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COMPARISON OF SIMULATED THERMAL LOADS OF BUILDINGS ERECTED AT FOUR DIFFERENT LOCATIONS IN CYPRUS

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ABSTRACT

Cyprus is an island in the Eastern Mediterranean. Its climate is characterised by abundant sunshine and by moderate to heavy winter conditions. The microclimate though, varies considerably from location to location and is strongly affected by the elevation of a particular location and the proximity to the sea. In this study, four locations are considered which are representative of all the microclimates encountered in Cyprus; coastal, lowland, semi-mountainous, and mountainous. The weather pattern in these locations presents distinct characteristics. Dry weather with high summer and low winter temperatures are encountered in lowland, high humidity and moderate temperatures in coastal areas whereas dry weather with moderate summer and very low winter temperatures in semi-mountainous and mountainous areas. These weather patterns affect the thermal loads of buildings. A typical house layout with three different construction characteristics is used in this study and is simulated with the TRNSYS program in respect to the heating and cooling loads for a complete year. The weather data file used includes the mean monthly values of ambient air temperature, solar radiation, humidity ratio and wind velocity. TRNSYS Type 54 was used in the simulations in order to generate the hourly weather data required. The results show that the lowland, coastal and semi-mountainous locations exhibit high cooling and heating loads whereas mountainous locations exhibit high heating loads and very low cooling loads.

INTRODUCTION

The objective of this study is to show the variation of the heating and cooling loads of typical building constructions with respect to the ambient weather conditions. Cyprus although a small island presents four distinct weather patterns, discussed in this paper. However detailed weather data are available for only one of these locations in the form of a Typical Meteorological Year. Therefore, to simulate the thermal load of buildings on an hourly basis it is required to generate hourly data from mean values.

In the past a lot of simulations and detailed analyses were carried out for houses erected in Cyprus (Florides *et al.*, 2000; 2001; 2002; Kalogirou *et al.*, 2002). All these however refer to buildings located in Nicosia. This is due to the fact that TMY data are only available for this town. It is therefore of interest to investigate the thermal loads of buildings erected at other locations, which have different weather conditions than that of Nicosia. Such a detailed analysis for the other three distinct locations is done for the first time.

Cyprus is an island in the Eastern Mediterranean and is situated at a latitude of 35° North and a longitude of 33° East, with an area of approximately 9250 km^2. A map of the island is shown in Figure 1. Its climate is characterised by the Mediterranean climate where the sun shines abundantly for more than nine months whereas in winter conditions vary from moderate to heavy.

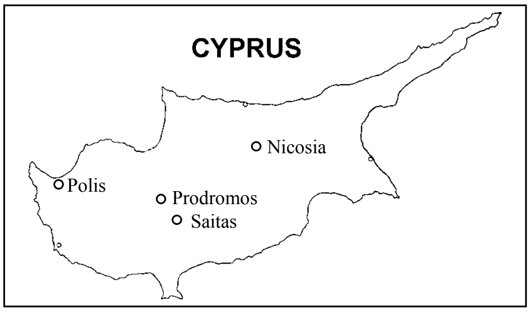

Figure 1 Map of Cyprus showing the four locations considered in this study

The island depends entirely on fuel imports from other countries for its energy requirements. The only available natural resources of energy are solar radiation and to a lesser degree aeolian energy. In fact, only solar energy is utilised extensively for water heating, by using thermosyphon solar collectors. A considerable amount of energy used in Cyprus is consumed for the heating and cooling of buildings. It is therefore important to carry out calculations for the thermal loads of buildings in order to minimise the energy requirements.

In the present study, the thermal loads of a typical building will be compared. Four different locations, which are representative of the four distinct weather patterns that can be encountered in the island, are considered.

WEATHER DATA

The four locations considered in this study with their corresponding height above mean-sea-level (amsl) are:

1. Nicosia (Lowland), height: 160m amsl
2. Poli (Coast), height: 15m amsl
3. Saittas (Semi-mountain), height: 640m amsl
4. Prodromos (Mountain), height: 1380m amsl.

For the above four locations mean monthly values of ambient air temperature, solar radiation, humidity ratio and wind velocity are available. These values were recorded for a 20-year period by the Meteorological Services. A TMY type of data is available for only one location of the four, that of Nicosia. Tables 1 to 5, below give the mean weather data for the four locations as well as the mean values for Nicosia as estimated from the typical meteorological year file data (Table 2).

