

On the relation between income, electricity and oil consumption for different types of houses in Athens

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ABSTRACT

This study is based on the analysis of approximately 1000 questionnaires, which include information about the incomes, the oil and electricity consumptions as well as characteristics linked to the type, the size, the existing thermal insulation materials and the indoor air temperatures of the buildings.

The data were normalised according to the outdoor air temperature as well as according to the surface area of the building. Then an attempt to correlate the two investigated parameters with income was made.

At first four different building categories were considered (non-insulated apartments, insulated apartments, non-insulated detached houses, insulated detached houses). Following this categorisation, it is evident that a better approach can be achieved considering exponential laws.

1. INTRODUCTION

Nowadays it is evident in building design that the construction should aim to:

- Use materials which are environment-friendly and do not harm the inhabitants health.
- High energy efficiency combined to the lowest possible cost not only of the construction but also of the subsequent energy demand for heating and cooling.
- The protection of the outdoor environment by minimising emissions and by avoiding bad microclimatic changes.

Public and residential buildings in Europe

have an energy consumption of 40% of the total energy demand (Brussels, 2001). In particular, from the energy consumed in residential buildings 57% is for space heating, 25% is for water heating, 11% is for electrical appliances and lighting and 7% is for cooking. Evolution of building energy consumption shows a continuous increase and considering the climatic changes, the heating energy consumption is expected to increase up to 70% until 2030. However, in Greece the above consumption are much higher considering that 77% of the buildings are not insulated. This percentage is the highest between the European countries.

The energy saving measures in the building sector, not including the use of renewable energy, can be summarised below:

- Replacement of old boilers, which can lead to reduction of about 5% of the total heating consumption.
- Insulation of old buildings.
- Reduction of energy consumption through bioclimatic building design, optimising the solar gains for natural lighting, heating, natural ventilation and cooling. It has been calculated that such an optimisation can reduce energy consumption up to 60% while ameliorating the outdoor air quality.

Given that oil is the mainly used fuel for central heating units, it is evident that not only the cost for the Greek economy but also the aggravation of the atmosphere by emissions are overwhelming quantities. Therefore, it is necessary to study in detail the existence of the relation between income, residential building quality, residential buildings characteristics and energy consumption.

Table 1: Regression lines ($y = ax^b$) between consumptions and surface area (x). R represents the correlation coefficient.

Type of building	Electrical consumptions (z_1)		Oil consumptions (z_2)	
Non-insulated apartments	$z_1 = 158.5x^{0.78}$	R = 0.429	$z_2 = 356.1x^{0.77}$	R = 0.428
Insulated apartments	$z_1 = 277.1x^{0.66}$	R = 0.316	$z_2 = 797.5x^{0.61}$	R = 0.337
Non-insulated detached houses	$z_1 = 392.3x^{0.60}$	R = 0.301	$z_2 = 365.6x^{0.84}$	R = 0.419
Insulated detached houses	$z_1 = 474.2x^{0.57}$	R = 0.417	$z_2 = 625.1x^{0.78}$	R = 0.518

2. STATISTIC RESEARCH

The statistic research was based on a series of questionnaires (National Statistical Organisation of Greece, 1993) that covered the city of Athens and provided with information about approximately 1000 residential buildings. From these residential buildings 57% are apartments and 43% detached houses. More than 75% of these buildings were constructed after 1970 and the main source for space heating is oil (94%). As far as the insulation is concerned, almost half of them are insulated while less have double glazing units.

The indoor temperature at which the users turn on the heating units varies between 15 and 25°C. Approximately, 45% of the users turn on the heating system when the indoor temperature is between 18 - 20°C, while the operating time of 60% of the heating units varies between 5-9 hours.

According to the above information, a correlation between the oil consumption, the electricity consumption and income was attempted.

It should be noted that the value for the energy consumed for heating has been normalised according to the outdoor temperature for the period that the questionnaires refer to, so that the results would be independent of the temperatures observed during that period.

3. RELATION BETWEEN CONSUMPTION AND SURFACE AREA

In this paper, four categories were generated according to the type of the residential building and the existence or not of insulation in each one. Therefore the four categories are:

- Non-insulated apartments.
- Insulated apartments.
- Non-insulated detached houses.
- Insulated detached houses.

