THE ENERGY BEHAVIOUR OF THE RESIDENTIAL BUILDING STOCK IN CYPRUS IN VIEW OF THE ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE IMPLEMENTATION

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Summary

The significance of the residential building sector in terms of energy consumption is well acknowledged. Several studies have shown that the potential of energy savings in this sector is quite significant. In this view the knowledge of the way the residential building stock of Cyprus behaves in terms of energy consumption is quite valuable. This knowledge will assist policy makers to formulate targeted measures aiming the improvement of energy efficiency and will provide valuable information for setting current legal standards and benchmarks in the energy performance certificate, a requirement of the 2002/91/EC Directive. Unfortunately, the existing knowledge on this subject is quite poor. As a remedy a research project supported by a national research grant is in operation since December 2008.

This paper presents the outline, goals and methodology of this research project and the findings regarding the energy behaviour and other characteristics of the residential building stock of Cyprus. From the analysis of the results for about 500 residential buildings examined, it seems that the energy demand and primary energy required is lower than that of other European countries. Moreover, it seems that the age of residential buildings has low correlation with the energy demand. Finally, in contrast with other

Northern and Central European countries, it is clear that the contribution of cooling energy requirements to the overall energy demand is quite significant.

Keywords: Residential building stock, energy performance, Directive 2002/91/EC, Cyprus, Operational rating

1 Introduction

Buildings consume about 40% of the final energy in EU and this consumption is responsible for 30% of carbon dioxide emissions [1]. Specialized studies showed that there is a large potential for the saving of energy in this sector [2]. Particularly for Cyprus, the fact that until recently there was no legislative regulation concerning the insulation of buildings, the potential of savings is even larger [3]. Under the target of the general scope of increasing the safety of energy supply [4], the reduction of greenhouse gas emissions [5] and the general policy for improving the energy performance, the European Commission issued the directive 2002/91/EC - energy performance of buildings [6]. According to this Directive, member states are required to specify their national methodology for the estimation of the energy performance of buildings and to establish the energy certification of buildings, following the specification of the highest limits of energy consumption per category of buildings [7]. The above Directive was harmonized in the national law system with the Law N.142 (I)/2006. In addition to this Directive, Cyprus adopted also Directive 2006/32/EC on energy end-use efficiency and energy services [8], which among others requires member states to establish and achieve a national indicative target in energy saving.

The establishment of the highest limits of energy consumption and the specification of energy classes, for the purpose of applying Directive 2002/91/EC, but also the drafting of a national plan for the achievement of the target set by 2006/32/EC, requires knowledge of the energy behaviour of the residential building stock of Cyprus.

It is important to note that this is the first time the total footprint of the energy performance of the building stock of Cyprus is attempted. This footprint will constitute the base which will support the application of a number of contractual obligations of the Republic of Cyprus which deal with energy efficiency and the energy performance of buildings. Additionally, the further processing of the obtained results will lead to the drafting of measures and targeted actions for the improvement of energy efficiency [9-14] which finally will support the central target of energy saving and the reduction of greenhouse gas emissions. At the same time it will support the basic target of independence of the economic development of Cyprus from the non regulated and unjustified increase the conventional fuels prices [15]. Finally, it is expected that the results of this research will create the prerequisites and the basis for the development of a critical research and educational core of knowledge in the area of development and design, energy policy and the drafting of subsidization schemes and other targeted actions for the energy conservation in buildings. It is also expected that the integrated recording of the energy performance of the building stock of Cyprus will be the reference point for comparison and a supporting tool for the drafting of an integrated energy policy in the buildings area.

In this work the results of the data collection and processing are presented. More specifically, the characteristics of the residential building stock of Cyprus are identified according to a selected sample as well as the energy consumption related results. Also, the interrelation between the actual collected results and the statistical weighted sample is shown.

2 Methodology

The methodology followed in this research project is shown on the figure 1 in the form of a process flow chart. The first step of this work was to elaborate the database of the Cyprus residential building stock on the basis of Statistics of Constructions and Housing [9] in order to classify the buildings according to the climatological zone, type, age and size of the housing units. The latter determined the residential building statistical weighted sample on which the research was to be undertaken. The target sample comprised about 500 houses. The next step was the data collection process which was divided into two parts namely; the sample of 500 houses based on the formulated questionnaire (operational rating) and the smaller sample of 20 selected houses for which in-situ measurements and asset rating using SBEM_Cy, which is the software provided by the Cyprus Energy Service for assessing the energy performance of buildings in Cyprus.

Both types of data will be properly processed and compared so as to lead to the creation of clusters for the energy consumption per category, based on today's consumption. After the creation of the clusters, some measures for the readjustment of the limits will be proposed according to the values collected, particularly for the two best cases A and B so as not only to reflect the current reality, but also to show the willingness of the political leadership for the improvement of the level of the constructions. Finally, based on the results and the conclusions coming out of the entire process some energy efficiency targeted measures will be proposed in the form of a guide.

