

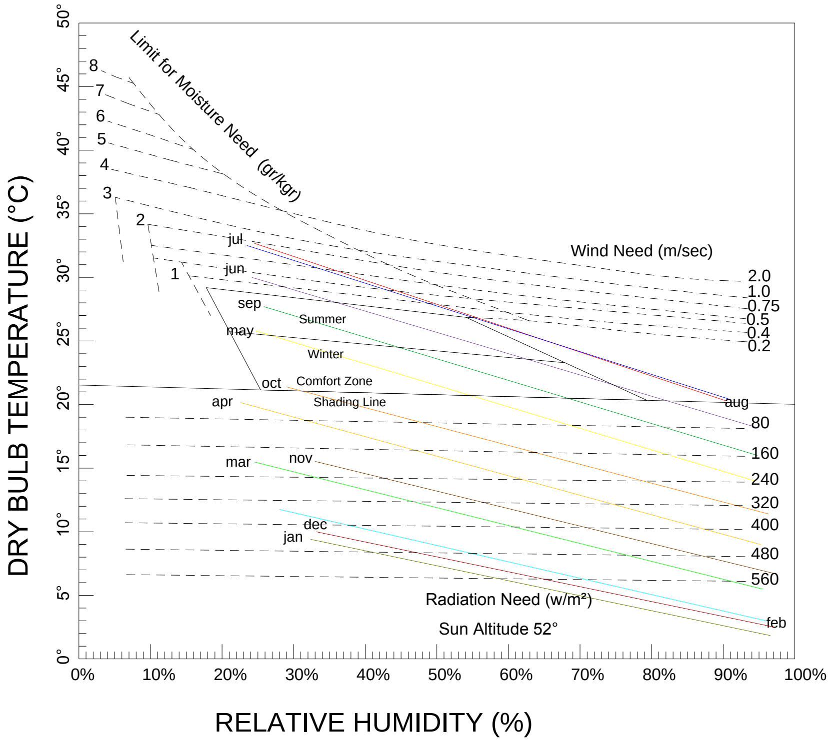

Fig. 14. Quantitative Bioclimatic chart of Drama. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

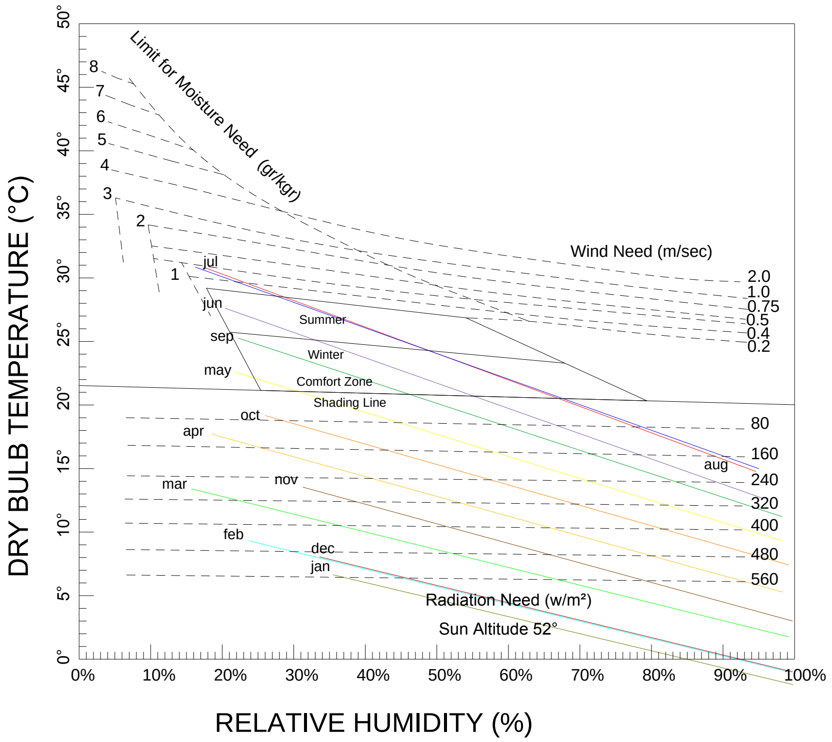

Fig. 15. Quantitative Bioclimatic chart of Kastoria. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

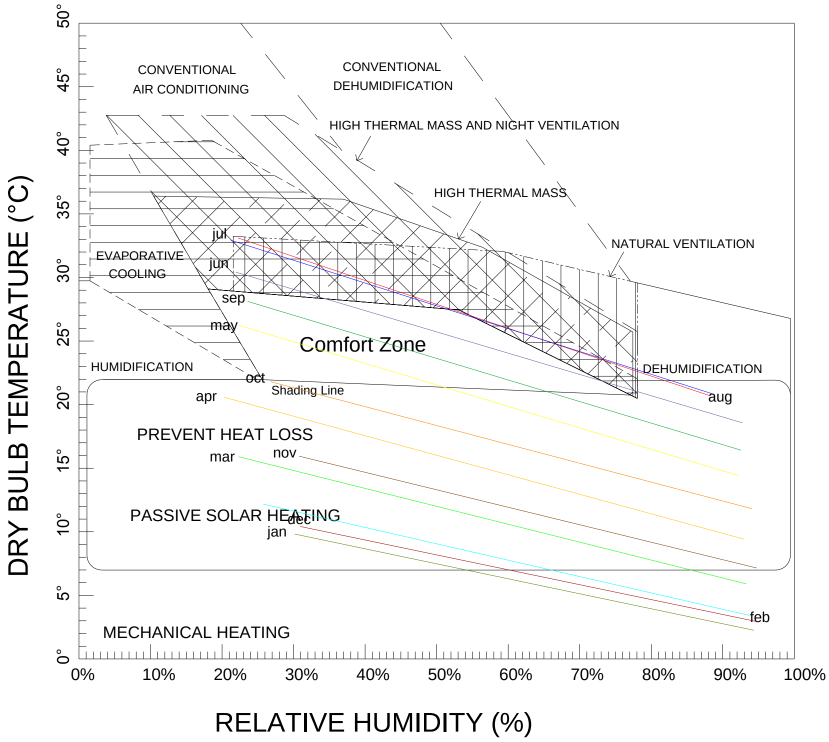

Fig. 16. Qualitative Bioclimatic chart of Drama. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

