Cluster Analysis in Energy Classification of School Buildings

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ABSTRACT

The present paper presents the results of the application of cluster analysis in the energy rating of school buildings. A complete program on energy and environmental quality of school buildings was undertaken by NKUA in collaboration with the School Authority of Greece. The research was based on the participation of 320 schools of secondary education from all the prefectures of Greece. The questionnaires used for this analysis contained data such as the annual consumption for heating and lighting, the area of the building, the number of students and professors, the installed power of the boiler, the manufacturing year of the building and the schedule of operation. Finally, the energy performance of the school buildings in relation to the normalized annual energy consumption with floor area and climatic severity index was rated using a fuzzy clustering technique (FCT) and an energy classification tool has been developed.

KEYWORDS: energy rating, school buildings, energy audits, heating consumption

INTRODUCTION

In Greece, the energy consumption, the potential for energy conservation as well as the identified indoor air quality problems in school buildings, have been initially investigated and presented in [1 and 2]. The analysis carried out has clearly shown that energy rating techniques have to be applied to better understand the characteristics of the buildings stock and thus organize efficiently possible energy and environmental improvements. Various national energy-rating schemes have been proposed, [3, 4]. It is evident that all rating schemes are based on the characteristics of the national building stock and may not be used elsewhere. Various techniques have been proposed to develop rating schemes, [5]. Most of the proposed methods define energy classes based on the cumulative frequency distribution of the energy consumption of the buildings stock. For example, classes A, B, C, D are associated with the zones below the 25, 50, 75 and 100 percent of the buildings stock in the cumulative frequency distribution of the energy consumption. Such a classification requires that the used sample of building energy data strictly follow a normal distribution while there is a very good representation of the existing building stock. However, given the variety of the characteristics of the buildings, such a condition rarely applies. In most cases, the existing energy data are combined around various clusters that may not represented by a normal distribution.

Energy Rating Using Clustering Techniques

The purpose of clustering is to identify natural groupings of data from a large data set to produce a concise representation of a system's behavior. Cluster analysis is a way to examine similarities and dissimilarities of observations or objects. Data often fall naturally into groups, or clusters, of observations, where the characteristics of objects in the same cluster are similar and the characteristics of objects in different clusters are dissimilar.

Clustering techniques have been extensively used for climate classification, [5, 6], while similar techniques have been used in the development of energy codes and standards.

Intelligent fuzzy clustering techniques permit to classify building energy data around clusters of similar characteristics. The technique provides information on how to group energy data that populate a multidimensional space into a specific number of different clusters. The method considers that each data object belongs to a cluster to some degree that is defined by a membership grade, [7,8].

Data on the total and specific energy consumption of about 320 school buildings have been collected in Greece. The energy consumption data have been provided by the school authority of the country, (OSK), in collaboration with the management of each school building. The energy consumption has been obtained from the detailed energy bills kept at each building. In parallel, information about the operational period of each building, the number of students, the construction characteristics, the installed equipment, etc have been collected as well.

Energy normalization techniques have been applied to homogenize the data set. Normalization has been carried out regarding the size of the building, the external climate variability as well as the operational period of the schools. The Climatic Severity Index [9], method has been used for the climatic normalization. The method presents many advantages compared to the Degree Days or the Modified Heat Utilization normalization methods.

The frequency distribution of the data set regarding heating, electricity and total energy consumption are shown in Figure 1.

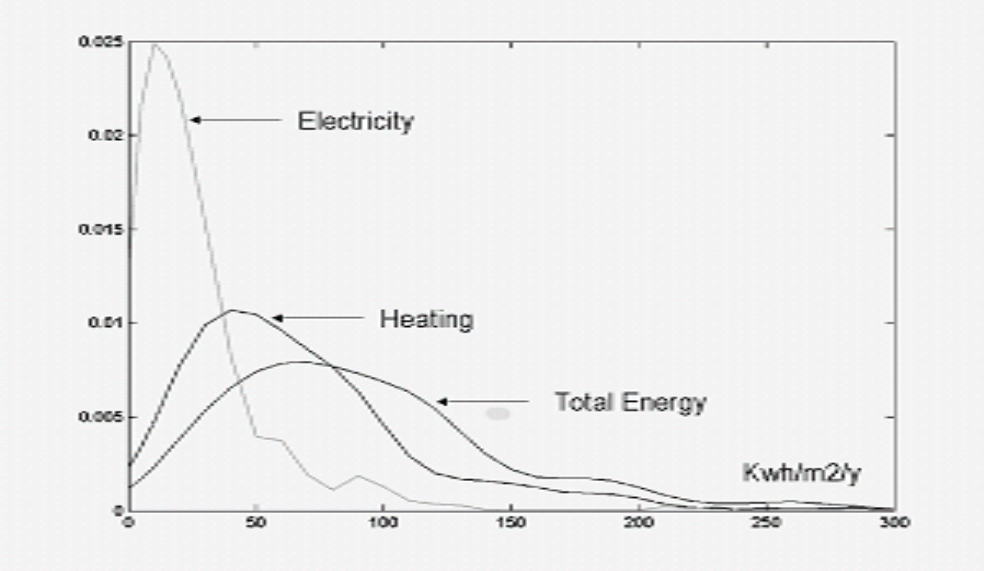

Figure 1 Frequency curve of the energy consumption for heating, electricity and total energy consumption.