Up to date the project is completed up to stage 4. The main objective of this paper is to present the results which concern the characteristics of the residential building stock and some energy consumption results for the sample of the 500 houses.

The initial number of the collected questionnaires was 530 where after their preliminary validation and evaluation was reduced to 482 questionnaires for which all data were recorded. This sample was judged as satisfactory and capable for secure conclusion making.

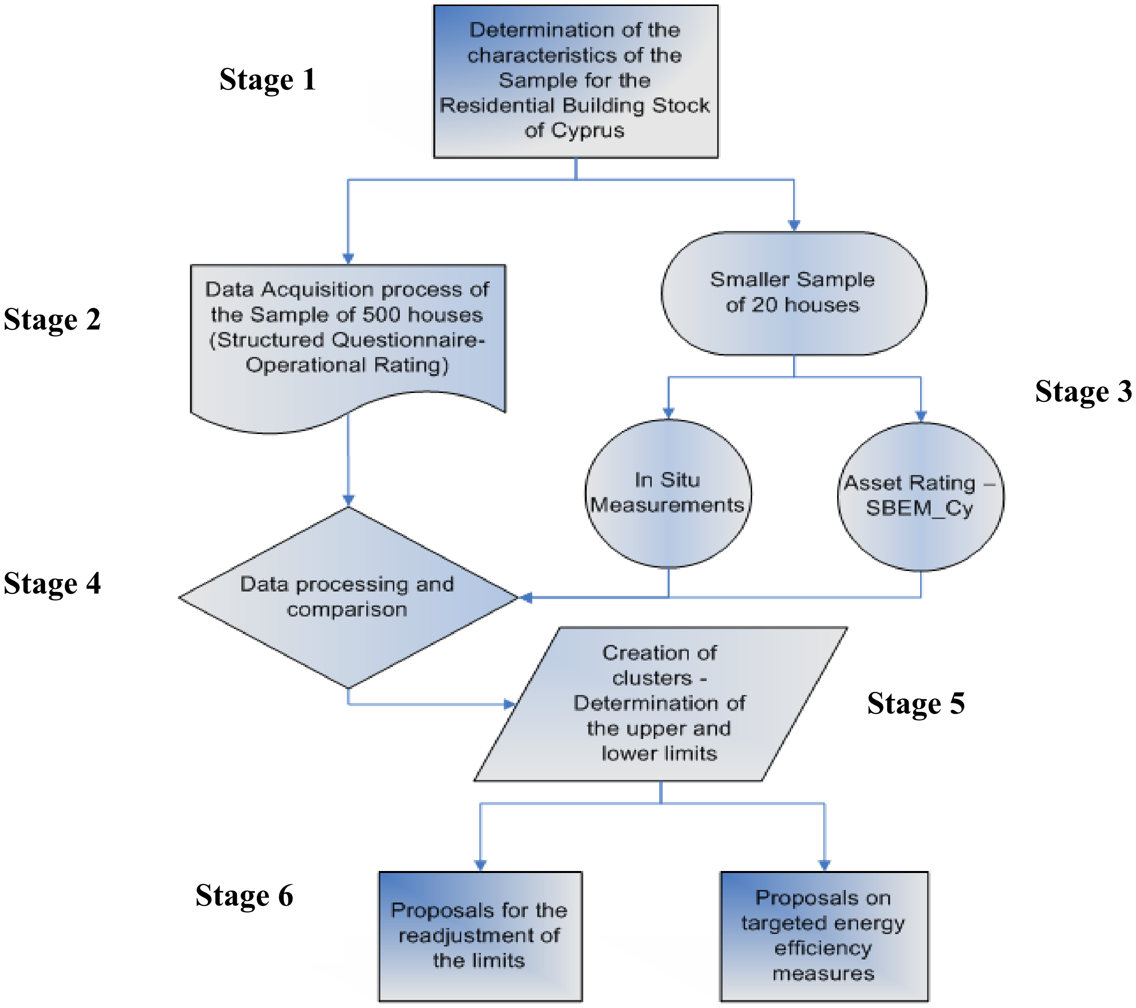

Fig. 1 Process flow chart the methodology followed in this research project

The results presented in this work are divided into two parts. In the first the characteristics of the residential building stock of Cyprus according to the complete sample are presented and discussed. In the second part the results concerning the energy consumption distributions as well as the correlation of energy consumption with various parameters like age, type, and zone are presented.

Some of the main data collected by the formulated questionnaires or properly calculated using these data are focused on the characteristics of the residential building stock of Cyprus. More specifically, these parameters are the climatological zone in which the house is built, the area of the house (m^2), the number of occupants per house, the year of construction, the type of house, the presence of insulation on the external walls, the type of the main heating system used, the house conditioned area (heating), the type of the main domestic hot water (DHW) system used and the use of double glazing. These parameters are focused mainly on the envelope of the structure and the HVAC and domestic hot water equipment.