Table 1 Monthly average weather data for Nicosia (h=160m amsl) from meteorological service

Month	Daily radiation (kJ/m^2)	Mean dry bulb temperature (°C)	Mean wind velocity (m/s)	Humidity ratio (g of moisture/kg dry air)
January	8824	10.0	3.0	5.8
February	11452	10.3	3.5	5.8
March	15901	12.4	3.7	6.5
April	20801	17.1	4.1	7.5
May	22889	21.2	4.3	9.0
June	24984	25.6	4.5	11.3
July	25225	28.4	4.5	13.5
August	22568	28.1	4.2	13.5
September	18677	25.6	3.8	12.5
October	13752	20.7	3.3	9.8
November	10170	14.9	2.9	9.8
December	8046	11.6	2.9	6.5

Table 2 Monthly average weather data for Nicosia estimated from data included in the TMY file

Month	Daily radiation (kJ/m^2)	Mean dry bulb temperature (°C)	Mean wind velocity (m/s)	Humidity ratio (g of moisture/kg dry air)
January	8594	9.9	3.0	5.7
February	10543	9.6	2.6	7.0
March	15561	11.5	3.8	6.4
April	20280	17.0	3.6	7.8
May	21019	19.8	4.0	7.5
June	24600	26.0	3.4	10.3
July	25432	28.9	4.4	11.7
August	24120	27.8	3.8	13.8
September	17651	25.9	3.6	12.2
October	14160	19.2	2.5	9.0
November	9406	15.1	2.0	8.6
December	8280	10.7	2.4	7.2

Table 3 Monthly average weather data for Poli (h=15m amsl) from meteorological service

Month	Daily radiation (kJ/m^2)	Mean dry bulb temperature (°C)	Mean wind velocity (m/s)	Humidity ratio (g of moisture/kg of dry air)
January	8834	11.4	3.1	6.3
February	11434	11.5	3.3	6.3
March	15437	12.7	3.0	6.8
April	19526	16.2	2.9	8.3
May	22378	19.7	3.0	9.5
June	24822	23.8	3.1	11.5
July	24433	26.7	3.1	13.0
August	22331	26.7	3.0	13.8
September	19037	24.5	3.0	12.3
October	14022	20.6	3.0	9.8
November	10177	16.2	3.0	7.8
December	7834	13.2	3.0	6.5

Table 4 Monthly average weather data for Saittas (h=640m amsl) from meteorological service

Month	Daily radiation (kJ/m^2)	Mean dry bulb temperature (°C)	Mean wind velocity (m/s)	Humidity ratio (g of moisture/kg of dry air)
January	7103	8.2	2.6	4.5
February	10519	8.2	2.8	4.3
March	14296	10.2	2.6	4.5
April	18821	14.7	2.5	5.0
May	21046	19.5	2.3	6.3
June	23360	24	2.3	7.3
July	23092	26.8	2.4	8.5
August	21449	26.6	2.3	8.8
September	18716	23.5	2.2	7.3
October	13795	19.8	2.3	6.8
November	9148	14.1	2.3	5.5
December	6390	9.9	2.4	5.0

Table 5 Monthly average weather data for Prodromos (h=1380m amsl) from meteorological service

Month	Daily radiation (kJ/m^2)	Mean dry bulb temperature (°C)	Mean wind velocity (m/s)	Humidity ratio (g of moisture/kg of dry air)
January	6577	2.7	2.8	3.5
February	8500	2.5	2.8	3.5
March	12208	5.1	2.6	3.8
April	17006	10.3	2.5	4.3
May	18292	14.2	2.4	5.0
June	20732	18.5	2.2	6.0
July	20952	21.7	2.1	6.5
August	19966	21.2	2.0	6.0
September	17064	18.4	2.1	5.8
October	11653	12.9	2.3	5.3
November	8237	8.0	2.3	4.5
December	6163	4.5	2.6	4.0

Both the data presented in Tables 1 and 2 refer to the town of Nicosia. Table 1 presents the mean weather data, obtained from the meteorological service and Table 2 those estimated from the TMY. By comparing the values in these two tables it can be seen that the various monthly values are rather similar. Greater differences concern the values of humidity ratio.