The mean annual energy consumption for heating is close to 68 kWh/m2/year and for electricity close to 27 kWh/m2/year. Based on the frequency distribution the following energy benchmarks applies for school buildings in Greece:

- Typical School Building, (50 % of the stock): Heating: 57 kWh/m2/y, Electricity: 20 kWh/m2/y
- Best Practice Building, (top 25 % of the stock): Heating: 32 kWh/m2/y, Electricity: 10 kWh/m2/y

In order to create energy classes for school buildings, fuzzy clustering techniques have been applied. Five energy clusters for both the total and the heating energy consumption have been calculated, Figures (2,3).

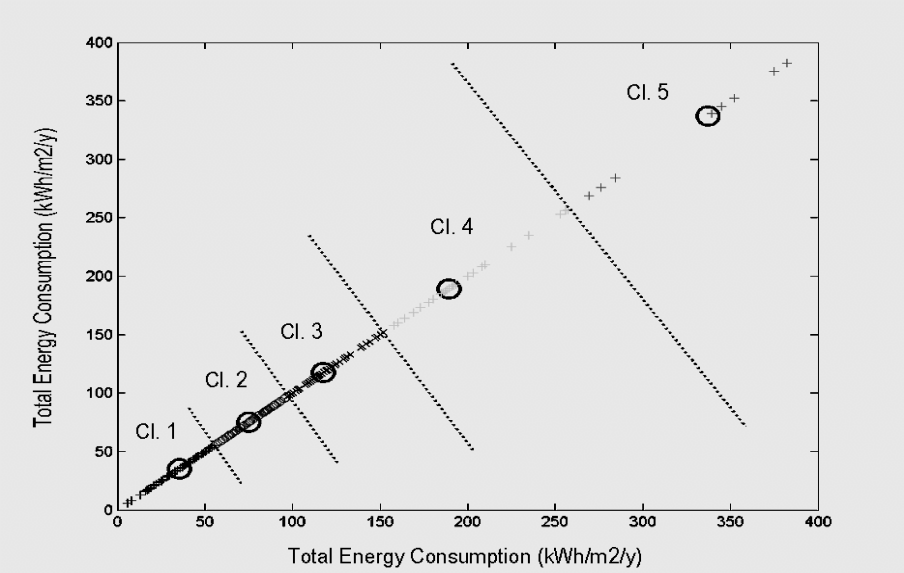

Figure 2 Defined clusters of total energy consumption for school buildings in Greece

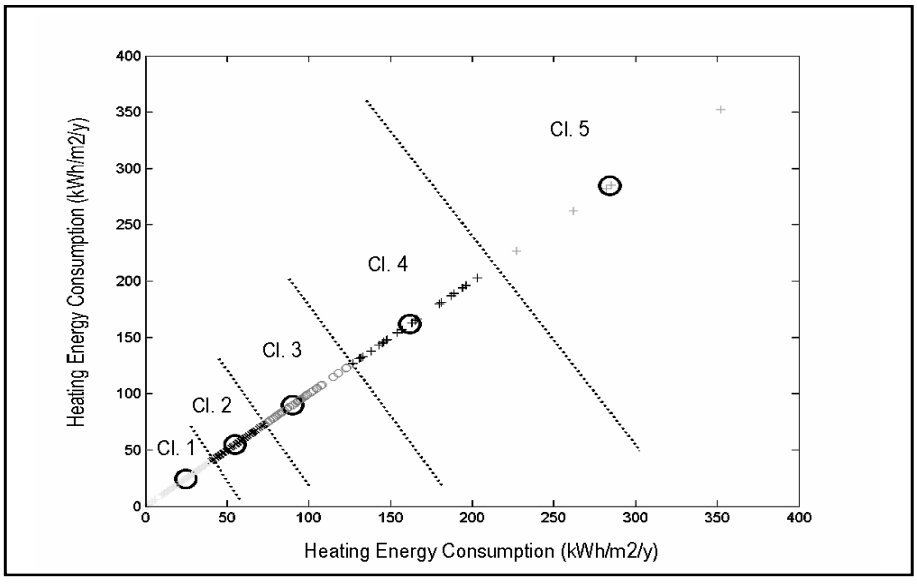

Figure 3 Defined clusters of heating energy consumption for school buildings in Greece

Given the calculated grouping of data, each cluster has been considered as an energy class. Thus a five classes rating for the total as well as the heating energy consumption is obtained, (Figures 4, Figure 5).