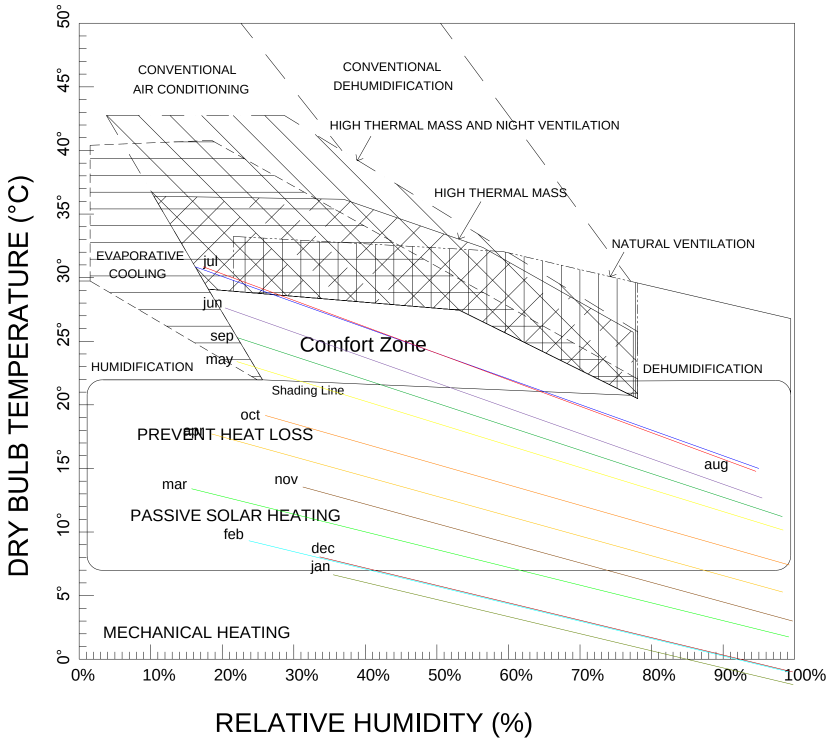

Fig. 17. Qualitative Bioclimatic chart of Kastoria. Adapted to temperate climatic conditions, redrawn by the authors [19, 20].

Month	Radiation needs (W/m^2)			Shading needs (%)			Wind needs (m/sec)			Moisture needs (gr/Kgr)		
	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**	(1)	(2)	**M.O.**
Jan	560	560	**560**	0	0	0	0	0	0	0	0	0
Feb	560	560	**560**	0	0	0	0	0	0	0	0	0
Mar	560	560	**560**	0	0	0	0	0	0	0	0	0
Apr	440	500	**470**	0	0	0	0	0	0	0	0	0
May	240	440	**340**	43	11	**27**	0	0	0	0	0	0
Jun	80	300	**190**	82	46	**64**	0,5	0	**0,25**	1,0	0	**0,5**
Jul	0	200	**100**	100	65	**82,5**	0,75	0,5	**0,63**	2,0	1,0	**1,5**
Aug	0	200	**100**	100	64	**82**	0,75	0,5	**0,63**	2,0	1,0	**1,5**
Sept	160	340	**250**	62	32	**47**	0	0	**0**	0	0	**0**
Oct	340	500	**420**	0	0	**0**	0	0	0	0	0	0
Nov	540	560	**550**	0	0	0	0	0	0	0	0	0
Dec	560	560	**560**	0	0	0	0	0	0	0	0	0

Table 7. Recording of maximum passive needs, derived from the analysis of quantitative bioclimatic charts of Drama and Kastoria. Exporting medium term for Climate Zone D.

The result from the analysis of the bioclimatic charts for the 4 climatic zones of Greece A (Fig2, Fig3, Fig4, Fig5) B (Fig6, Fig7, Fig8, Fig9) C (Fig10, Fig11, Fig12, Fig13) and D (Fig14, Fig15, Fig16, Fig17) are presented in the tables (Table4, Table5, Table6, Table7).

- Climatic Zone A

Analyzing the bioclimatic charts shows that in the prefectures of Messinia and Heraklion, mechanical means are not required for heating during the winter as the temperatures are not very cold, nor are mechanical means required for cooling during the summer. For January, February, March, April, November and December, due to low temperatures, heating strategies are required such as avoiding heat loss and increasing sunlight demand, from 0 to 560W/m^2. During May and October, passive heating is required with sun radiation up to 300W/m^2 and avoiding thermal losses usually in the morning and evening hours, there are also periods with shading needs, usually at noon where high sunshine is observed, while there are periods with thermal comfort. During September and June, a large part of the lines are in the comfort zone, in the morning mainly due to low temperatures, passive heating is required, with solar radiation needs up to 140W/m^2, shielding of the outer shell to avoid heat loss and during noon there are shading needs. At times, however, the cooling achieved by shading is not enough, so there is a need for natural ventilation at wind speeds of up to 0.5m/sec and evaporation cooling with humidity requirements of up to 1.0gr/Kgr, as well as an increase in thermal mass with simultaneous night ventilation. During July and August, no section is within the comfort zone due to the extremely high temperatures. The requirements for solar radiation are as low as 50W/m^2. Therefore, there should be shading during almost all sunshine period (up to 100%), natural ventilation with wind speeds up to 1.2m/sec, evaporative cooling with a moisture requirement of 3.2gr/Kgr, passive cooling with an increase in the building's thermal mass and ventilation overnight.

