IMPACT OF CLIMATE CHANGE ON A NATURALLY NIGHT VENTILATED RESIDENTIAL BUILDING, GREECE.

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ABSTRACT

The climate of Greece is typical Mediterranean with wet, cool winters and hot, dry summers. The temperature range is on average between 5°C to 35°C without many extreme temperatures and weather events. The cool sea breeze on the islands makes summer conditions milder. According to researchers and assessment reports of the United Nations climate change is inevitable in the 21st century. Regional climate models related to Greece show low uncertainties. As far as Greece is concerned, this climate change will be related to an increase in the ambient surface temperature and to a decrease in the annual precipitation. Wind patterns show that they will not change significantly. No significant changes are expected also for global radiation.

In this paper a typical single family two storey detached residential building for five occupants, in the hottest area of Greece – Rhodos island, is thermally optimized with various processes – strategies and the effect of the night natural flush ventilation. The cooling and heating demands of the building are less than 15 kWh/m²/yr (nearly zero). For the dynamic thermal simulation and performance of the examined building, the TAS software has been used. The thermal simulations for this paper run with the most updated weather data from Meteonorm software. In addition thermal demands of the same building are checked with the use of future data from the same source, for different emission scenarios, until 2050, per decade. In general, the A1B medium – emission scenario, which is the most pessimistic for the area, assumes rapid economic growth, increase of the population and social interactions until the middle of the century and more efficient technologies with a balance across all sources. The heating and cooling demands of the future compared with the present situation. Finally new night ventilation patterns are checked for optimization purposes for the A1B emission scenario at the end of the examined period.

KEYWORDS

single family building, building performance simulation, night ventilation, climate change, Mediterranean – Greece.

1 INTRODUCTION

The built environment offers the largest potential of cost – effective energy and greenhouse gas emission savings [1]. In Greece the continually increasing building sector, before the economic recession of 2010, was responsible on average for 30% to 35% of the greenhouse gas emissions and for 35% to 40% of the total energy consumption, mainly through electricity [2]. The Greek households consume more energy (mainly electricity) than the households from countries with similar Mediterranean climate and weather, like Portugal, Spain, Cyprus and Malta [3]. The greatest percentage of the buildings constructed before 90's without insulation and they are single family or multifamily buildings. Passive systems for heating or cooling and bioclimatic design are not part of the construction process. The main reason for these results is the absence, until 2010 and TOTEE/KENAK, of modern non conservative legislation [4].

There is no doubt that the energy performance of a building is straight related with the climate of a region [5]. The great advantage of Greece compared to the other countries is the mild Mediterranean climate that helps to relatively balance energy needs compared to northern countries [6]. In general, the year may be mainly divided into two seasons, the cold and rainy winter period, from November to the middle of April and the warm, drought period from the middle of May to October. In addition, the winter weather is often interrupted by sunny days. Rains in Greece even during the winter period, do not last for many days. During the hot and drought period the weather is constant, the sky is cloudless and it never rains, except for a few intervals of intense, short – lasted storms. Finally the high temperatures are tempered by the cool sea breeze of the northern winds blowing in the sea. Spring usually does not last long.

This advantage of Greece will not be very important as it approaches the new world, the world of the "climate change". According to researchers and assessment reports of the United Nations (IPCC) climate change is unequivocal [7]. During the last 150 years, 129 out of a total 274 days with temperature over 37 °C were in the period 1998 – 2007 in Greece [8]. Also, in the same period there were 19 extreme heatwaves events out of a total of 52 in the last 150 years. The increased number of events was accompanied with an increase in the intensity and the duration. The regional climate models related to Mediterranean Sea and Greece show low uncertainties [9]. As far as Greece is concerned, this climate change will be related to an increase in the ambient surface temperature and to a decrease in the annual precipitation [10]. Wind patterns show that they will not change significantly. No significant changes are expected also for global radiation. These changes would have serious impacts on local communities, on the environment – ecosystems, on the agriculture and tourism. There is no doubt that this climate change will have also a serious impact on building performance and occupant comfort. This situation will affect mainly low income households, especially during the period of the economic recession. Results of assessment reports related to possible emission greenhouse gas future scenarios.