In Nicosia, the capital of Cyprus, temperatures vary between 10°C and 15°C during winter whereas in summer temperatures often exceed 40°C. The annual average wind velocity is 3.7m/s.

In Poli, a coastal city located southwest of Cyprus, temperatures are moderate both in summer and winter compared to Nicosia. The humidity levels are high and the annual average wind velocity is 3m/s.

Saittas is situated at Troodos range. Temperatures are moderate in summer and low in winter. Humidity values are within acceptable limits and the annual average wind velocity is 2.4m/s.

Prodromos is also located at Troodos range but much higher compared to Saittas. Severe conditions are experienced in winter with temperatures down to -10°C in some cases. Humidity levels are within acceptable limits and wind velocities are 2.4m/s on the average.

The selection of typical weather conditions for a given location is very crucial in computer simulations for performance predictions and has led various investigators either to use observational data of long periods or to select a particular year, which appears to be typical from several years of data. Typical meteorological file is only available for Nicosia. This was generated from hourly measurements, of solar irradiance (global and diffuse on a horizontal surface, ambient temperature, wind speed and direction, and humidity ratio). The recorded data refer to a seven-year period, from 1986 to 1992 using the Filkenstein – Schafer statistical method (Petrakis *et al.*, 1998). The measurements were performed by the Meteorological Service of the Ministry of Agriculture, Natural Resources and Environment of Cyprus, at the Athalassa region, an area very close to the town of Nicosia. Athalassa is at a latitude of

35°09', longitude 33°24' and 162 m high above the mean sea level.

For the modelling of the buildings the TRNSYS program was used (Klein *et al.*, 1996). TRNSYS runs through hourly values of various weather parameters included in a typical meteorological year (TMY) file or data generated within the program by a special routine (Type 54) estimated from mean monthly weather data. The results thus obtained can be used to determine the hourly load of buildings throughout the year, thus the annual energy use and the maximum load for equipment selection.

DESCRIPTION OF BUILDINGS

TRNSYS model 19 is used in order to simulate the temperature variation observed within a model house. The model house illustrated in Figure 2 has a floor area of 196 m^2 and consists of four identical external walls, 14 m long by 3 m high, with a total window opening of 5.2m^2 in each wall. The window area is approximately equal to the area that a typical house would have, but instead of considering a number of single windows on each wall, only one double glazed window is considered. The model house is further divided into four identical zones and the partition walls are considered as walls separating the four zones.

Details of the input parameters required to model the typical house shown in Figure 2 are given in Florides *et al.* (2000).

Three different construction cases were considered one with no insulation one with insulated roof and walls and one with light construction and insulation. Details of the construction cases are indicated in Table 6.

The loads of the above constructions are analysed in respect to the monthly cooling and heating loads for keeping the house temperature at 25°C during summer and 21°C during winter.

WEATHER DATA GENERATOR

TRNSYS Type 54 is the weather data generator. This component is used for the generation of hourly weather data when the monthly average values of solar radiation, humidity ratio and wind velocity are given. The aim, is to generate typical data for a single year similar to those of a Typical Meteorological Year. TRNSYS can then be used for load estimations for any location for which standard yearly average weather statistics are known.

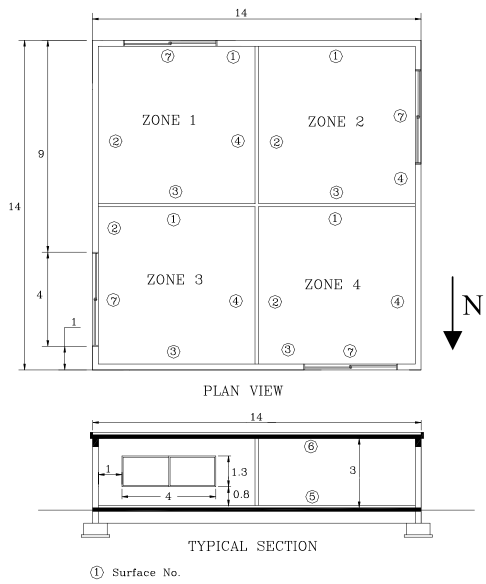

Figure 2. Model house.

Type 54 component requires a data file with the monthly average radiation, humidity and temperature values. It is possible within TRNSYS to add new data for specific locations. Any number of locations can be entered into the data file.