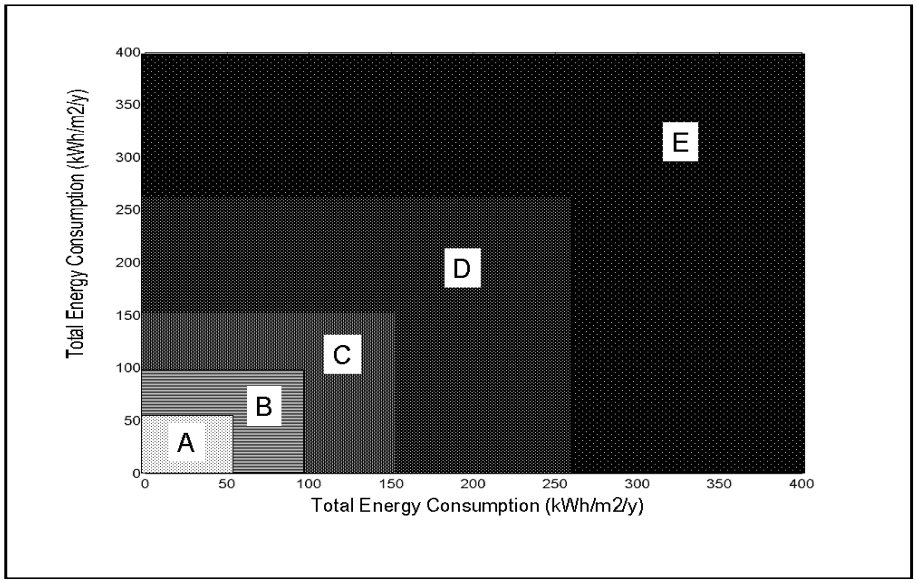

Figure 4 Defined energy classes of total energy consumption for school buildings in Greece when clustering techniques are applied

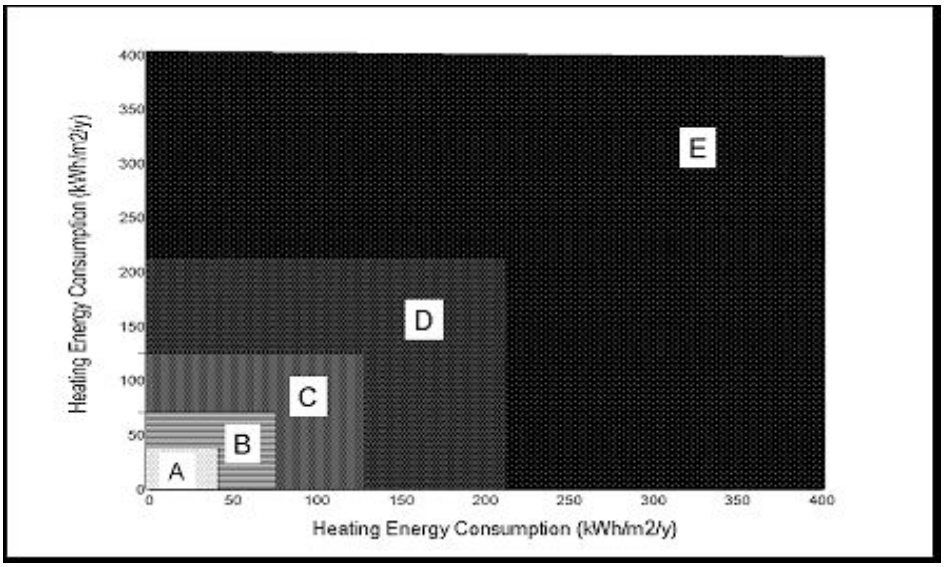

Figure 5 Defined energy classes of heating energy consumption for school buildings in Greece when clustering techniques are applied

Comparison Against Equal Frequency Rating Procedures

Equal Frequency Rating Procedures define energy classes based on the frequency distribution of buildings and by considering an equal number of buildings for each class. Thus, in case that five classes have to be defined, the upper class involves the top 20 % of the building stock, the second class buildings between the top 20 and 40 % of the buildings, and the last class the worst 20 % of the stock.

The obtained energy classification for total and thermal energy consumption of the school buildings in Greece is given in Figures (6-7).