The specifications of the required sample concerning the climatological zone, the type of the house and the year of construction were determined according to the Census of

Population Vol III, 2001 [18] and the Construction and Housing Statistics, 2006 [19] of the Statistical Service of Cyprus and is presented in table 1.

Tab. 1 Required distribution of the sample according climatological zone, the type of the house and the age of the construction

<table>
<tr><th colspan="5">Required Sample</th></tr>
<tr><td>ZONE 1
(Coastal area)</td><td>ZONE 2
(Low Land area)</td><td>ZONE 3
(semi Mountainous area)</td><td colspan="2">ZONE 4
(Mountainous area)</td></tr>
<tr><td>(54%) 270</td><td>(27%) 135</td><td>(16%) 80</td><td colspan="2">(3%) 15</td></tr>
<tr><td>Single house</td><td>Duplex house</td><td>Apartment</td><td>Mixed Use</td><td>Row of houses</td></tr>
<tr><td>(44%) 220</td><td>(17%) 85</td><td>(21%) 105</td><td>(8%) 40</td><td>(10%) 50</td></tr>
<tr><td>Dwellings built prior 1960</td><td colspan="2">Dwellings built between 1961 and 1990</td><td colspan="2">Dwellings built after 1990</td></tr>
<tr><td>(14%) 70</td><td colspan="2">(61%) 305</td><td colspan="2">(25%) 125</td></tr>
</table>

The climatological zone in which the house is built is crucial both in terms of weather conditions, architectural style and therefore energy behaviour. It is noticed that Cyprus Energy Service acknowledges four major climatological zones (figure 2) namely coastal, low land, semi-mountainous and mountainous areas.

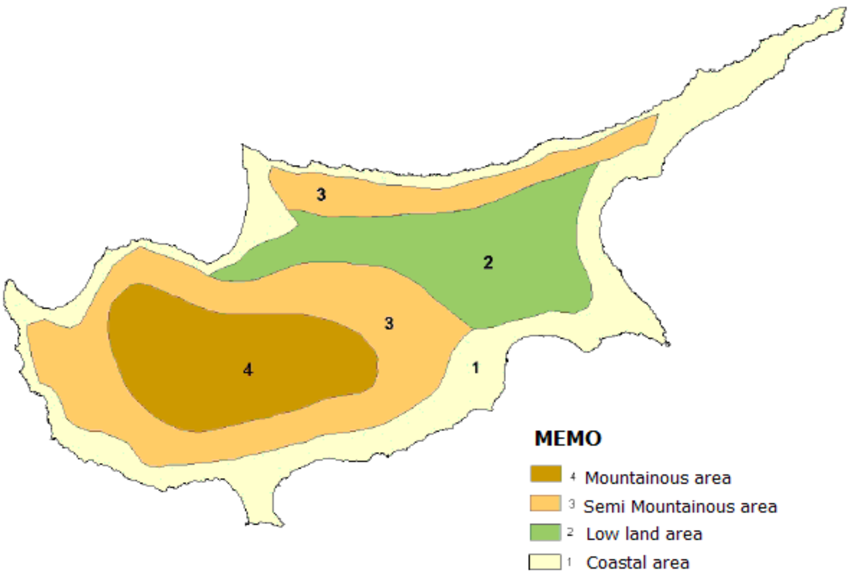

Fig. 2 Map of Cyprus showing the four major climatological zones

3 Characteristics of the residential building stock and energy consumption results

3.1 Characteristics of the residential building stock of Cyprus

The sample distribution according to the area of the house is graphically represented in figure 3 and as it can be easily noticed most of the houses are in between 51 and 200 m^2 with the mean area is 172.9 m^2. With a rough approximation the average area per occupant is equal to 57 m^2/occupant. The equivalent average European numbers are much lower than those in the present sample are equal to 84.5 m^2 and 33.8 m^2/occupant respectively [20].

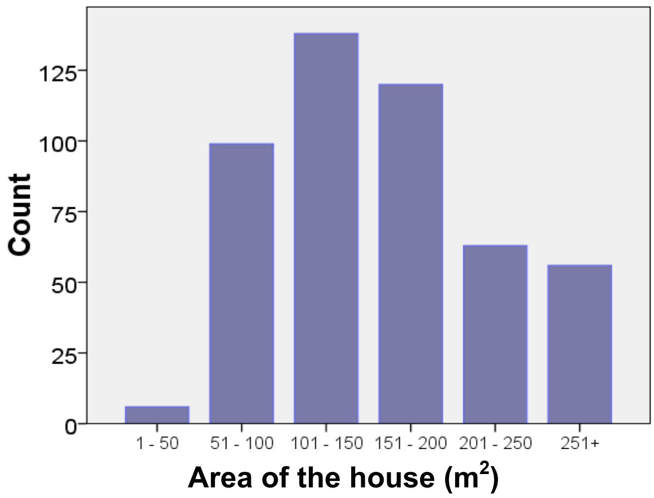

Fig. 3 Sample distribution according to the area of the house (m^2).