At this point other parameters such as the

floor, the neighbouring with other apartments, the existence of double glazing units, the use of air-conditioning etc, were not taken into account.

Then for each building category a correlation between the electricity or the oil energy consumption and the surface area of the building was attempted.

It is evident (Table 1) that the consumption is correlated to the surface area in a power-law fashion and all the correlations are statistical significant in the significant level of 0.05 ($R > R_{0.05}$ (critical)). This statistical significant result allowed the normalisation of the consumption values according to the relations in table 1. The constant a of the relation for the insulated buildings is greater than that for the non-insulated ones, which primarily seems uncompromising. However, by calculating the average income for each type of building, which was 11 - 34% higher for the people living in insulated houses, this diversification can be justified.

4. ELECTRICAL CONSUMPTION AND INCOME

As a first approach the relation between the normalised values of electrical consumptions (kWh/m²year) and income (x) for each of the categories previously defined.

It is obvious for all 4 categories (Figs. 1a, b, c, d) that the optimum regression line is logarithmic, i.e. a statistical significant linear correlation exists between the logarithmic values of income and normalised values of the electrical consumption (kWh/m²year). In all cases a statistical significant decreasing tendency for the consumption is observed as a function of income, approximately 2 - 5 kWh/m²year for every 1000 euros raise of income. It is also evident that, the consumption of electricity in apartments is of this order of magnitude regardless of the existence of insulation. Moreover, the consumption in detached houses is slightly higher, especially in insulated detached houses,

where the decreasing tendency of the consumption in relation to income is more significant.

5. ENERGY CONSUMPTION FOR HEATING AND INCOME

In order to extract a relation between energy consumption for heating and income x the residential buildings were categorised as stated previously. The optimum regression line was logarithmic (Figs. 1a, b, c, d) and statistical significant in the significant level of 0.05.

Generally, a statistical significant negative correlation is observed between consumption and income, which varies from 2 to 9 kWh/m²year per 1000 euros raise of income. In this case the consumption in detached houses is higher than in apartments which can be attributed to the fact that the walls of detached houses are exposed to outdoor conditions.

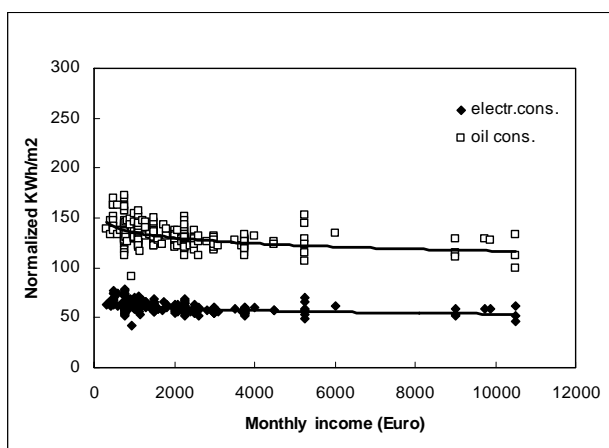


Figure 1a: Apartments without insulation.

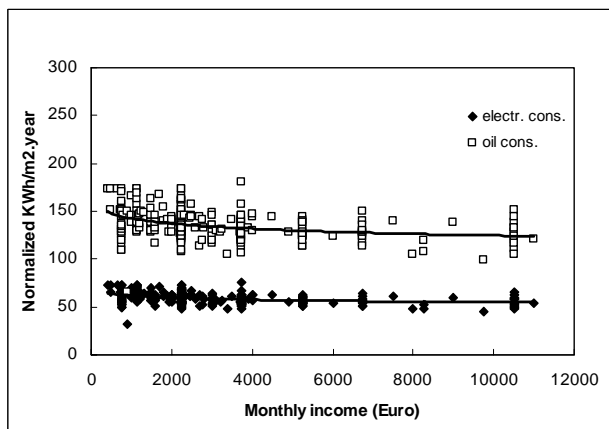


Figure 1b: Insulated apartments.