Radiation is often described as a dimensionless form called the clearness index, which is the ratio of the total radiation on a horizontal surface to the extraterrestrial global solar radiation on a horizontal surface at the same time. The instantaneous values can be integrated into any time period. Hourly values of clearness index for each day of the month are calculated from the daily clearness index cumulative distribution function. A correlation is used to approximate the distribution as a function of the monthly clearness index. To determine the order in which the days should occur a sequence is used by

Table 6. Details of the construction cases.

Case	Wall type	Roof type
A	Single wall, hollow brick 0.2 m and 0.02 m plaster on each side	Flat non-insulated roof, constructed from fair-faced 0.15 m heavy- weight concrete
B	Double-wall, 0.1 m hollow brick, 0.02 m plaster on each side and a layer of 0.05 m polystyrene insulation in between	Flat insulated roof, fair-faced 0.15 m heavy weight concrete, 0.05 m polystyrene insulation, 0.07 m screed and 0.004 m asphalt covered with aluminum paint of 0.55 solar absorptivity
C	0.1 m face brick, 0.1m insulation, 0.025 m wood	Clay tile, 0.01 m felt and membrane, 0.1 m insulation and 0.025 m wood

assigning integers 1 to 31 to the 31 daily clearness index values obtained from the distribution. The sequence consists of the integers 1 to 31, ordered such that when the daily clearness index values corresponding to the integers are placed in that order, the appropriate daily clearness index autocorrelation is reproduced. A similar process is used for the other weather variables. More details of the weather data generator model are given in Knight *et al.* (1991).

Other additional parameters required by the Type 54 model are the hourly radiation correction which is suitable for systems non-sensitive to hourly autocorrelation of radiation data. When the radiation values are summed, the daily total of the generated radiation is not necessarily equal to the "target" daily radiation value. Over a month, these discrepancies tend to average out.

For the temperature a stochastic model is used in which the hourly values are determined from a second order autoregressive model. In this model 24 hourly monthly-average dry bulb temperature values are computed, and the hourly deviations from these average values are then calculated with a second order autoregressive model (SOAM). The coefficients in the SOAM have constant values. To ensure the correct monthly-average dry bulb temperature value, the entire month's hourly values are generated on the first hour of the month. A month average value is computed from the hourly values and compared to the input monthly-average value; the hourly values are then adjusted by adding the difference to each hourly temperature. This model represents better the hourly autocorrelation structure of the dry bulb temperatures; however, it does not always generate temperature data with correct daily autocorrelation and daily distribution.

The relative humidity model is actually a dewpoint temperature model. The input humidity ratios are converted to monthly average dewpoint temperatures. Daily-average dewpoint temperatures are obtained from a normal distribution and ordered according to a "sequence". A special algorithm is used to determine the dewpoint depressions at the hours corresponding to the maximum and minimum dry bulb temperature each day. Hourly dewpoint depressions are computed by linearly interpolating between the dewpoint depressions at the minimum and maximum dry bulb temperatures. Dewpoint temperatures and relative humidities are calculated from the dewpoint depressions (Degelman, 1976).

RESULTS AND DISCUSSION

Simulation results for the three construction cases of the houses considered are given in this section. Initially the load estimated by running TRNSYS with the TMY data and Type 54 generated data from mean weather conditions (Table 1) is compared. This comparison which refers to buildings of case B is shown in Figures 3 and 4 for the cooling and heating loads respectively. As can be seen the correlation coefficient is acceptable for the case of the cooling load but is low for the case of the heating load. It should be noted that the accuracy of heating and cooling loads which were estimated inherently reflect the differences of all the weather parameters included in the weather files used in simulations. Some large variations, were expected as the weather data were completely different. What is of more importance here is the agreement in the total annual load.