This paper deals with the subject how the climate change will affect the thermal demand of an efficient single family detached building, like the nearly zero energy building (cooling and heating demand under 15 kWh/m^2) in the hottest area of Greece, Rhodos island (zone A). The thermal performance of the building is optimized with the use of the extra movable shadings strategy during the mornings and the natural night ventilation strategy during all year. It is goal is to display the importance of design not just for today but for the whole life cycle of a building, through representative dynamic future weather data. Finally different ventilation strategies – patterns are simulated for the worst scenario in 2050.

For this paper three emission scenarios is used (A1B, A2, B1). In general, the A1B emission scenario assumes rapid economic growth, increase of the population and social interactions until the middle of the century and more efficient technologies with a balance across all sources. The A2 emission scenario family assumes a preservation of the local structure and economic development, an increase in population rates and a smaller increase in technological changes. The B1 scenario assumes similar population pattern as the A1 family scenario and social and environmental sustainability. Economic structures focus on services and information and technologies are more efficient [11]. The warming at the end of the 21st century for Greece is in range of about 3 °C to 6 °C for the A2, 3 °C to 5.5 °C for the A1B and 2.5 °C to 4.5 °C for the B1 scenarios [10]. Also with A2 and A1B scenarios is estimated a decrease in precipitation up to 30% in southern Greece. These values are more pessimistic than the average Mediterranean values of the global climate models.

2 METHODOLOGY – BUILDING DESIGN SETTINGS

The paper is split in three parts. At the first part is presented all the initial high efficient structural and physical characteristics of the building. At this building is applied the strategies of the extra movable shadings and the one of the night ventilation during all year. All these characteristics arise by the Greek regulations and by the Greek Center of Renewable Energy Sources (CRES), which is the research center responsible for sustainable and ecological development in Greece. The building is simulated with weather data exported from the Meteonorm software version 7.0.16. As far as the initial design process the output of the software is stochastically interpolated "typical" year for temperature until 2009 and for radiation until 2005. These data are the most updated weather data for simulations in Greece. At the second part the same building with all the characteristics is simulated with various data sets from the future (every decade from Meteonorm) for different emission scenarios (A2, A1B, B1). Finally for the worst case, in 2050, different ventilation patterns are simulated. For the dynamic thermal simulation and performance of the examined single family building in one of the hottest areas of Greece, the Rhodos island, the Thermal analysis software or Tas (EDSL Ltd.) version 9.2.1.3 and the response function method has been used.

2.1 Design of the energy efficient building

For the designing of the single family residential building of this paper is used:
1) Minimum exposed surfaces and compact design
2) Sufficient and continuous thermal airtight insulation for the walls and the roof ($U=0.2W/m^2K$) and the ground floor ($U=0.8W/m^2K$) of the building, exceeding the minimum limits of Greek regulations for the thermal transmittance of the building elements. The building envelope is designed with infiltrations of 0.7 ach.
3) The long axis of the building is set to be at the west – east axis. There are no openings on the west and east sides. Losses from the west and east directions are net higher than the others during winter and the danger of overheating and glaring because of the solar sunshine during summer is high. The main façade for purposes of solar gains and daylight comfort, faces the south direction. Direct passive heating systems, like Trombe wall and sun spaces, are not used because the low heating requirements of the building.
4) For the decreasing of solar gains in summer, extended fixed shading (double length compared with the opening) and pergolas are applied for the southward orientated apertures. Fixed shading is designed to cover the openings at the highest points of the sun from 16th of April until 31st October.
5) Double glazing air filled with low emissivity in high quality openable vertical windows with a wooden frame is used ($U_g=1.5W/m^2K$, $g=0.6$).
6) The prevailing cold North winds creating efficient cross – ventilation to the building mainly for the summer and the spring. The night flush ventilation (0:00 – 5:00) is an important cooling strategy for the whole year. The high ceiling (2.6 m) and the open stair wells achieve temperature stratification and a vertical air movement through the building.
7) Rooms with limited use and lower temperature requirements during the day (closets, corridors, warehouses, bathrooms etc.) are located in the northern part of the building. The living room is located on the southern part of the ground floor.