- Climatic Zone B

The prefectures of Ileia and Aitoloakarnania are located in the climatic zone B, which is colder than the A zone. Analyzing the bioclimatic charts shows that in Aitoloakarnania there is a need of mechanical heating during the winter (January, February and December). In January, February, March, April, November and December, due to low temperatures, heating strategies are also necessary such as passive solar heating with solar radiation ranging from 0 to 560W/m^2 and avoiding heat loss. It is also noticed that mechanical means are not required for cooling during the summer. In May and October, monthly lines fall within two zones, so in the morning and in the evening, because of low temperatures, passive solar heating up to 320W/m^2, is required and heat losses must be avoided. At midday hours shading is required due to high sunshine, while there are periods of thermal comfort. During September and June most part of the monthly lines are within the thermal comfort zone. Passive heating, with solar radiation up to 160W/m^2, ensures thermal comfort. At midday, shading is mostly required. In some intervals the shading is not sufficient to ensure thermal comfort, so natural ventilation is required at wind speeds of up to 1.0m/sec and evaporation cooling with humidity requirements up to 3.0gr/Kgr, as well as an increase in the thermal mass with simultaneous night ventilation. During July and August, particularly elevated temperatures, lead the monthly lines outside the thermal comfort zone. There are minimal solar radiation requirements of 70W/m^2, with a shading need of about 96% of the day, with simultaneous natural ventilation with wind speeds of up to 2.0m/sec, evaporation cooling with a moisture requirement of up to 4,0gr/Kgr, passive cooling with increasing building's thermal mass and overnight ventilation.

- Climatic Zone C

The prefectures of Alexandroupolis and Larissa are located in the climatic zone C, characterized by temperatures lower than the climatic zones A and B. From the observation of the bioclimatic charts, it appears that in the cold months of January, February, March and December, passive heating strategies, such as, using the sun's radiation to the fullest, of 560W/m^2 and the avoidance of thermal losses from the building shell are not enough. In addition, mechanical heating means are required. However, it is noticed that mechanical means are not required for cooling during the summer. In the months of April, October and November, low temperatures can be addressed by applying only passive heating strategies, avoiding heat losses and increased levels of solar radiation, ranging from 0 to 560W/m^2. During May and September, solar radiation of the order of 320W/m^2, is required, mainly in the morning. The high levels of sunshine of the midday are treated by shading, while there are periods of thermal comfort. In June, solar radiation up to 130W/m^2 is required to provide a desired indoor climate. Also, much of the day is within the thermal comfort zone. High sunshine at noon can be treated by shading. When shading is insufficient, ventilation is applied at an air velocity of up to 0.5m/sec, evaporation cooling, increased thermal mass and night ventilation. Drought in the atmosphere is treated with humidity up to 1.5gr/Kgr, to ensure comfort. During July and August, solar radiation is not required and the most of the sunshine period, shading is required, with simultaneous natural ventilation at wind speeds of up to 1.2m/sec, evaporation cooling with a moisture requirement of up to 3.2gr/Kgr, passive cooling by increasing the building's thermal mass and ventilation during the night.

- Climatic Zone D

The prefectures of Drama and Kastoria are in climatic zone D, which is the coldest climate zone. From the bioclimatic charts, it is noted that in January, February, March and December, due to low temperatures, except passive solar heating with maximum solar radiation up to 560W/m^2 and the avoidance of thermal load leakage, are also needed engineering heating devices at intervals. Mechanical heating means are also required in April and November in Kastoria. In the summer months no passive cooling measures are required. In April, October and November, passive heating and solar radiation of 0-540W/m^2 is sufficient. During May, June and September, part of the monthly lines is within the comfort zone. There are times that there is a need for solar heating from 0 to 440W/m^2. Overheating at noon can be treated with shading. In June, similar conditions prevail in Drama with the requirements for solar radiation minimal, 0-80W/m^2. Also, much of the day is characterized by favorable indoor climate conditions and shading needs. When shading is not sufficient, natural ventilation with wind speeds of up to 0.5m/sec, evaporation with humidity up to 1.0gr/Kgr, increased thermal mass of the building for passive cooling and night ventilation is necessary. During July and August, high temperatures prevail, so in Drama no solar radiation is required and in Kastoria solar radiation of 0-200W/m^2 is required. The hot sun rays can be treated with shading, natural ventilation with a wind speed of up to 0.75m/sec, passive cooling with increased building mass and evaporation cooling with humidity up to 2.0gr/Kgr. Also there are times that the night ventilation is not enough in Drama because of the large amounts of moisture, so dehumidification of the atmosphere is required. This strategy is applied when there are high levels of humidity, and is achieved by mechanical means.

VIII. BIOCLIMATIC EQUATIONS FOR CLIMATIC ZONES A, B, C AND D

In the Tables 4, 5, 6, 7, which resulted from the analysis of the quantitative bioclimatic charts of the two regions per climatic zone, are contained, the maximum values of the needs of solar radiation (W/m^2), shading, wind (m/sec) and moisture (gr/kg). The average of passive needs for each climate zone was then calculated. Then the following figures were designed:

1. average solar radiation needs in W/m^2 per month
2. average shading needs in % per month
3. average wind needs in m/sec per month
4. average moisture needs in gr/Kgr per month

In the vertical histograms, the x axis only includes the months that each strategy is required to apply, with unit gradients (where the 1 corresponds to the first month of the graph, the 2 to the second month of the graph, etc.) and the y axis represents the passive heating and cooling needs.

A statistical solution follows, where the relationship of two variables is investigated, with the purpose of predicting one with the help of the other, namely regression analysis. Thus, the regression lines, which are non-linear are derived and from them the 2nd degree polynomial equations. Also, the coefficient of determination, R^2, is determined with values from 0 to 1. The coefficient R^2 expresses the percentage of variability of the dependent variable y that is explained by the independent variable x. The closer to the unit is R^2, the more powerful the model is [44, 45].

The values of passive heating and cooling needs are obtained by replacing to the polynomial equations as x the values 1,2,3, etc corresponding to the 1st, 2nd, 3rd, etc month of the figure (Fig18-33).