The number of occupants in a house is also important and directly related to the overall energy behaviour of the house. In figure 4 the number of occupants is graphically represented and as it can be seen more than 60 % of the houses have 2 to 4 occupants. The average number of occupants per house is 3.3 while the corresponding average European number is 2.5 [20].

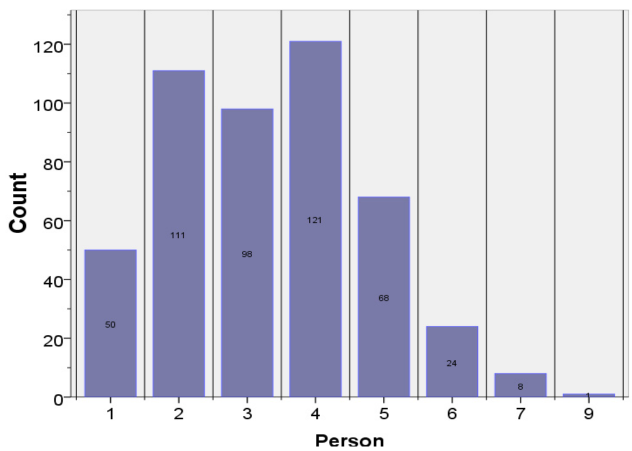

Fig. 4 Sample distribution according to the number of occupants per house

The sample distribution according to the year of construction is shown in figure 5. As can be observed the majority (~90%) of the residential building stock in Cyprus is constructed from 1971 and beyond. A rapid increase on dwelling construction was made between 1970-1980 as a result of the construction of refuges settlements to house the refuges of the Turkish invasion of 1974. Also, another fact worth noticing is that the sample distribution according to the year of construction is in very good agreement with the required one which is illustrated in table 1.

Fig. 5 Sample distribution according to the year of construction.

The dominant type of building in our sample is that of the single house which represents 68% of the total number which is much bigger than the required one which was 44% (see figure 6). The second most common type of building is that of the apartments. These results revile a very interesting fact for the Cyprus reality since 68% of the sample is single houses which are much higher than the average of other European countries [20].

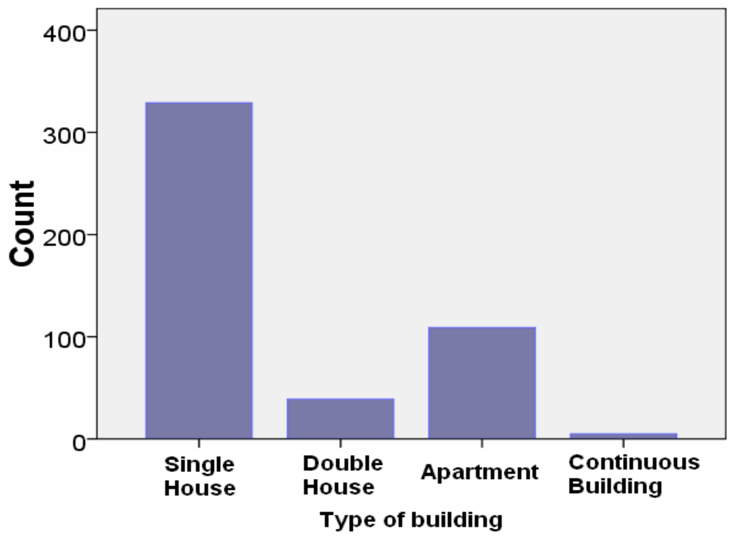

Fig. 6 Sample distribution according to the type of building.

The collected data show that more than 80% of the dwellings do not have thermal insulation on their external walls. This of course is a very disappointing fact since insulation is very important in the climatological conditions of Cyprus, especially during the summer period where the temperature rises as high as 42-45°C during daytime. Nevertheless, this observation reflects the reality on both past and present trend on dwellings' construction in Cyprus.

The type of heating system used in the buildings of the sample is shown in figure 7. The dominant heating system used as a primary source in Cyprus is that of the boiler using heating oil with a share of 37%. The second most commonly used heating system is that of air conditioning units most of which are split type and have the advantage of being used both for heating and cooling, which are both necessary for the climatological conditions of Cyprus. It should be cleared out that category 'Other' include central electrical heating systems which represent the majority of cases of this percentage. Finally, it is clear that the three central types of heating systems used in Cyprus are those of boiler (heating oil and gas) and electrical. The use of split type air conditioning units cannot be considered as a central system due to the fact that it consists of separate units for each room which operate individually according to the needs of the occupants.