The building covers all the needs of a typical Greek family with five occupants. The total floor area of the building is 143.38 m^2 and the total volume 440.89 m^3. The compactness (surface/volume) of the building is 0.65.

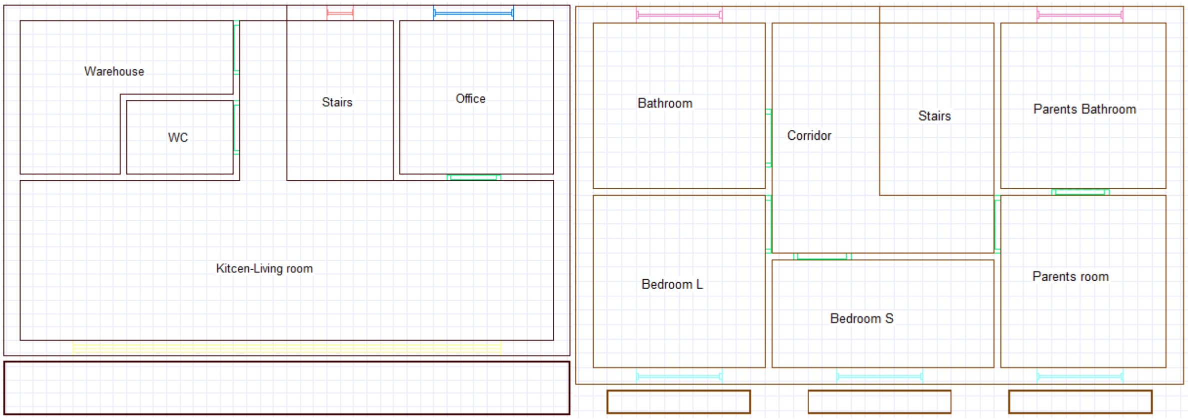


Figure 1: Plans (ground floor and upper floor) of the building (North direction is upwards).

The internal conditions are due to the Greek and European regulations [12]. The temperature band is set to be between 20 °C and 26 °C for all of year and day round. Lower and upper limit regarding the relative humidity is applied, which is the 40% and the 90% also for the whole year and day round. The movable shadings are applied at the southern openings during the morning (working hours) for the spring and the summer. For the optimization process, the night flush ventilation is applied for five hours at night. Every day of the year at night all apertures automatically start to open when the internal temperature of the zone is over 20.5 °C (fully opened at 21 °C) and the temperature outside is below the interior temperature. In Fig.2 the psychrometric chart of the updated weather data for Rhodos island, from Meteonorm, is presented. The prevailing strong cold northern or western winds mild the summer extreme conditions.

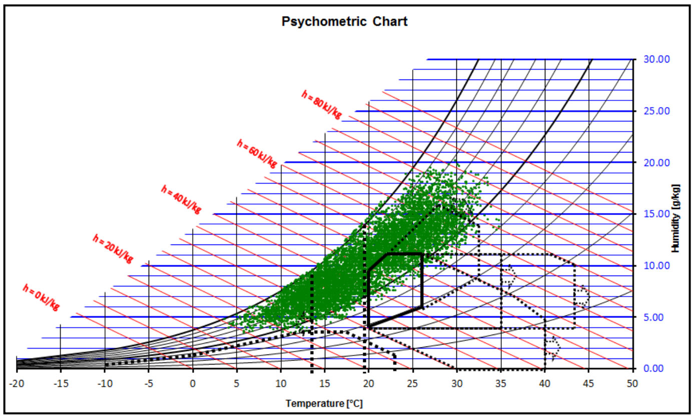


Figure 2: Psychrometric chart of the “typical” year of the most representative weather data of Rhodos island – Greece [13].