- Climatic Zone A

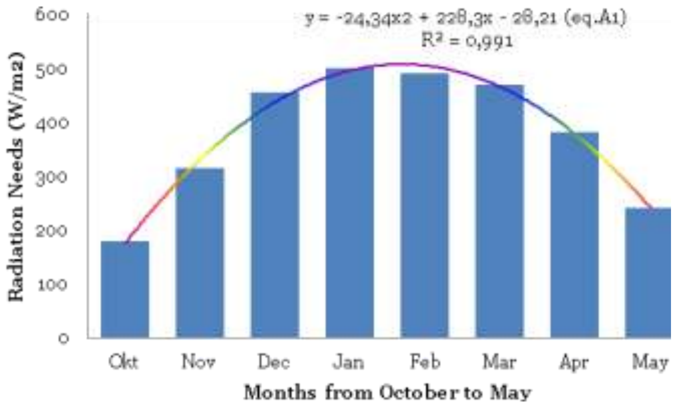

Fig. 18. Average values of solar radiation needs in W/m^2, from October to May, in climatic zone A.

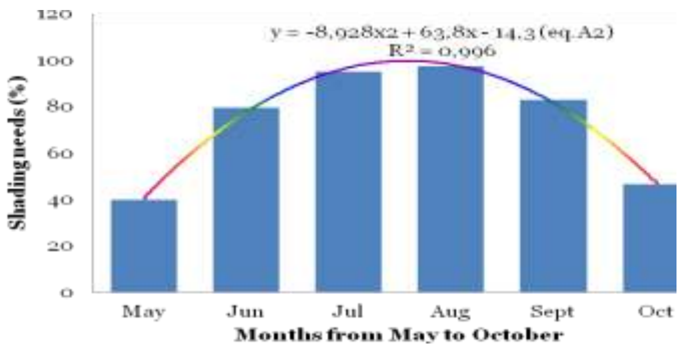

Fig. 19. Average values of shading needs in %, from May to October in climatic zone A.

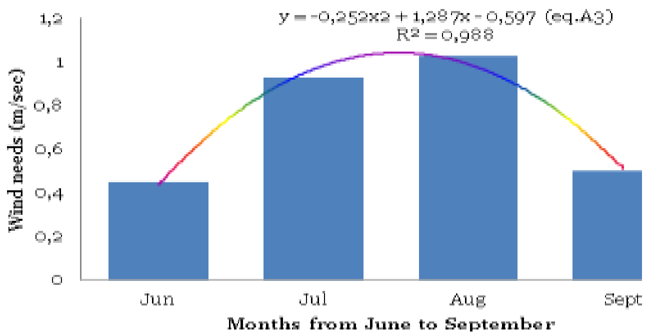

Fig. 20. Average values of wind needs in m/sec, from June to September in climatic zone A.

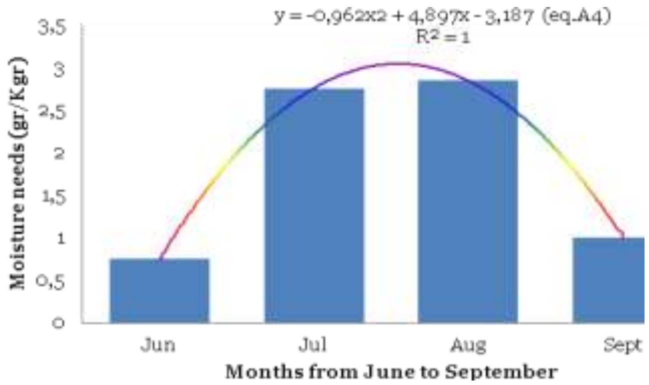

Fig. 21. Average values of moisture needs in gr/Kgr, from June to September in climatic zone A.

Climatic Zone B

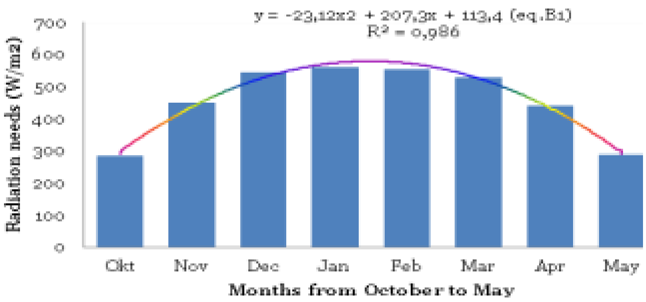

Fig. 22. Average values of solar radiation needs in W/m^2, from October to May, in climatic zone B.

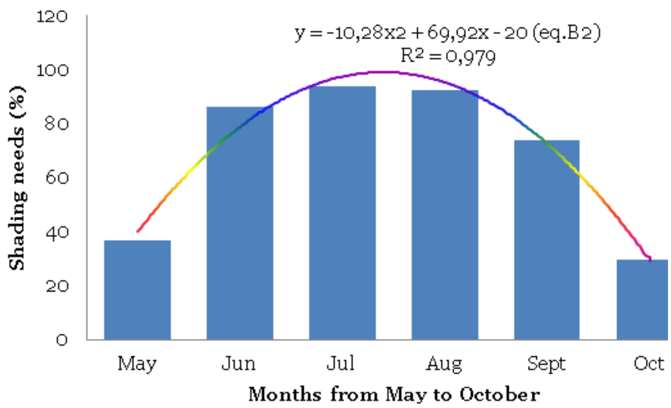

Fig. 23. Average values of shading needs in %, from May to October in climatic zone B.

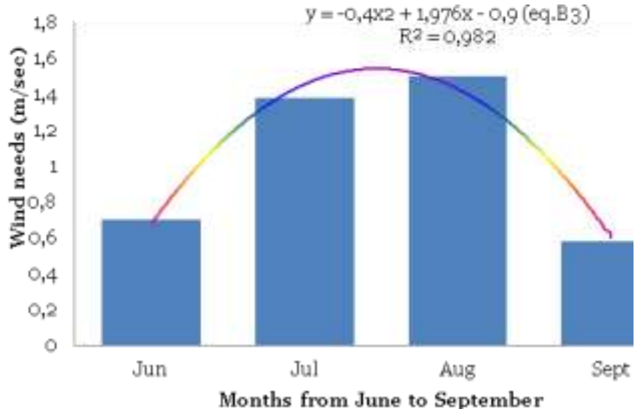

Fig. 24. Average values of wind needs in m/sec, from June to September in climatic zone B.