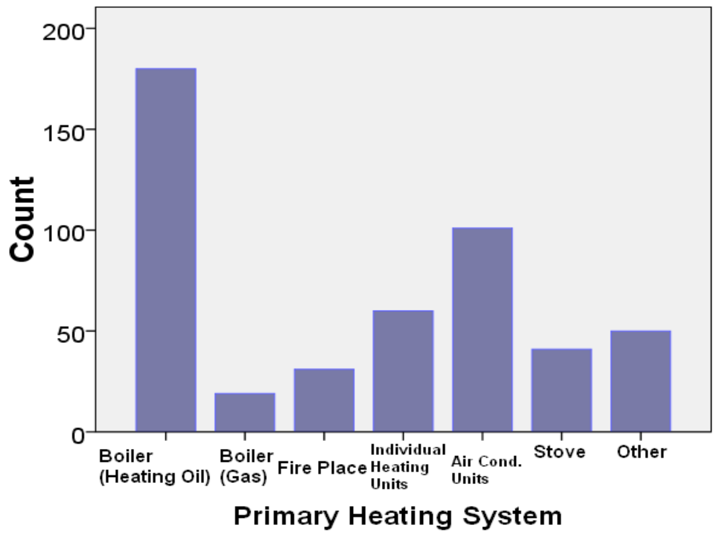

Fig. 7 Sample distribution according to the type of the main heating system used.

The results concerning the number of houses having their total area conditioned are in good agreement with the number of cases using central heating systems which correspond to about 50% in the sample.

According to Maxoulis and Kalogirou [21] Cyprus is a world champion in terms of solar thermal energy usage. This is also reflected on the results in our sample since solar thermal systems are used in more than 82% of the houses in Cyprus for the production of domestic hot water (DHW). This is close to the estimated 90% coverage of houses with DHW systems. This record should be credited to the favourable weather conditions, to a pioneering thermal solar industry and to the coordinated efforts of the various stakeholders. This result is also strengthened and confirmed by Weiss et al. [22] where Cyprus has the largest MWh_{th} per 1000 inhabitants.

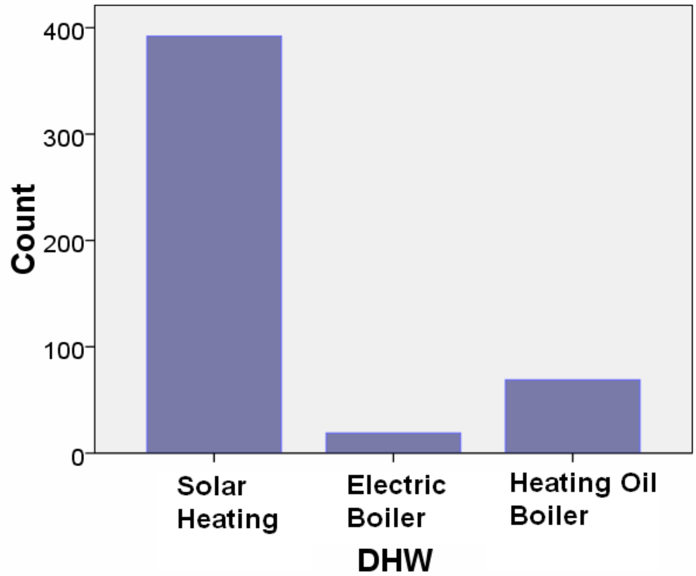

Fig. 8 Sample distribution according to the type of the main domestic hot water system used.

As the double glazing usage is concerned, the results where evenly split between those dwellings having double glazing installed and those which do not have, with a slight difference of 1% in favour of those that have. This is a very good result for the Cyprus reality but it is rather contradictory with the above stated fact that 82% of the dwellings do not have any insulation on their external walls. This occurred recently due to the subsidisation scheme and the preference given by the public to the change of single to double glazing [23].

3.2 Energy Consumption Results

In this part of the work the energy consumption related results are presented. More specifically, the mean electricity consumption along with the primary energy per total area as a function of the year of construction, the type of building, the salary of the occupants and the climatological zone are presented and discussed. The primary energy is calculated from the individual end energy per usage, such as electricity, oil, gas etc., by using the conversion factors given by the Cyprus Energy Agency that are shown in table 3.

Tab. 3 Conversion factors for different types of fuels to primary energy units (PEU) [24]

Fuel	CO_2 emissions	Primary Energy
	$kgCO_2/kWh$	kWh/kWh
Diesel Oil	0.266	1.1
Grid Supplied Electricity	0.794	2.7
Grid Displaced Electricity	0.794	2.7
LPG	0.249	1.1
Biomass	0.025	1.1

The mean electricity consumption on a bi-monthly basis is shown in figure 9. As it can be observed from the following figure there are two peaks on the consumption of electricity. The period in which the highest consumption of electricity is observed is that of

July-August due to the fact that this period has the highest temperature and humidity in the year and the need for cooling is imperative. This is a very important observation since this shows that the electricity demand for cooling is higher than that for heating, a fact which is not observed in other European countries especially the Northern ones. The second highest electricity consumption is observed during January-February where the lowest temperatures are present and the split type units are used for heating. Also, another point worth noticing is that the autumn and spring periods have more or less the same electricity consumption.