2.2 Future climate change and scenarios

This building, with all the characteristics, is simulated with various dynamic data sets from the future for different emission scenarios. The average, maximum and minimum values for temperature and relative humidity of the present and future weather data, for three different emission scenarios, for Rhodos island in Table 1 are presented. The A1B scenario, which is the medium critical scenario for IPCC, presents the highest increase until 2050 as far as the average and the maximum temperature. The relative humidity as far as the upper and lower bands remains almost constant. The “typical” year of the measured solar radiation in Fig.3 is presented. The future changes of global radiation in the Mediterranean region are less than 4% increase until 2100 [14].

Table 1: Present and future weather data from Meteonorm software for different emission scenarios of Rhodos island – Greece.

a/a	Average Temperature (°C)	Minimum Temperature (°C)	Maximum Temperature (°C)	Minimum R. Humidity (%)	Maximum R. Humidity (%)
Present Data	19.5	3.6	34.8	39	100
A2/2020	19.8	4.7	35.5	35	100
A2/2030	20.2	5.0	36.2	34	100
A2/2040	20.4	4.6	36.3	34	100
A2/2050	20.8	5.5	37.0	34	100
A1B/2020	19.8	4.1	35.5	34	100
A1B/2030	20.2	4.6	36.3	34	100
A1B/2040	20.5	5.0	36.3	34	100
A1B/2050	20.9	5.3	37.2	34	100
B1/2020	19.8	4.2	35.5	33	100
B1/2030	20.1	4.5	36.2	34	100
B1/2040	20.2	4.6	36.2	35	100
B1/2050	20.5	4.9	36.5	34	100

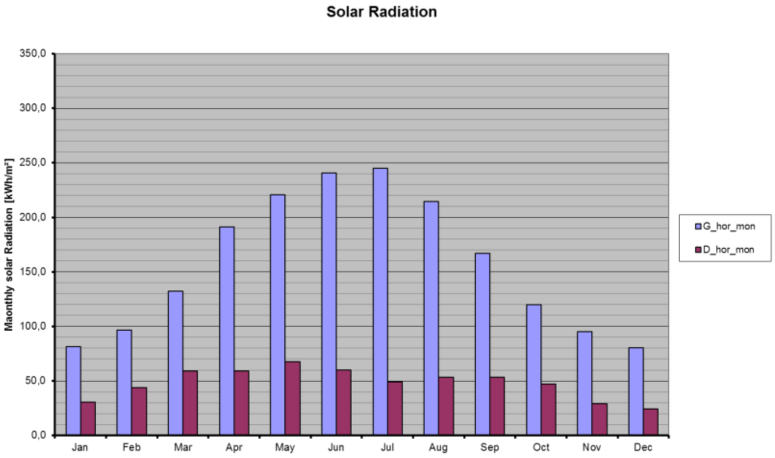


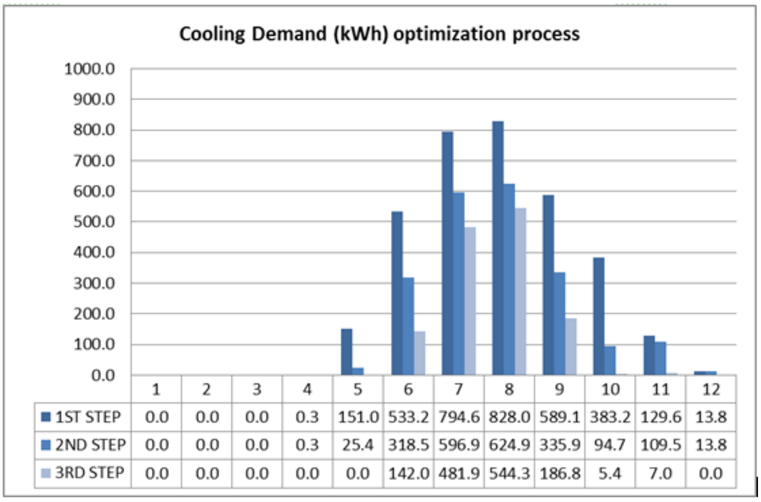
Figure 3: “Typical” year of the solar radiation (global and diffused), until 2005, of Rhodos island – Greece [13].