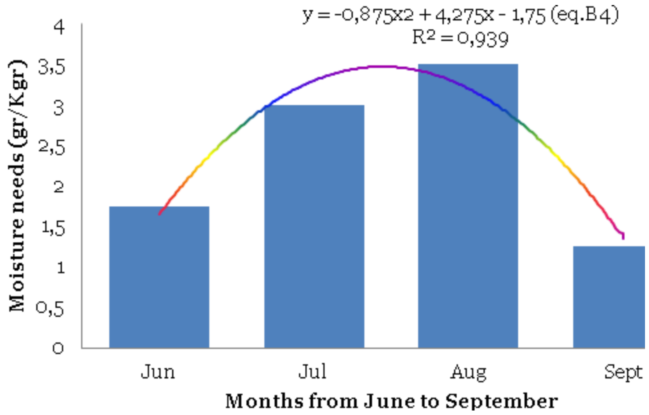

Fig. 25. Average values of moisture needs in gr/Kgr, from June to September in climatic zone B.

- Climatic Zone C

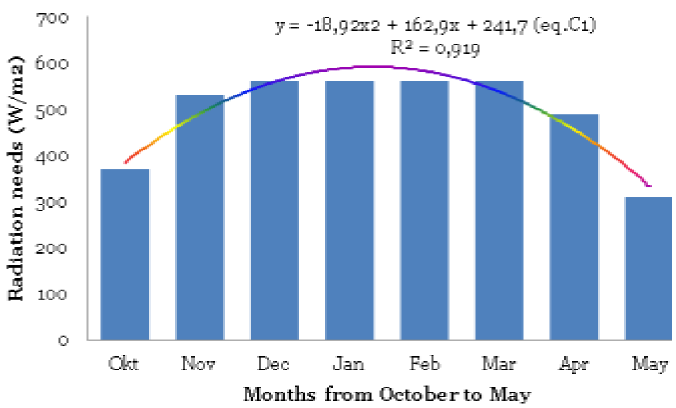

Fig. 26. Average values of solar radiation needs in W/m^2, from October to May, in climatic zone C.

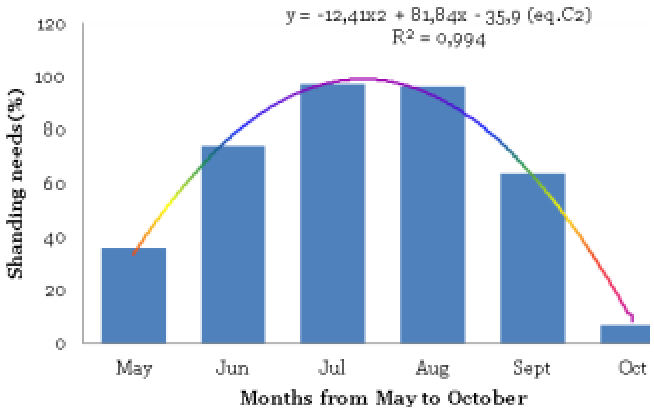

Fig. 27. Average values of shading needs in %, from May to October in climatic zone C.

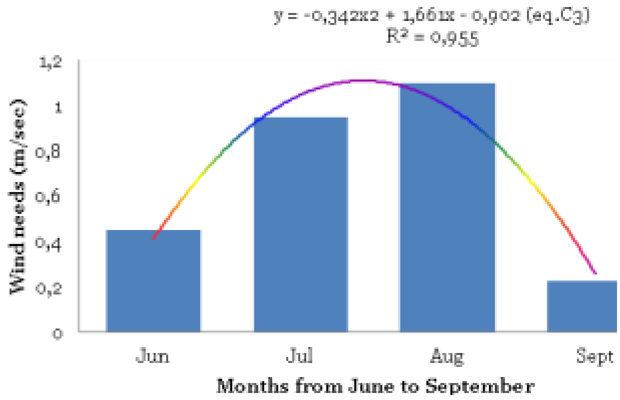

Fig. 28. Average values of wind needs in m/sec, from June to September in climatic zone C.

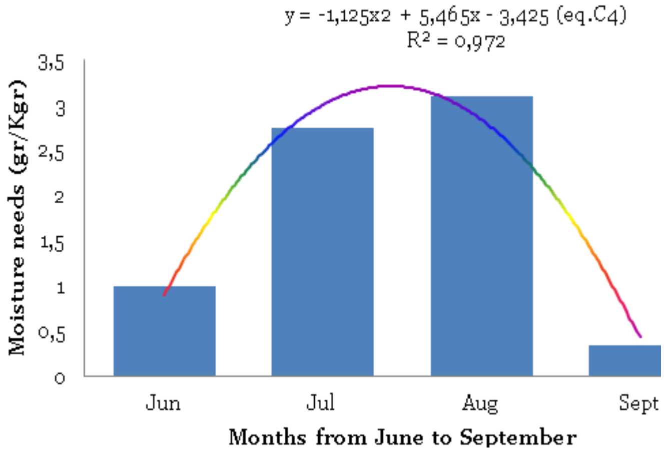

Fig. 29: Average values of moisture needs in gr/Kgr, from June to September in climatic zone C.

- Climatic Zone D

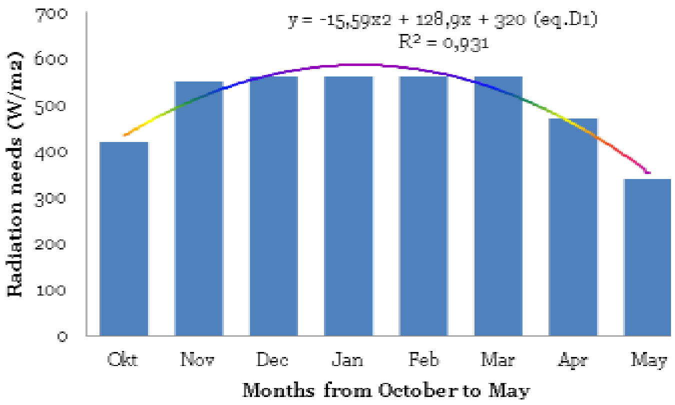

Fig. 30. Average values of solar radiation needs in W/m^2, from October to May, in climatic zone D.