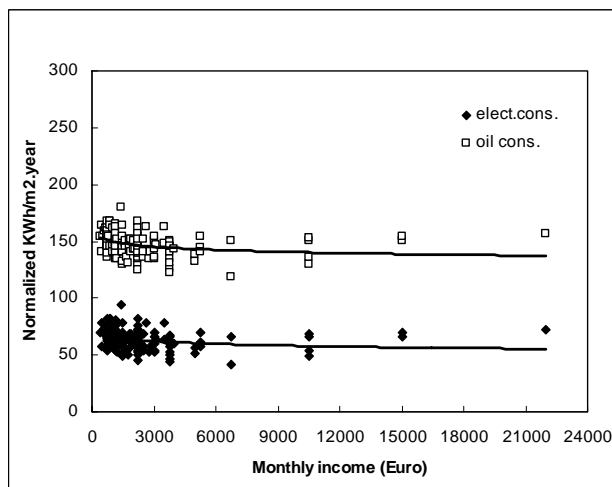


Figure 1c: Detached houses without insulation.

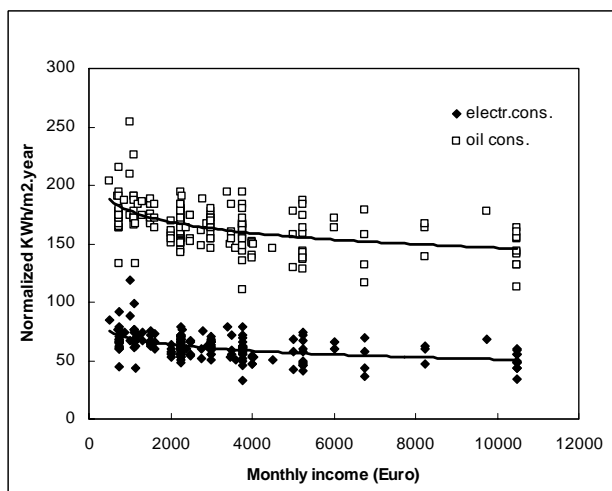


Figure 1d: Insulated detached houses.

6. CONTRIBUTION OF DOUBLE GLAZING IN THE REDUCTION OF ELECTRICAL ENERGY CONSUMPTION

The categories defined previously were divided into two sub-categories depending on whether the building had double glazing windows or not. The purpose of this was to investigate the impact of double glazing units on energy consumption for heating.

As shown in Table 2 only in the case of insulated buildings the existence of double glazing contributes in the statistical significant consumption decrease (t values are greater than the critical value 1.96 at the 0.05 significant level). The presence of double glazing especially for the non-insulated detached houses does not offer any reduction of energy consumption for heating due to the fact that all walls are exposed

Table 2: Mean values of oil consumption (kWh/m²year) and t values statistics of the differences of the mean.

Type of building	Double glazing	Single glazing	t
Non-insulated apartments	129.4	132.4	1.65
Insulated apartments	134.0	139.8	2.72 s.s.
Non-insulated detached houses	145.6	147.9	0.13
Insulated detached houses	163.7	170.0	2.05 s.s.

Residential Buildings Based on Their Actual Energy Consumption. Final Report, July 2001
Survey: Energy Consumption in Residential Buildings 1987-1988. National Statistical Organisation of Greece, Athens 1993 (in greek).

to the outdoor conditions.

7. CONCLUSIONS

The first general conclusions drawn from the study of the electrical and space-heating energy consumption of approximately 1000 residential buildings situated in the greater region of Athens can be summarised below:

1. The normalised values of electrical consumption and the respective monthly income values are related logarithmically. The observed negative correlation is statistical significant for all cases. Furthermore, the observed reduction of consumption with the increase in income is significant.
2. The energy consumption for space heating is inversely proportional to income for all types of buildings. These parameters are related by a logarithmic law and have a statistical significant reduction in consumption (2-9 kWh/m²year) for every 1000 euros increase of the income.
3. The presence of double glazing units in residential buildings results in a statistical significant lower mean value of space-heating energy consumption only for the case of insulated residences. Especially in non-insulated detached houses no reduction in consumption is observed.

REFERENCES

- Proposal for a directive of the European parliament and of the council on the energy consumption of the buildings in the residential and tertiary buildings. Brussels 9.3.2001.
- EURO-CLASS: Development of an European Methodology to Experimentally Assess and Classify Existing