FORECASTS OF FUTURE ENERGY REQUIREMENTS BY THE MANUFACTURING SECTOR OF GREECE *

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An econometric model consisting of two equations is used to forecast the future electricity and other fuel requirements by the manufacturing sector of Greece. In the model, the energy prices and the manufacturing output are treated as exogeneous variables while total energy requirements and the ratio of electricity to other fuels constitute the endogeneous ones. Further to the forecasting the model is used to calculate short-run and long-run price elasticities and also the time period needed to pass for the manufacturing sector to complete its adjustment process towards its desired ratio of electricity and other fuel consumption. In view of these considerations it is concluded that the model can be used both for forecasting purposes and also as an instrument for formulating a proper price policy for energy with respect to the manufacturing sector.

I. INTRODUCTION

The purpose of this paper is to assess for the industries employing 10 persons or over and covering more than 85 per cent of the whole manufacturing sector of Greece, the probable cource of the demand for energy in total and for electricity and other fuels separately. Total energy demand is assumed to depend on the rate of growth of the manufacturing output, while the division of the demand between electricity and other fuels (among which oil constitutes about the 95 per cent) is governed by decisions which are influenced by the relative price and suitability of these types of energy. Therefore, estimates about the prospective demand for energy will be based on assumptions referring to the growth of the manufacturing output and to the relative prices charged to the manufacturing industries.

* I am indebted to Mr. P. Papadopetrakis who did the basic statistical work. I would like also to thank Mr. A. Gizelis for running the multiple regression programs. This paper was submitted to the «Symposium on the Role of Electric Power in Meeting Future Energy Needs and on International Cooperation in this Field», held by the ECE of the U.N., in Athens, in May, 1975, as a reference paper.

In particular, the probable future energy requirements by the manufacturing industries are estimated by using an econometric model consisting of two equations. The first equation is the energy input function which relates the total energy consumption to the manufacturing output. The second, a dynamic flow-adjustment equation, is the energy ratio function which relates, for each year, the ratio of electricity to other fuel consumption to the ratio of their price indices and to the consumption ratio achieved in the preceding year.* The energy input function will be used to estimate total energy requirements on the basis of assumptions referring to the growth rates of the manufacturing output. The energy ratio function, on the other hand, will be used to estimate the future ratios of electricity to other fuel requirements, on the basis of assumptions referring to the change in the ratio of their price indices.

II. PAST CHANGES IN ENERGY CONSUMPTION

The total energy consumption of the manufacturing industries was in 1971 85.49 million giga joule (GJ).** The relevant figure for 1963 was 43.35 million GJ. Thus, over the eight-year period, total energy consumption increased by an annual growth rate of 8.86 per cent. Electricity consumption increased from 3.91 million GJ in 1963 to 12.85 million GJ in 1971, that is, by an annual growth rate of 16 per cent. On the other hand, over the same time period, the consumption of other fuels (mainly oil) increased from 39.44 million GJ to 72.64 million GJ, that is, by 7.93 per cent. The result of this evolution was that the share of electricity consumption to total energy consumption rose from 9 per cent in 1963 to 15 per cent in 1971.

The manufacturing output of the industries considered, increased from 43.0 thousand million drs. in 1963 to 95.0 thousand million drs. in 1971 (in constant 1963 prices). This corresponds to an annual growth rate of 10.4 per cent. Thus, while in 1963 1.01 GJ was required for every one thousand drs. of output, the relevant figure for 1971 was 0.90 GJ, that is, a reduction of about 11 per cent which may be attributed to the improvements in energy utilisation, thanks mainly to technical progress.

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* A similar model relating to the substitution of oil for coal has been used in the «Demand for Fuel, 1948-1975, A sub-model for the British Fuel Economy» published for the Department of Applied Economics, University of Cambridge, by Chapman and Hall, 1968.

** The standard international unit for energy is the joule (J). The unit used in this paper is the giga joule (GJ), which is equal to a thousand million J. One GJ is approximately equal to 278 kwh or 239000 kcal., or to the thermal equivalent of 0.035 tce or 0.023 toe.