2.3 Different night ventilation patterns

Finally for the most pessimistic scenario, in 2050, different night ventilation patterns are simulated. The night flush ventilation at the initial building is from 0:00 am to 5:00 am. The thermal demand for different sets of night hours is checked. Also the effect on the thermal demand of the open internal doors for cross ventilation is simulated. Finally different ventilation patters as far as the apertures of the upper or ground floor and the north or the south façade are calculated.

3 RESULTS

The Fig. 4 below presents the results for the cooling demand of the energy efficient single family two storey detached building of Rhodos island in kWhs, for every month for the three steps of optimization. The annual cooling demand for every step is 29.7 kWh/m²/yr, 18.4 kWh/m²/yr and 11.8 kWh/m²/yr respectively. The specific heating demand is annually less than 0.3 kWh/m²/yr and only in January and February (not presented). For March, April, May and December the thermal demand (cooling – heating) is zero. The second and third steps show an annual decrease in thermal demand of 38% and 34% respectively (59% in total). Also the cooling period is shortened from April – December to June – November. The shading process is critical from May to October and the natural ventilation process in June and from September to November.



	1	2	3	4	5	6	7	8	9	10	11	12
■ 1ST STEP	0.0	0.0	0.0	0.3	151.0	533.2	794.6	828.0	589.1	383.2	129.6	13.8
■ 2ND STEP	0.0	0.0	0.0	0.3	25.4	318.5	596.9	624.9	335.9	94.7	109.5	13.8
■ 3RD STEP	0.0	0.0	0.0	0.0	0.0	142.0	481.9	544.3	186.8	5.4	7.0	0.0

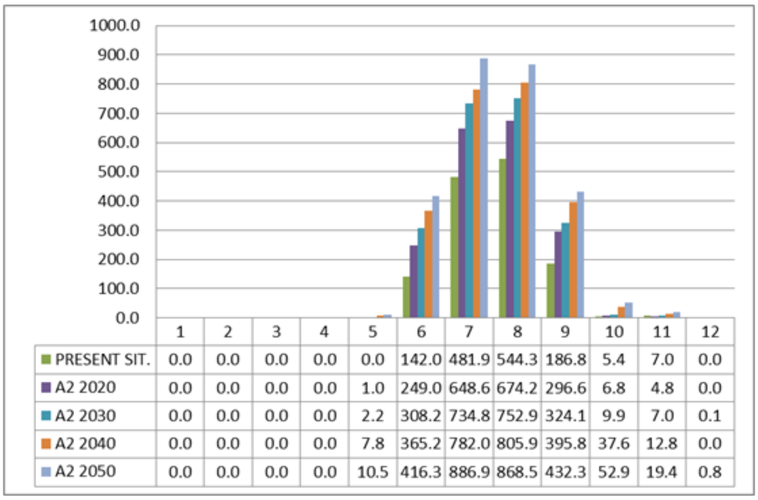
Figure 4: Monthly cooling demand (kWhs) for the three steps of optimization process of the energy building, of Rhodos island – Greece.

In the following Fig. 5 – 8 the cooling demand for every future scenario and every decade of simulation until 2050 for the optimized energy efficient NZE building of Rhodos island are presented. The cooling demand increases in every year and in every scenario until 2050. In 2020 the highest increase of the cooling demand is presented in scenario B1 (41.4% - optimistic scenario). Until 2050 the highest increases are presented in scenario A1B (109.2%) and in scenario A2 (96.5%), always compared with the results of the designed initial building. In summary the scenario with the greatest changes in cooling and heating demand is the A1B (104.6%).