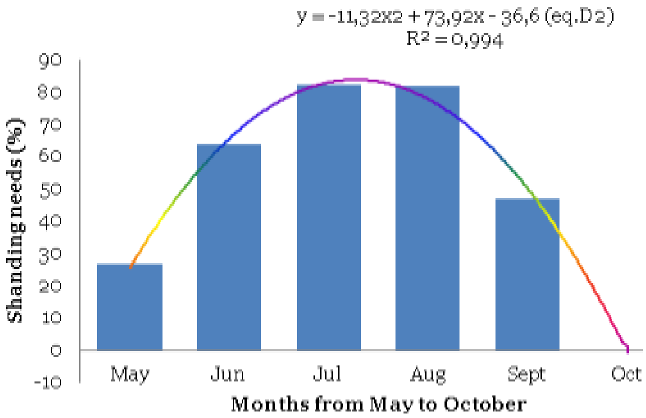

Fig. 31. Average values of shading needs in %, from May to October in climatic zone D.

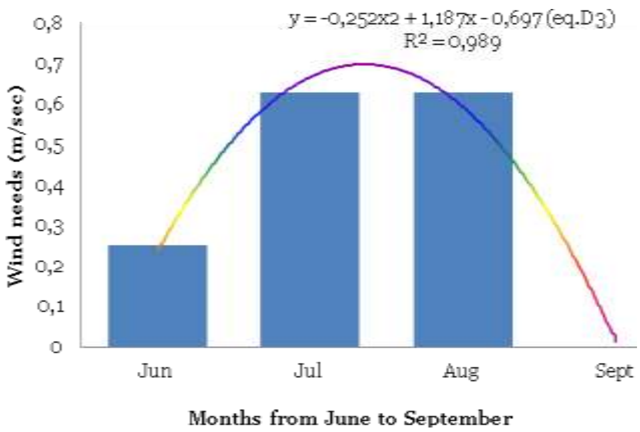

Fig. 32. Average values of wind needs in m/sec, from June to September in climatic zone D.

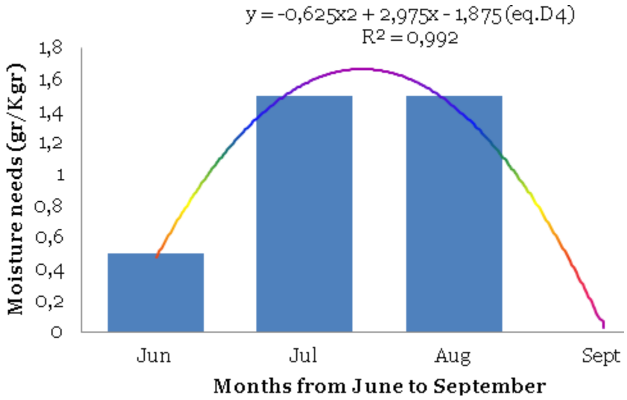

Fig. 33. Average values of moisture needs in gr/Kgr, from June to September in climatic zone D.

IX. CONCLUSIONS

As discussed in this paper, the quantitative and qualitative bioclimatic charts of Victor and Aladar Olgyay determine the values of the passive solar radiation, the shading, the wind and the moisture needs for each month and for each climate zone in Greece, so as to ensure conditions of thermal comfort.

However, it should be noted that the process of finding the climatic data required for each area to design the monthly lines mapping the external climatic conditions to the bioclimatic charts, namely the values of the maximum and minimum monthly mean temperature and the respective values of minimum and maximum relative humidity, was extremely difficult, as these data are not readily available. They therefore arose after the climatic data processing of the Hellenic National Meteorological Service.

In order to overcome the above difficulty and to save time and effort for the building designers, simplified equations, representative of each climate zone of Greece, were developed to replace the quantitative bioclimatic charts.

These equations are different for each climate zone and represent the solar radiation needs (y) in W/m^2, the shading needs (y) in %, the wind needs (y) in m/sec and the moisture needs (y) in gr/Kgr. These values are obtained by replacing the variable x with the fixed values 1,2,3 and so on, which represent the 1st, 2nd, 3rd, etc month of the graph.

The results from the bioclimatic equations are supposed to be used by engineers and architects as the primary guide for determining the passive strategies of designing bioclimatic buildings for each climate zone in Greece, as well as for areas with similar climatic conditions.

REFERENCES

[1]. European Parliament and Council of the European Union of 16 December 2002, (2003). Direction 2002/91/EC: on the energy performance of buildings. Official Journal of the European Communities, L001/0065. Retrieved on 2018-07-20, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0091.
[2]. Gorz, A., translated by Vigderman, P., and Cloud, J., (1980). Ecology as Politics. Montreal-New York: Black Rose Books.
[3]. Members of the commission. Bruntland Report, (1987). Report of the world commission on environment and development: Our Common Future. United Nations World Commission on Environment and Development (WCED). Retrievedon20180720,https://www.sswm.info/sites/default/files/reference_attachments/UN%20WCED%201987%20Brundtland%20Report.pdf.
[4]. Maroulas, B., C.M., (2011, Issue 8). Bioclimatic Residential Design. Building-Architecture & Energy (Technical Pages). Pp.105-112. Retrieved on 2018-07-22, http://www.ktirio.gr/system/files/2011-08-105.pdf.
[5]. Efthimopoulos, H., (2017). The Butterfly Dove, Ecological Interpretation and Environmental Relativism. Athens: Academy of Athens Research Center for Atmospheric Physics and Climatology Publication No.19, Mariopouloui-Kanaginio Foundation for Environmental Sciences.
[6]. Cao, X., Dai, X., Liu, J., (2016). Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. Elsevier. Energy and Buildings. 128, pp.198-213. Retrieved on 2018-07-25, https://www.sciencedirect.com/science/article/pii/S0378778816305783.
[7]. Athienitis, A.K., Santamouris, M., (2002). Thermal Analysis and Design of Passive Solar Buildings. USA, Canada, New York: Earthscan, Third Avenue.
[8]. Manzano-Agugliaro, F., Montoya, F.G., Sabio-Ortega, A., Amós, G.-C., (2015). Review of bioclimatic architecture strategies for achieving thermal comfort. Elsevier. Renewable and Sustainable Energy Reviews. 49, pp.736-755. Retrieved on 2018-07-27, https://www.sciencedirect.com/science/article/pii/S1364032115003652.
[9]. Nguyen, A.-T., Reiter, S. (2014). A climate analysis tool for passive heating and cooling strategies in hot humid climate based on Typical Meteorological Year data sets. Elsevier. Energy and Buildings. Pp.756-763. Retrieved on 2018-07-27, http://dx.doi.org/10.1016/j.enbuild.2012.08.050.
[10]. Joint Ministerial Decision 21475/4707. Government Gazette (FEK) 880. (19-08-1998). Determination of carbon dioxide emissions by setting measures and conditions for improving the energy performance of buildings. Government Gazette,