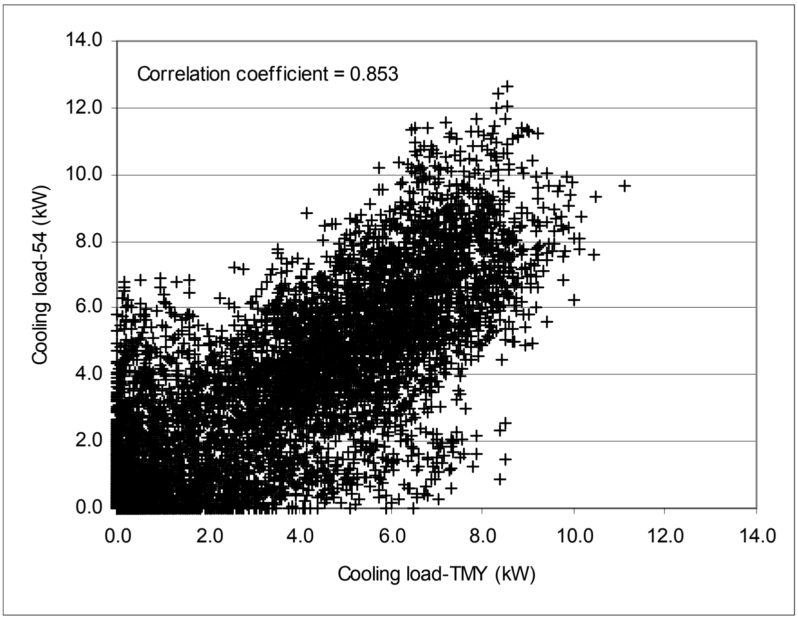

Figure 3 Comparison between cooling load estimated with TMY data and Type 54 generated data from mean monthly values-Building case B.

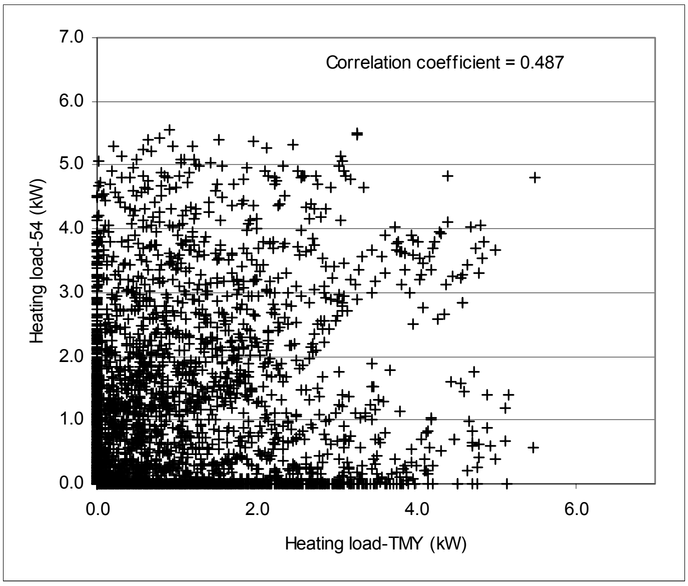

Figure 4 Comparison between heating load estimated with TMY data and Type 54 generated data from mean monthly values-Building case B.

Comparison between the results obtained by running TRNSYS, with TMY and hourly values generated with Type 54 from mean monthly data obtained from the TMY file (Table 2), for the annual cooling and heating loads are shown in Tables 7 and 8 respectively. As can be seen the bigger differences occur for the annual heating load. The loads obtained from the Type 54 are greater than the TMY estimated ones whereas the difference of the cooling loads is smaller.

Table 7. Comparison between TMY and Type 54-generated data from TMY for the annual cooling load

Weather file used	Case A	Case B	Case C
TMY 54-TMY	42398 42208	21732 20840	21058 20151
Absolute difference % difference	190 -0.45	892 -4.1	907 -4.3

Table 8. Comparison between TMY and Type 54-generated data from TMY for the annual heating load

Weather file used	Case A	Case B	Case C
TMY 54-TMY	16012 17485	3480 4303	2880 3671
Absolute difference % difference	1473 9.2	823 23.6	791 27.5

The greater percentage differences observed in the case of the heating load is due to the relatively small numbers that are compared. This can be seen from the values of the absolute differences which are similar in most cases but give much smaller percentage difference in the case of the cooling load.

A similar comparison for the TMY data and Type 54 generated data from mean values obtained from the meteorological service (shown in Table 1) for the two cases is shown in Tables 9 and 10.