For the A2 future scenario, even as early as 2020 the cooling demand extends from May to November. The maximum sensible cooling peak load is increased too from 2.5 kW to 3 kW in 2050. The highest cooling demand for the A2 and A1B future scenario occurs in August except for 2050 when it takes place in July. The cooling demand is higher in September than in June for every scenario and decade.

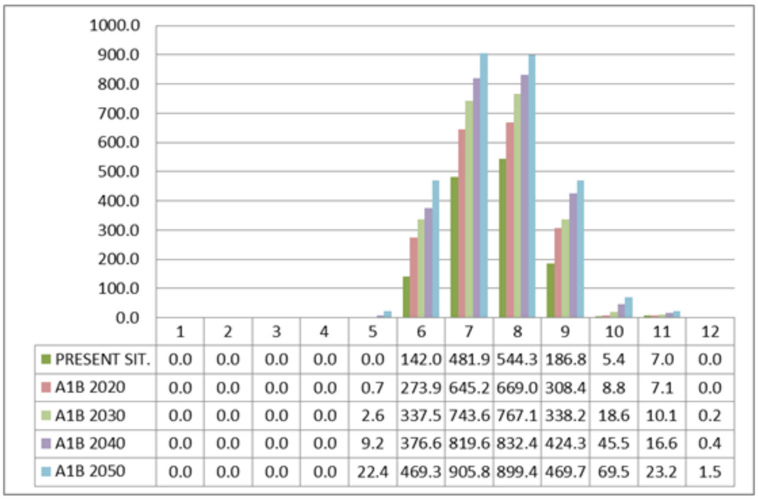
The annual cooling demand in the A1B future scenario is always higher than the demand in A2 future scenarios for every year until 2050. The peak cooling load remains constant on average until 2050 at 2.3 – 2.5 kW. From 2030 and afterwards the cooling period is extended from November to December.

Concerning the B1 future scenario apart from 2020 the cooling demand is always lower than the other scenarios for every year and almost every month. The cooling period does not include December and always August is the month with the highest demand. The sensible cooling peak load remains constant on average until 2040 at 2.2 kW and increased in 2050 at 2.9 kW. In Table 2 all the specific heating and cooling results of the simulations as a summarization are presented.



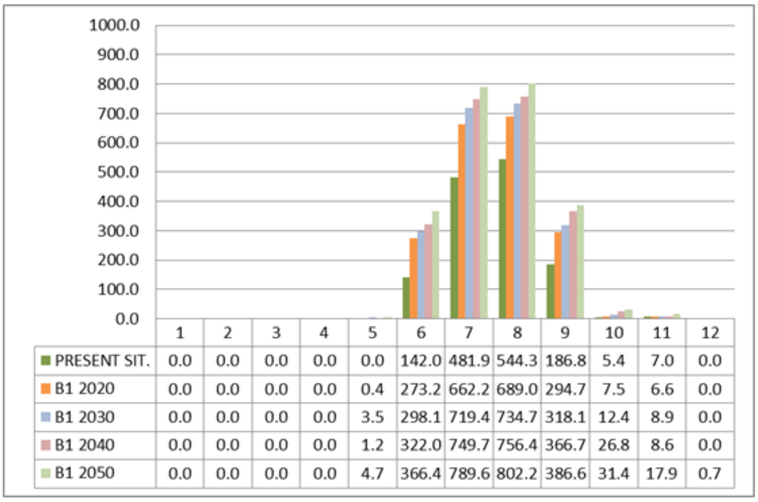
	1	2	3	4	5	6	7	8	9	10	11	12
PRESENT SIT.	0.0	0.0	0.0	0.0	0.0	142.0	481.9	544.3	186.8	5.4	7.0	0.0
A2 2020	0.0	0.0	0.0	0.0	1.0	249.0	648.6	674.2	296.6	6.8	4.8	0.0
A2 2030	0.0	0.0	0.0	0.0	2.2	308.2	734.8	752.9	324.1	9.9	7.0	0.1
A2 2040	0.0	0.0	0.0	0.0	7.8	365.2	782.0	805.9	395.8	37.6	12.8	0.0
A2 2050	0.0	0.0	0.0	0.0	10.5	416.3	886.9	868.5	432.3	52.9	19.4	0.8

Figure 5: Monthly cooling demand (kWh) for the energy efficient building, for A2 scenario until 2050, of Rhodos island – Greece.