III. THE MODEL

The following notation is used :

Z = total energy consumption, in million GJ

E = electricity consumption, in million GJ

F = other fuel consumption, in million GJ ($Z = E + F$)

P^e = electricity price index (1963 = 1.00)

P^f = other fuel weighted price index (1963 = 1.00)

Q = manufacturing industries' output, in thousand million drs.

t = time in years.

1. The energy input function

Experimenting between linear and logarithmic relations, it was seen that the former proved to be less satisfactory. Thus, the following form of relationship for the energy input function is used, which is based on the assumption of a constant percentage change in energy consumption resulting from a change in the manufacturing output by one per cent :

$$Z = aQ^b$$

where, a, b are the regression coefficients to be estimated.

2. The energy ratio function

Assuming that, the ratio of electricity to other fuel consumption, achieved in year t, is a weighted geometric average of the ratio which is desired for this year and the ratio achieved in the preceding year, we may write :

$$(E/F)_t = (E/F)_t^{*c} \, (E/F)_{t-1}^{(1-c)} \qquad (2)$$

where, $(E/F)^*$ denotes the desired ratio and c and (l-c) $(0 < c \leqslant 1)$ are the relative weights. Also c can be interpreted as indicating the speed of adjustment of the achieved in year t ratio to the desired ratio. In fact, if $c = 1$ the whole adjustment process isr. completed in one year, while if $c < 1$ this process can not be finished in one year.

Assuming further that, the desired consumption ratio in year t is a function of the ratio of the electricity to other fuels' price indices of this year :

$$(E/F)_t^* = u \, (P^e / P^f)_t^s \qquad (3)$$

equation (2) can be written :

$$(E/F)_t = d_0 \, (P^e / P^f)_t^{d_1} \cdot (E/F)_{t-1}^{d_2} \qquad (4)$$

where, $d_0 = u^c$, $d_1 = sc$ and $d_2 = (1\text{-}c)$ are the regression coefficients to be estimated.

IV. APPLICATION OF THE MODEL

Equations (1) and (4) have been estimated by fitting them by the method of least squares to the annual data given in the table attached to the end of the paper. As can be seen, this table shows for the years 1963 to 1971 the total energy in million GJ and also, the ratio of electricity to other fuels consumed by the manufacturing industries employing 10 persons or over and covering more than 85 per cent of the manufacturing sector of Greece. The table gives also the ratio of electricity and other fuels price indices and the output, in thousand million drs. of these industries, in 1963 prices.

1. The energy input function

In particular, for the energy input function the following regression equation has been estimated :

$$\log Z = 0.30825 + \underset{(17,1)}{0.82508} \log Q \qquad (5)$$

$$\bar{R}^2 = 0.98 \qquad d = 1.37$$

The figure in brackets under the regression coefficient b is the value of the t-student used to test the significance of this coefficient. Thus, b is significantly different from zero even at the probability level of 0.01 per cent. Given the form of the relationship used, this coefficient indicates the elasticity of the total energy consumption with respect to the manufacturing output. Thetefore, 10 per cent change in Q will result in 8.25 per cent change in total energy consumption.

The coefficient of determination $\bar{R}^2$, corrected for the degrees of freedom, indicates that 98 per cent of the variance of the dependent variable Z, is explained by the equation. On the other hand, the value of the Durbin and Watson d statistic, being 1.37, is not indicative of existing serial correlation between the residuals. In view of these considerations, the above equation is regarded satisfactory from both the statistical and economic point of view.

2. The energy ratio function

For the energy ratio function, on the other hand, the following regression equation has been estimated :

$$\log (E/F)_t = -0.430 - \underset{(1,69)}{0.7603} \log (P^e / P^f)_t + \underset{(2,41)}{0.5927} \log (E/F)_{t-1} \qquad (6)$$

$$\bar{R}^2 = 0.95 \qquad d = 1.83$$

The regression coefficient d_2 is significantly different from zero. On the other hand, although the value of the t student of the coefficient d_1 is low, we may accept the hypothesis that d_1 is also significantly different from zero, since the standard error is less than the estimated coefficient. The value of the coefficient of determination, shows that the regression equation explains the 95 per cent of the variance of the dependent variable. Finally the value of the d statistic shows that the successive residuals are serially uncorrelated. Consequently, from the statistical point of view, the above equation is regarded as satisfactory.