Table 9. Comparison between TMY and Type 54-generated data for the annual cooling load

Weather file used	Case A	Case B	Case C
TMY 54-Nicosia	42398 41654	21732 21764	21058 21216
Absolute difference % difference	744 -1.8	32 -0.15	158 -0.75

Table 10. Comparison between TMY and Type 54-generated data for the annual heating load

Weather file used	Case A	Case B	Case C
TMY 54-Nicosia	16012 16382	3480 3876	2880 3362
Absolute difference % difference	370 2.3	396 11.4	482 16.7

The percentage differences presented in Tables 9 and 10 are similar, or even better, to the percentage differences given between the TMY and the Type 54 generated weather data obtained from the TMY hourly values, presented in Tables 7 and 8. The above analysis proves the adequacy of the weather data produced by the Type 54 Weather Data

Generator. It can therefore be concluded that the Type54-generated weather data can be used with a degree of confidence to estimate the thermal loads of buildings in the other three locations where TMY data are not available.

The annual results for Nicosia and the other three locations considered using Type 54 generated data from mean monthly values obtained from the meteorological service are shown in Table 11.

As can be seen in the mountainous locations (Prodromos) the need for cooling is less than half than the rest of the locations considered. All the other three locations, lowland (Nicosia), coastal (Polis) and semi-mountainous (Saitas) have very similar cooling requirements with the actual load decreasing with altitude. The reverse is true for the heating load where the lowland and coastal areas benefit from a very mild climate whereas the heating requirement in the mountains is more than three times that of the coastal and lowland locations.

Insulation also plays a major role in the loads of buildings and its effect can be evaluated from the results presented in Table 11. As can be seen the insulated (Case B) and light construction (Case C) houses have very similar loads and are much lower than the non-insulated house (Casee A). Insulation is important in all locations considered especially for the summer time in lowland and coastal locations and for wintertime in semi-mountainous and mountainous locations.

A monthly analysis of the cooling and heating loads estimated with Type 54, for the four locations is shown in Table 12 and 13 for the building cases A and B respectively. The respective loads for the building case C is very similar to those of case B and therefore are not presented here.

Table 11 Annual thermal loads obtained from simulations

Location	Cooling loads (kWh)			Heating loads (kWh)		
	Case A	Case B	Case C	Case A	Case B	Case C
Nicosia	41654	21764	21216	16382	3876	3362
Poli	41735	20071	19511	13292	2655	2386
Saitas	40714	16887	15770	22177	6288	5160
Prodromos	20879	7439	7508	47144	16428	13505

Table 12 Monthly cooling loads in kWh for the building cases A and B erected in the three locations considered.

Month	Nicosia-A	Nicosia-B	Polis-A	Polis-B	Saitas-A	Saitas-B	Prodromos-A	Prodromos-B
JAN	134.5	54.1	184.7	93	54.7	9.7	51.8	0
FEB	86.8	15.8	131.2	32.8	59.4	1.8	0	0
MAR	437.3	94.8	590.6	119.7	338.7	11.1	105	0
APR	2052	900.5	2246	858.1	1896	538.3	853.8	136
MAY	3958	1987	4050	1784	4211	1557	1577	314.4
JUN	6996	3519	6926	3163	7343	2951	3967	1422
JUL	9295	4835	8934	4254	9000	3839	5541	2202
AUG	8713	4639	8548	4241	8558	3767	5140	2051
SEP	6364	3478	6250	3249	5979	2672	3142	1240
OCT	2560	1613	2725	1645	2587	1296	437.2	61
NOV	808.7	525.2	863.7	510.8	560.7	220.7	98.4	10.6
DEC	249.2	101.8	285.3	120.6	128	24.2	17.2	1.3
Year	41654	21764	41735	20071	40714	16887	20879	7439

Table 13 Monthly heating loads in kWh for the building cases A and B erected in the three locations considered.

Month	Nicosia-A	Nicosia-B	Polis-A	Polis-B	Saitas-A	Saitas-B	Prodromos-A	Prodromos-B
JAN	4539	1436	3717	1089	5961	2074	10070	4041
FEB	3500	941.9	2751	614.9	4681	1524	8855	3528
MAR	2157	302.6	1832	199.2	3101	712.6	6765	2479
APR	631.6	13.6	675.7	19.5	1078	104.8	2954	821.3
MAY	73.2	0	98.4	0	109	74.3	1141	98.2
JUN	23.9	0	55.6	0	66.2	0	598.5	108.8
JUL	0	0	0	0	0	0	4.4	0.3
AUG	0	0	0	0	0	0	47.5	0
SEP	12.1	0	17.7	0	45.5	0	402.0	12
OCT	41.7	44.7	36.7	0	80.5	2.4	1948	240.5
NOV	1631	192.2	1170	80	2066	350.1	5467	1773
DEC	3772	989.3	2939	652.3	4991	1520	8890	3326
Year	16382	3876	13292	2655	22177	6288	47144	16428

It should be noted that the program counts loads when the temperature in summer is above 25°C and below 21°C in winter. This is the reason that in some months very small loads are presented. These are not actual loads as they occur at very small time intervals during which the occupants of a building do not actually use mechanical heating or cooling. They are preserved however in the tables in order to have agreement with the total loads.