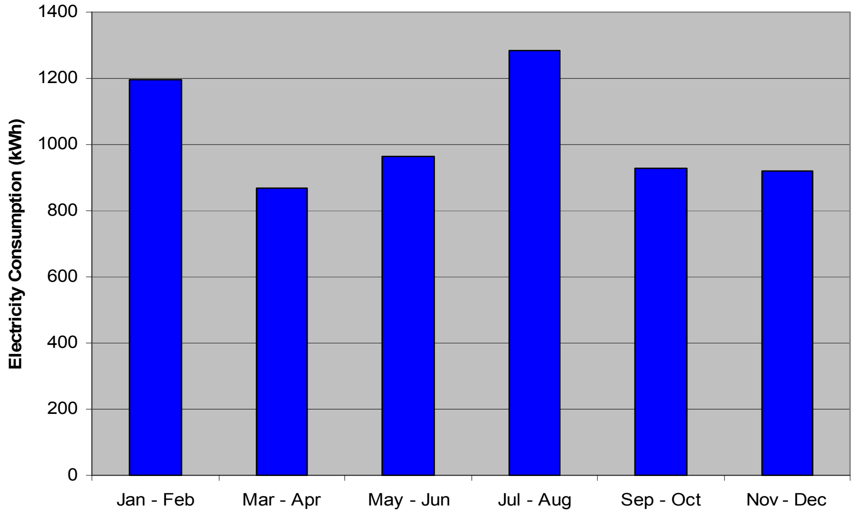

Fig. 9 Mean electricity consumption (kWh) of the sample per two month period

In figure 10 the primary energy per total area is represented graphically and as it can be seen, more than 60% of our sample is between 51-150 kWh/m^2. This energy demand is much lower than that of the equivalent European one [20]. In spite of the fact that in this work we examine the primary energy per total area the relatively low results are due to the fact that the houses in Cyprus do not use central cooling systems and only 50% use central heating.

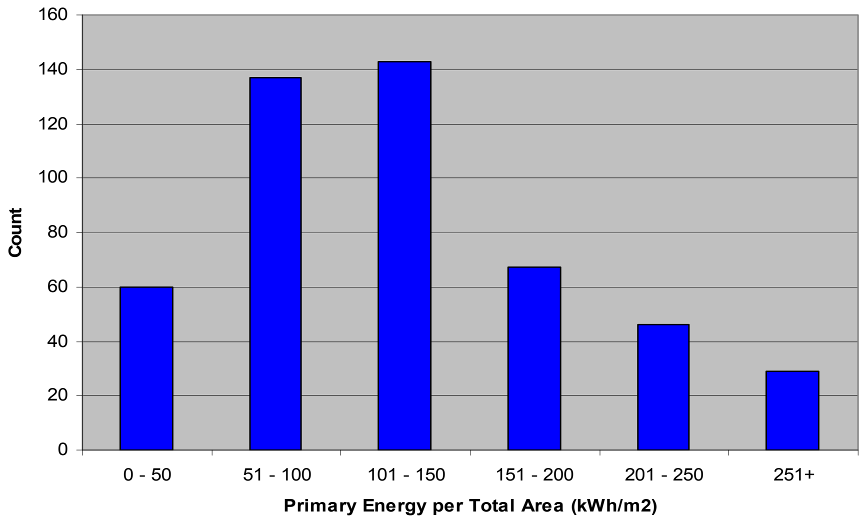

Fig. 10 Primary energy per total area.

As can be observed in figure 11 there is a slightly decreasing trend on the primary energy per total area over the years which is mainly caused by the fact that the construction materials and techniques are improving over the years. Also, another reason causing those improvements is due to the new legislative frameworks concerning the materials and more specifically the compulsory level of insulation to be used in each new house built.