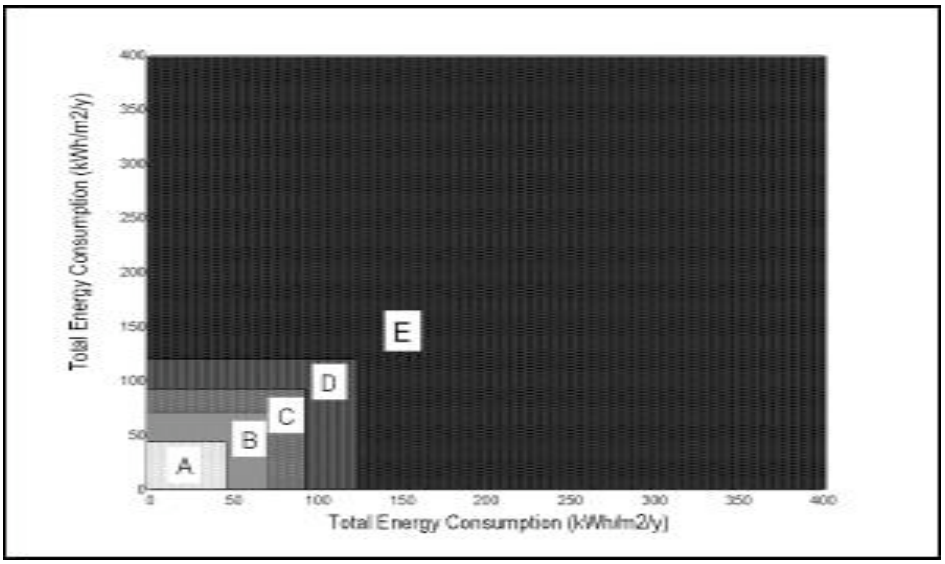

Figure 6 Defined energy classes of total energy consumption for school buildings in Greece when equal frequency techniques are applied

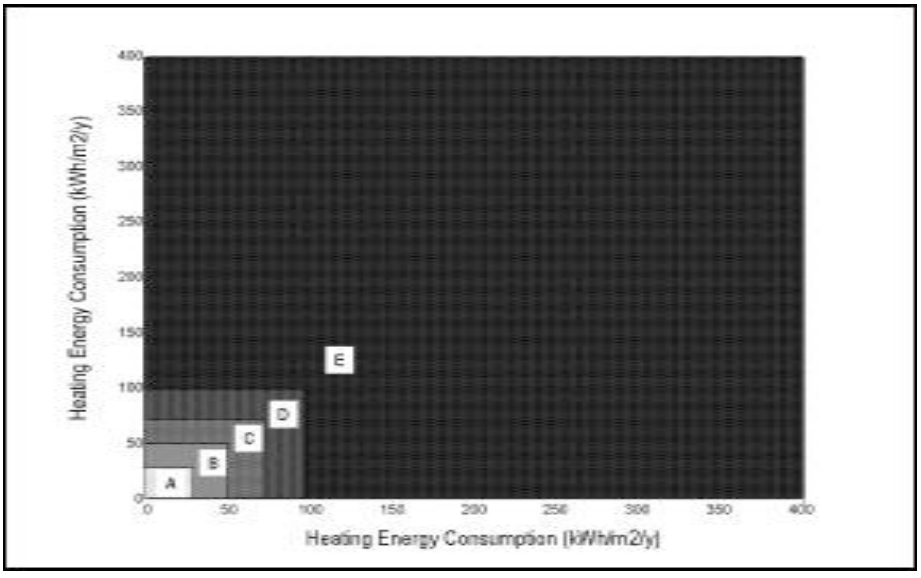

Figure 7 Defined energy classes of heating energy consumption for school buildings in Greece when equal frequency techniques are applied

As shown, the obtained classification varies considerably from the corresponding classification when fuzzy clustering techniques are used.

The use of the equal frequency rating procedure has resulted to four classes of short energy range and a class of very high range.

The classification given by the EFR methodology seems unbalanced and may be the source of many problems, like:

a) The energy range of the classes is low and close to the monitoring error and the normalization inaccuracies.

b) Classes with short ranges may produce a very non-balanced rating of buildings as small or non-significant changes may modify the classification of the building in both directions.

c) The class of the high-energy consumption, 'E Class' is so large that may discourage buildings with very high-energy consumption to undertake energy retrofitting measures to improve classification.

On the contrary, classification using clustering techniques offers more robust classes avoiding the problems mentioned previously. In parallel, such classifications consider, in a more consisting way, the common characteristics of the buildings and classify them according to existing similarities.

CONCLUDING REMARKS

A new method for energy classification and rating of school buildings has been presented. The method is based on the application of fuzzy clustering techniques and presents important advantages compared to the frequency rating procedures. The method offers more robust classes avoiding problems of unbalanced classification while it considers in a more concise way the common characteristics of the buildings and classify them according to existing similarities.

The proposed energy classification method can be applied easily to classify the energy performance of school or other types of buildings.

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