Some very important conclusions can be drawn from the monthly data presented in Tables 12 and 13. The higher cooling load occurs during the month of July, which is the hotter month of the year and the higher heating load occurs in January, which is the colder month of the year. The monthly cooling loads in the three locations, lowland, coastal and semi-mountainous are very similar whereas the respective ones for the mountain location is considerably reduced. Similarly, the monthly heating loads in lowland and coastal locations are very similar whereas the heating load requirements increase with the elevation of a location. From the monthly loads the advantage of insulation of buildings is also clearly shown.

CONCLUSIONS

The data presented refer to the simulated results obtained for the three cases of buildings considered by using the mean monthly weather data for the four distinct locations considered. The following conclusions can be derived from this work:

1. In the mountainous locations (Prodromos) the need for cooling is less than half than that of the rest of the locations considered.
2. All the other three locations, lowland (Nicosia), coastal (Polis) and semi-mountainous (Saitas) have very similar cooling requirements with the actual load decreasing slightly with altitude.
3. The heating load of the buildings in the various locations has great differences. This is due to the fact that in lowland and coastal areas a very mild climate exists whereas the heating requirement in the mountains is more than three times that of the coastal and lowland locations.
4. The maximum monthly cooling load occurs during the month of July, which is the hottest month of the year and the maximum heating load occurs in January, which is the coldest month of the year.
5. The monthly cooling loads in the three locations, lowland, coastal and semi-mountainous are very similar whereas the respective ones for the mountainous location is much more reduced.
6. The monthly heating loads in lowland and coastal locations are very similar whereas the heating loads increase with the elevation of the location.
7. Insulation is important in all locations considered especially for the summer time in lowland and coastal locations and winter time in semi-mountainous and mountainous locations. As can be seen from the results presented here the insulated (Case B) and light construction (Case C) houses have very similar loads which are much lower than those of the non-insulated house (Case A). The advantage of using insulation in buildings is also clearly shown from the monthly loads.

REFERENCES

Degelman L.O. Monte Carlo Simulation of Solar Radiation and Dry Bulb Temperatures for Air Conditioning Purposes. Report No. 70-9, Department of Architectural Engineering, The Pennsylvania State University, 1970.

Florides, G, Kalogirou, S., Tassou, S. and Wrombel, L. Modelling of the Modern Houses of Cyprus and Energy Consumption Analysis. *Energy,* 2000; 25(10): 915-937.

Florides, G., Tassou, S., Kalogirou, S. and Wrobel, L., Evolution of Domestic Dwellings in Cyprus and Energy Analysis, *Renewable Energy,* 2001; Vol. 23, No. 2, pp. 219-234.

Florides, G., Tassou, S., Kalogirou, S. and Wrobel, L., Measures Used to Lower Building Energy Consumption and their Cost Effectiveness, *Applied Energy Journal*, 2002; Vol. 73, No. 3-4, pp. 299-328.

Kalogirou, S., Florides, G. and Tassou, S., Energy Analysis of Buildings Employing Thermal Mass in Cyprus, *Renewable Energy*, 2002; Vol. 27, No. 3, pp. 353-368.

Klein S.A. *et al*. TRNSYS Manual, University of Wisconsin, 1996.

Knight K.M., Klein S.A. and Duffie J.A. A Methodology for the Synthesis of Hourly Weather Data, *Solar Energy*, 1991; Vol. 46, No. 2, pp. 109-120.

Petrakis M, Kambezides H.D., Lykoudis S., Adamopoullos A.D., Kassomenos P., Michaelides, I.M., Kalogirou S.A., Roditis G., Chrysis I. and Hadjigianni A. Generation of a Typical Meteorological Year for Nicosia Cyprus. *Renewable Energy,* 1998; Vol. 13, No. 3, pp. 381-388.