	1	2	3	4	5	6	7	8	9	10	11	12
PRESENT SIT.	0.0	0.0	0.0	0.0	0.0	142.0	481.9	544.3	186.8	5.4	7.0	0.0
A1B 2020	0.0	0.0	0.0	0.0	0.7	273.9	645.2	669.0	308.4	8.8	7.1	0.0
A1B 2030	0.0	0.0	0.0	0.0	2.6	337.5	743.6	767.1	338.2	18.6	10.1	0.2
A1B 2040	0.0	0.0	0.0	0.0	9.2	376.6	819.6	832.4	424.3	45.5	16.6	0.4
A1B 2050	0.0	0.0	0.0	0.0	22.4	469.3	905.8	899.4	469.7	69.5	23.2	1.5

Figure 6: Monthly cooling demand (kWh) for the energy efficient building, for A1B scenario until 2050, of Rhodos island – Greece.



	1	2	3	4	5	6	7	8	9	10	11	12
PRESENT SIT.	0.0	0.0	0.0	0.0	0.0	142.0	481.9	544.3	186.8	5.4	7.0	0.0
B1 2020	0.0	0.0	0.0	0.0	0.4	273.2	662.2	689.0	294.7	7.5	6.6	0.0
B1 2030	0.0	0.0	0.0	0.0	3.5	298.1	719.4	734.7	318.1	12.4	8.9	0.0
B1 2040	0.0	0.0	0.0	0.0	1.2	322.0	749.7	756.4	366.7	26.8	8.6	0.0
B1 2050	0.0	0.0	0.0	0.0	4.7	366.4	789.6	802.2	386.6	31.4	17.9	0.7

Figure 7: Monthly cooling demand (kWh) for the energy efficient building, for B1 scenario until 2050, of Rhodos island – Greece.

Table 2: Specific heating and cooling demand (kWh/m^2/yr) for the optimization process and every future scenario until 2050 for the building, of Rhodos island – Greece.

a/a	Heating	Cooling				
Step 1	0.1	29.7				
Step 2	0.1	18.4				
Step 3	0.3	11.8				
a/a	**A2-Heating**	**A2-Cooling**	**A1B-Heating**	**A1B-Cooling**	**B1-Heating**	**B1-Cooling**
2020	0.3	16.3	0.3	16.6	0.3	16.8
2030	0.2	18.5	0.2	19.2	0.2	18.2
2040	0.1	20.9	0.1	21.9	0.2	19.3
2050	0.1	23.3	0.1	24.8	0.1	20.8

Table 3: Specific heating and cooling demand (kWh/m^2/yr) for different opening hours for all the apertures of the building, of Rhodos island – Greece.

a/a	Specific Heating Demand (kWh/m^2)	Specific Cooling Demand (kWh/m^2)
00:00-01:00	0.0	29.5
00:00-02:00	0.0	27.9
00:00-03:00	0.0	26.6
00:00-04:00	0.0	25.6
00:00-05:00	0.1	24.8
01:00-02:00	0.0	29.3
01:00-03:00	0.0	27.7
01:00-04:00	0.0	26.4
01:00-05:00	0.0	25.4
02:00-03:00	0.0	29.2
02:00-04:00	0.0	27.6
02:00-05:00	0.0	26.3
03:00-04:00	0.0	29.2
03:00-05:00	0.0	27.5
04:00-05:00	0.0	29.2