Issue 2, 10072. Retrieved on 2018-07-16, http://portal.tee.gr/portal/page/portal/SCIENTIFIC_WORK/arxeia_diafora/energeiaki%20apodosi%20ktiriwn/KYA_21475_4707_CO2.pdf.
[11]. Bonnette, A.L., Bruel, C., (1994). Xenophon Memorabilia. Ithaca and London: Cornell University Press.
[12]. Fokaides, P.A., (2012). Towards Zero Energy Buildings (ZEB): The Role of Environmental Technologies. Green and Ecological Technologies for Urban Planning: Creating Smart Cities. Pp.93-111. IGI Global: USA: Ercoskun OY, ISBN 978-1-61350-453-6.
[13]. Morgan, M.H., Warren, H.L., (1914). Vitruvius the ten Books of Architecture. London: Cambridge Harvard University Press.
[14]. Ganem, C., Esteves, A., Coch, H., (2006). Traditional climate-adapted typologies as a base for a new contemporary architectural approach. PLEA2006-The 23rd Conference on Passive and Low Energy Architecture. Geneva, Switzerland. Retrieved on 2018-08-20, https://www.researchgate.net/publication/228902335_Traditional_climate-adapted_typologies_as_a_base_for_a_new_contemporary_architectural_approach.
[15]. Heberden, W., (1826). An account of the heat of July 1825, together with some remarks on sensible cold. Philosophical Transactions of the Royal Society of London. Pp.69-74. London: Royal Society. Retrieved on 2018-07-16, http://rstl.royalsocietypublishing.org/content/116/69.extract.
[16]. Haldane, J.S., (1905). The Influence of High Air Temperatures No. 1. The Journal of Hygiene. Pp.494-513. London: Cambridge University Press. Retrieved on 2018-07-16, https://www.jstor.org/stable/107801?seq=1#page_scan_tab_contents.
[17]. Houghton, F.C., Yaglou, C.P., (1923 (a)). Determining lines of equal comfort. American Society of Heating and Ventilating Engineers (ASHVE) Translation. Pp.361-384.
[18]. Houghton, F.C., Yaglou, C.P., (1923(b)). Determination of the comfort zone. American Society of Heating and Ventilating Engineers (ASHVE) Translation. Pp.165-176.
[19]. Olgyay, V., Olgyay, A., (1963). Design with Climate-Bioclimatic Approach to Architectural Regionalism. New Jersey: Princeton University Press.
[20]. Katafygiotou, M.C., Serghides, D. K., (2014). Bioclimatic chart analysis in three climate zones in Cyprus. Indoor and Built Environment (published online). 24(6).pp.1-15. Retrieved on 2018-08-20, http://ktisis.cut.ac.cy/bitstream/10488/9406/1/Katafygiotou-Sergidi.pdf.
[21]. Reiter, S., Herde, A. De., (2003). Qualitative and quantitative criteria for comfortable urban public spaces. In Proceedings of the 2nd International Conference on Building Physics. Pp.1001-1009. Lisse (The Netherlands): A. A. Balkema. Retrieved on 2018-08-20, https://orbi.uliege.be/bitstream/2268/20554/1/reiqaq.pdf.
[22]. Metallinou, V.A., (2006). Ecological propriety and architecture. In: Broadbent G, Brebbia CA. Eco-Architecture: Harmonisation between Architecture and Nature, WIT Transactions on the Built Environment. Pp.15-22. Retrieved on 2018-08-20, https://www.witpress.com/elibrary/wit-transactions-on-the-built-environment/86/16330.
[23]. Attia, S., Hensen, J.L.M., (2014). Investigating the Impact of Different Thermal Comfort Models for Zero Energy Buildings in Hot Climates. In Proceedings 1st Int. Conf. on Energy and Indoor Environment for Hot Climates, ASHRAE. Doha, Qatar. Retrieved on 2018-08-20, https://www.researchgate.net/profile/Jan_Hensen3/publication/288364460.
[24]. Hoppe, P., (2002). Different aspects of assessing indoor and outdoor thermal comfort. Elsevier. Energy and Buildings. 34, pp.661-665. Retrieved on 2018-07-27, https://www.sciencedirect.com/science/article/pii/S0378778802000178.
[25]. ISO 7730-International Standard, second edition. (1994). Moderate Thermal Environments-Determination of the PMV and PPD Indices and specification of the conditions of Thermal Comfort. Switzerland: International Organization for Standardization. Retrieved on 2018-07-27, https://www.iso.org/standard/14567.html.
[26]. ASHRAE Standard 55-2010, (2010). Thermal Environmental Conditions for Human Occupancy. Atlanta, USA: American Society of Heating Refrigerating Air-Conditioning Engineers. Retrieved on 2018-07-20, http://arco-hvac.ir/wp-content/uploads/2015/11/ASHRAE-55-2010.pdf.
[27]. Mayer, E., (1993). Objective Criteria for Thermal Comfort. Elsevier. Building and Environment. 28, pp.399-403. Retrieved on 2018-07-27, https://www.sciencedirect.com/science/article/pii/036013239390016V.
[28]. Fanger, P.O., (1972). Thermal Comfort. New York: McGraw-Hill Book Company.
[29]. Auliciems, A., Szokolay, S.V., (2007). Thermal Comfort. Brisbane 4072: PLEA: Passive and Low Energy Architecture International in association with Department of Architecture, The University of Queensland.
[30]. CEN/TC, 156-prEN, 15251, (2006). Indoor environmental input parameters for design and assessment of energy performance of buildings-addressing indoor air quality, thermal environment, lighting and acoustics. EU for Standardization, Brussels, Belgium: European Standard. Retrieved on 2018-07-27, http://www.cres.gr/greenbuilding/PDF/prend/set4/WI_31_Pre-FV_version_prEN_15251_Indoor_Environment.pdf
[31]. Arcos, Aspiazu, A.M., (2012). Thermal Comfort in Social Housing, The Case of Socio Vivienda 1, Guayaquil-Ecuador. Lund University, spring semester. Retrieved on 2018-07-15, http://www.hdm.lth.se/fileadmin/hdm/Education/Undergrad/ABAN06_2012/Ana_Maria_Arcos-Thermal_comfort_in_Social_housing.pdf.
[32]. Planton, S., (2013). Annex III: Glossary. IPCC, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker, T.F., Qin, D., et.al. Pp.1447-1465. France: Cambridge University Press. Retrieved on 2018-07-25, https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_AnnexIII_FINAL.pdf.
[33]. Biket, A.,P., (2006). Architectural Design Based on Climatic Data. 1st International CIB Endorsed METU Postgraduate Conference Built Environment & Information Technologies. Pp.261-267. Ankara. Retrieved on 2018-07-25, http://www.irbnet.de/daten/iconda/06059010253.pdf.
[34]. Hellenic National Meteorological Service. The climate of Greece. Retrieved on 2018-05-29, http://www.emy.gr/emy/el/climatology/climatology.
[35]. Peel, M.C., Finlayson, B.L., Mcmahon, T.A. (2007). Updated world map of the Köppen-Geiger climate classification. HAL Id: hal-00305098. Pp.1633-1644. Retrieved on 2018-05-25, https://www.hydrol-earth-syst-sci.net/11/1633/2007/hess-11-1633-2007.pdf.
[36]. Androutsopoulos, A., Aravantinos, D., Axarli, K., Theodossiou, Th., Tsikaloudaki, K., (2011). Training of Energy Inspectors. Educational material. Building Inspection. Climate and indoor environment. Bioclimatic design of buildings. Unit: ΔΕ3. Athens: TEE. Retrieved on 2018-04-21, http://portal.tee.gr/portal/page/portal/tptee/dg2013/ktirio/DE3-Bioklimatika-final.pdf.
[37]. KENAK 2017, FEK-2367/B, (2017). Building Energy Efficiency Regulation Approval. Government Gazette. Pp23905-