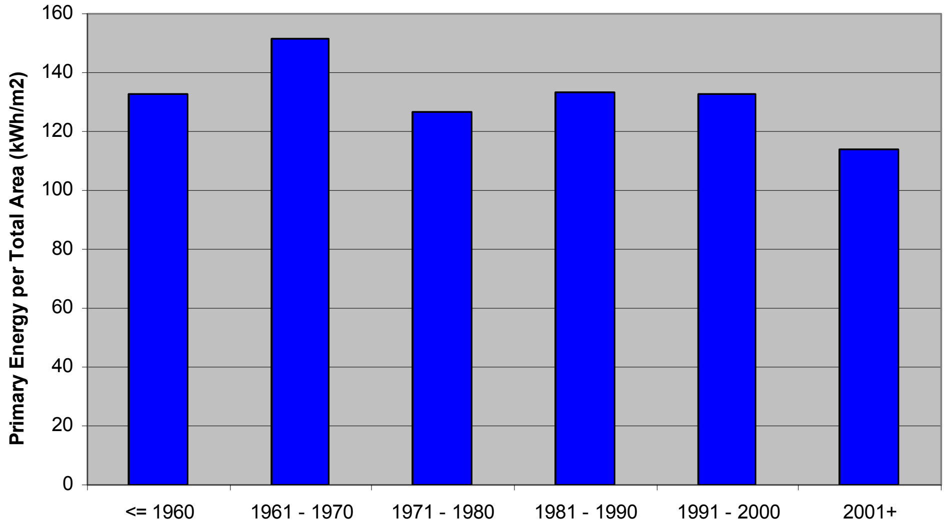

Fig. 11 Primary energy per total area as a function of the year of construction

The primary energy consumption per total area as a function of the house type is shown in figure 12. The house type is directly related to the primary energy per total area and as it can be seen the type of house with the lowest primary energy per total area is the continuous one due to the fact that it has reduced thermal losses from the external walls since it is in contact with other houses. On the other hand, the type with the highest primary energy per total area is the double house, which is a two storey building with two separate houses.

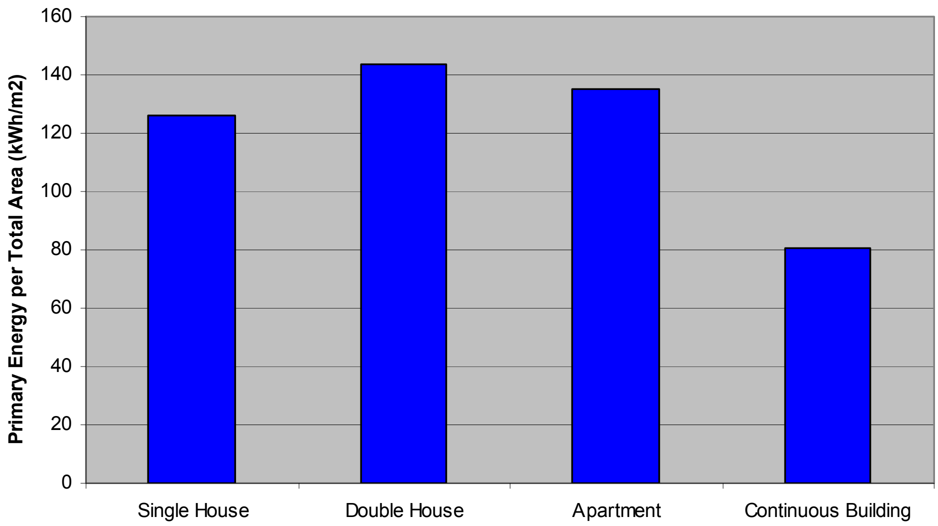

Fig. 12 Primary energy per total area as a function of the house type.

The effect of salary range of all occupants in a house is represented graphically in figure 13. Between 9,000-13,000 € and 24,000-63,000 € per year the primary energy per total area is around 130 kWh/m^2. The highest primary energy per total area is ~165 kWh/m^2 which corresponds to a salary range of 0-9,000 €. A possible explanation is that due to the low salary there isn't any type of insulation installed in the house while the low quality of the energy consuming systems also affects the overall energy consumption.

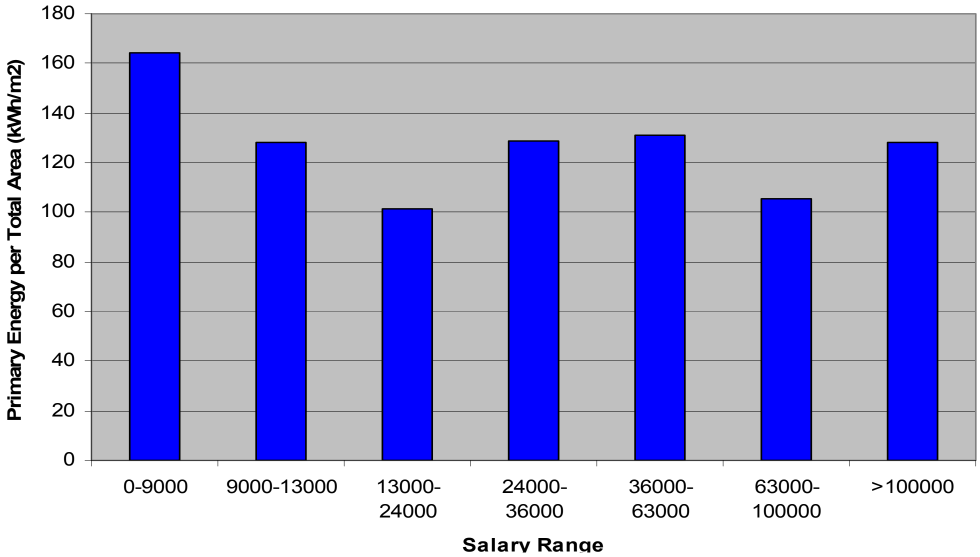

Fig. 13 Primary energy per total area as a function of salary range.