In Tables 3 – 4 all the specific heating and cooling demands for different opening patterns of all apertures as far as the time and the season of operation for night ventilation are presented. Also different patterns of night ventilation as far as the apertures of different facades are simulated (Table 5). As it was expected the maximum hours of application of night ventilation during all year decrease the cooling demand of the building. The open internal doors help the cross ventilation and decrease significantly the cooling demand of the building, more than the cooling demand of every zone – room separately (Table 5). The apertures of the upper floor (7.5 m^2), as expected, are more important for ventilation cooling than those of the ground floor (15 m^2). Finally the apertures of the south façade (17.7 m^2) are more important for cooling purposes than those of the north façade (4.75 m^2). The explanation of this larger increase in efficiency is the four times larger size of the apertures compared to the northern one.

Table 4: Specific heating and cooling demand (kWh/m^2/yr) for different seasons of application of the night ventilation for the building, of Rhodos island – Greece.

a/a	Specific Heating Demand (kWh/m^2)	Specific Cooling Demand (kWh/m^2)
Annual	0.1	24.8
Spring-Summer-Autumn	0.0	26.7
Spring and Autumn	0.0	29.0
Summer	0.0	29.0

Table 5: Specific heating and cooling demand (kWh/m²/yr) for different strategies – orientations of application of the night ventilation for the building, of Rhodos island – Greece.

a/a	Specific Heating Demand (kWh/m^2)	Specific Cooling Demand (kWh/m^2)
Internal Doors	0.1	23.9
Upper Floor openings	0.0	25.2
Ground Floor openings	0.0	25.6
North Façade openings	0.0	25.7
South Façade openings	0.0	24.4

4 CONCLUSIONS

The Greek – Mediterranean climate offers excellent weather conditions for thermally efficient, carbon neutral, fuel's independent and low budget family houses. The absence of extreme uncomfortable temperatures and the refreshing summer cool breeze help the bioclimatic design of really efficient energy buildings. In a dynamic situation, like climate change, the use of meteorological data from previous years, as for Greece from 2003 (TOTEE/KENAK), is not precise and scientifically acceptable. The climate change will significantly affect the thermal demands (mainly cooling) and non significantly the cooling loads, of a highly efficient NZE building in one of the hottest regions of Greece and Mediterranean Sea (Rhodos island) with an increase of more than 90% in 2050 on average. The cooling period is also extended. The increase of the cooling demand even from the first decade is really impressive (on average close to 40%). This is probably because the "typical" weather year used for the initial design utilizes data from a longer period than the last year (2009). For this reason the weather characteristics are milder than these of the present years and those of the next decades. Also in the summer warm period September is included (hotter than June). Mainly, because of the low standards of performance – construction of the old buildings in the area, the thermal demands will increase seriously due to weather changes, especially affecting low income households.

In contrast with the assumption of the IPCC for the Mediterranean Sea, the worst results in thermal demands for the area of the South Aegean with scenario A1B (medium) and then with scenario A2 (pessimistic) are presented. Only in the first decade (2020) scenario B1 (optimistic) is the leading worst scenario. The great increase in the first sets of simulation for 2020, as far as thermal demand, confirms the dramatically changed conditions of the weather and the climate. The decrease in precipitation and the changes of the drought periods have to be included in our design beyond the thermal simulations. This change of the parameter do not observed at the future meteorological data of Meteonorm.

The structural characteristics of this building like orientation, compactness, insulation, airtightness and shadings may be used as reference for the hottest areas of Greece. The used strategies of movable shadings and night natural cross ventilation are critical for the optimization of the thermal results close to the higher levels of international energy standards.

This paper is a contribution to deal with the effects of climate change in the thermal demands of a building, in Greece. For further research the investigation of the thermal demands of the future conditions until the end of the century is suggested, with outputs from meteorological regional climate models (not software – black boxes) and more greenhouse gas emission scenarios. The same research will be interesting for the coldest regions of Greece, too.

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