23924. Retrieved on 2018-04-15, http://tdm.tee.gr/wp-content/uploads/2017/07/fek_12_7_2017_egrisi_kenak.pdf.

[38]. Sayigh, A., Hamid Marafia, A. (1998). Chapter 1: Thermal comfort and the development of bioclimatic concept in building design. Renewable and Sustainable Energy Reviews. 2. pp.3-24. Retrieved on 2018-04-20, https://www.deepdyve.com/lp/elsevier/chapter-1-thermal-comfort-and-the-development-of-bioclimatic-concept-gjXtfTIoBu.

[39]. Givoni, B., (1969). Man, climate and architecture. Madison, Elsevier: University of Wisconsin.

[40]. Arens, E.A., Gonzalez, R., Berglund, L. (1986). Thermal comfort under an extended range of environmental conditions. ASHRAE Transactions. Pp.18-26. Retrieved on 2018-04-13, https://escholarship.org/uc/item/qt1jw5z8f2.

[41]. TOTEE20701-3, (2010), Issue C, FEK2945/B, (2014). Climate Data of Greece Regions. Government Gazette. Retrieved on 2018-04-10, http://portal.tee.gr/portal/page/portal/tptee/totee/TOTEE-20701-3-Final-TEE%202nd.pdf.

[42]. Hellenic National Meteorological Service. Agriculture Bulletin. Retrieved on 2018-04-04, http://www.emy.gr/emy/el/agriculture/agriculture_bulletin.

[43]. Al-Azri, N., Zurigat, Y., Al-Rawahi, N., (2012). Development of Bioclimatic Chart for Passive Building Design in Muscat-Oman. Environment and Power Quality (EA4EPQ). International Conference on Renewable Energies and Power Quality (ICREPQ'12). Pp.1809-1815. Santiago de Compostela (Spain): European Association for the Development of Renewable Energies. Retrieved on 2018-05-10, https://doi.org/10.24084/repqj10.841.

[44]. Papaioannou, T., Loukas, S.B., (1990 (Second Reprint, March 1994)). Introduction to Statistics. Ioannina: K.A. University Press.

[45]. Kitikidou, K., (2013). Forestry Biometrics Laboratory Website-Notes: Introduction to Regeneration. Department of Forestry and Management of Environment and Natural Resources of the Democritus University of Thrace. Retrieved on 2018-08-03, http://www.fmenr.duth.gr/labwebpages/dasikiviometria/.

[46]. Giannarou, S., Tsatiris, M., Kitikidou, K. 2018. Energy Conservation in Buildings with Passive Heating and Cooling Strategies in Greece's Climatic Zones. International Refereed Journal of Engineering and Science (IRJES). Pp.29-45. Retrieved on 2018-05-10, http://www.irjes.com/Papers/vol7-issue7/E0707012945.pdf.

Sofia Giannarou" Bioclimatic analysis based on the climate of Greece, in order to minimize energy consumption in buildings" International Refereed Journal of Engineering and Science (IRJES), vol. 07, no. 09, 2018, pp. 25-50