Finally, the climatological zone effect on the primary energy per total area as shown in figure 14. It should be noticed that the vast majority, over 80%, of the population of Cyprus lives in zones 1 and 2. As it can be observed zone 3, which is the semi-mountainous area, has the highest primary energy demand per total area. This is caused by the fact that this area has lower temperatures during the winter than zones 1 and 2 while it has relatively more people living in it than zone 4. On the other hand zone 4 has the lowest primary energy consumption per total area which is mainly caused to the fact that central heating systems are not used during winter time and due to mild weather in summer there is no need for air conditioning systems. The reason for not using central heating systems in this zone is because most of the inhabitants are old people living in old houses that do not have this kind of systems installed and they are using wood burning stoves or fireplaces for heating. Zones 1 and 2 have more or less the same primary energy per total area, ~125 kWh/m^2, with a slight increase for zone 2.

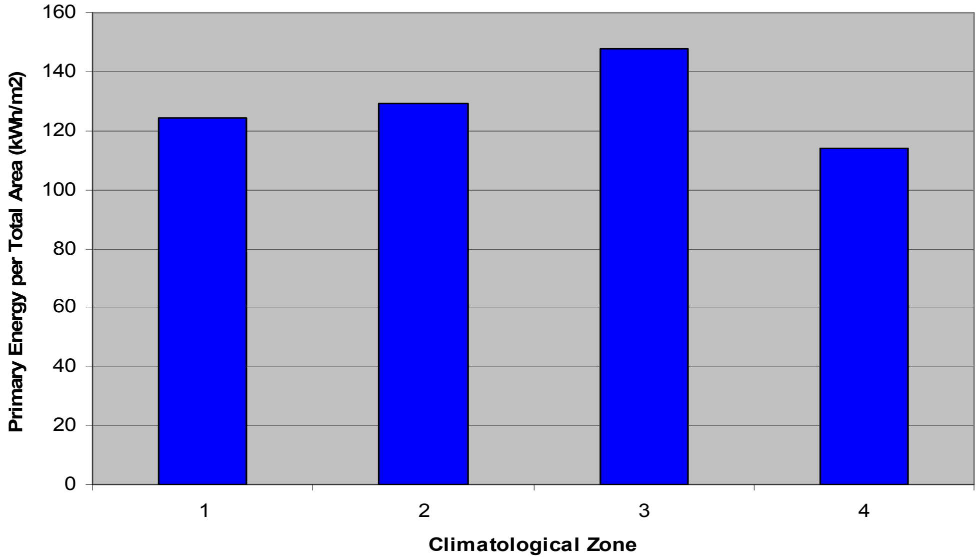

Fig. 14 Primary energy per total area as a function of climatological zone.

4 Conclusions

In this work the outline, goals and methodology followed in this research project were exhibited along with the findings regarding the energy behaviour and other characteristics of the residential building stock of Cyprus. Also, some very interesting results concerning the energy consumption are presented.

From the analysis of the results for 482 residential buildings examined some very interesting conclusions are extracted. The total house area together with the area per occupant are much higher than the average European numbers. The majority of the residential building stock of Cyprus was built after 1971 and more specifically during the mid 80's to 2001. The dominant type of house in Cyprus is that of single-house which represents 68% of the total residential building stock.

A very disappointing fact is that more than 80% of the houses in Cyprus do not have insulation installed on their external walls. In contradiction to this, more than 50% of the houses have double glazing installed. On the other hand, a very optimistic and important fact is the vast usage of solar thermal systems for the production of domestic hot water (DHW) that makes Cyprus a worldwide champion on the use of these systems.

The fluctuation of the mean consumption of electricity has two peaks occurring during the worst winter and summer periods namely January to February and July to August respectively. The primary energy per total area in more than 60% of our sample is between 51-150 kWh/m^2 which is much lower than other European countries. Also, a slightly decreasing trend of the primary energy per total area is observed over the years probably caused by the improvement on the construction materials and the obligatory use of insulation due to new legislative frameworks. The most energy consuming type of house is that of double house while the most energy saving type is the continuous one.

As the effect of annual salary range of the occupants is concerned it is worth noticing that between 9,000-13,000 € and 24,000-63,000 € the primary energy per total area is around 130 kWh/m^2 while the highest primary energy per total area is ~165 kWh/m^2 corresponding to a salary range of 0-9,000 €. A possible explanation is that due to the low salary there isn't any type of insulation installed in the house while the low quality of the energy consuming systems also affects the overall energy consumption

Finally, the climatological zone with the highest primary energy demand per total area is that of zone 3 and the one with the lowest demand is zone 4. Zones 1 and 2 which have more than 80% of Cypriot population living in them have more or less the same primary energy demand per total area of ~125 kWh/m^2.

Acknowledgement

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