Furthermore, and perhaps more important, the regression coefficients are also satisfactory from the economic point of view, since they have the expected signs and values. Thus, relative price changes affect inversely the relative consumption of electricity to other fuels. Similarly, the value of $c = 1\text{-}d_2$, is found to be less than one and greater than zero, which implies that, the adjustment process towards the desired ratio of electricity to other fuels is not completed in one year.

From the above equation we can derive some additional relationships and analyse their economic implications. Thus :

Deducting from both sides of equation (6) $\log (E/F)_{t-1}$ and then factorising out from the right side $c = 0.4073$, we obtain :

$$A \log (E/F)_t = 0.4073\,[-0.8421 - 1.8667 \log (P^e / P^f)_t - \log (E/F)_{t-1}] \qquad (7)$$

where, A denotes the achieved change of the variable within the brackets in year t relatively to the year t-1.

The desired ratio of the electricity to other fuel consumption can directly be derived from equation (7) :

$$\log (E/F)^*_t = -0.8421 - 1.8667 \log P^e / P^f)_t \qquad (8)$$

Inserting now equation (8) into equation (7), adding to both sides of this equation $\log (E/F)_{t-1}$ and converting it to non-linear form, we obtain :

$$(E/F)_t = (E/F)_t^{*0.4073}\ (E/F)_{t-1}^{0.5927} \qquad (9)$$

Equation (9) indicates that the ratio of electricity to other fuel consumption achieved in year t, is a weighted geometric average of the desired ratio and the ratio existing in the preceding year, the weight of the former being about 70 per cent of the weight of the latter. This means that the achieved in year t ratio depends more on the existing ratio in year t-1 than on the desired ratio in year t. However, the weight of the desired ratio is high enough. This may be explained by the fact that the necessary equipment to switch from the other fuels to electricity does not require a very long period of time and also, perhaps, because the opinions of the management towards the future course of the ratio are in the same direction.

Expressing equation (8) in non-linear form, we obtain :

$$(E/F)^*_t = 0.1438\ (P^e / P^f)_t^{-1,8667} \qquad (8a)$$

which implies, that the desired ratio is expected to rise by 1,87 per cent for every one per cent fall in the price of electricity relatively to the price of the other fuel.

Equation (6) can be written in non-linear form :

$$(E/F)_t = 0.4539\ (P^e / P^f)_t^{-0.7603}\ (E/F)_{t-1}^{0.5927} \qquad (6a)$$

which implies, that the ratio of electricity to other fuel consumption, achieved in year t, is proportional to the power 0.7603 of the inverse of the same year's relative price ratio, multiplied by the power 0.5927 of the previous year's consumption ratio.

As can be seen from equations (6a) and (8a), two values for price elasticity have been estimated. The one is related to the ratio achieved in year t, while the other is related to the ratio which is desired for the same year. Thus, both the short-run and the long-run price elasticities of the relative changes in consumption of electricity and other fuels have been estimated. The short-run price elasticity is equal to (-) 0.76, while the long-run, as one could safely expect, is higher, being equal to (-) 1.87.

IV. FORECASTING THE FUTURE ENERGY REQUIREMENTS

1. Total energy requirements

Equation (5) is used to calculate the total future energy requirements by the manufacturing industries, given that reasonable assumptions are made with respect to the expected growth rates of their total output.

The following Table A shows the total energy requirements which have been calculated for the period 1975 to 1990 on the basis of three alternative assumptions for the expected growth of the manufacturing output.

2. Electricity and other fuel requirements

Equation (6) is used to calculate the expected ratios of electricity to other fuel consumption for the period 1975 to 1990, on the basis of alternative assumptions referring to the future course of the price indices ratio. Therefore, knowing the expected total energy requirements, on the one hand, and the ratios of electricity to other fuels on the other, we may divide the former to obtain the electricity and the other fuel requirements separately.

In particular, the ratios of electricity to other fuels have been calculated on the basis of the following two simple alternative assumptions :

Assumption 1 : price indices ratio, 1971/73 = 0.875, 1974/90 = 0.60

Assumption 2 : price indices ratio, 1971/73 = 0.875, 1974 = 0.60
1975/90 = 0.50.

The following Table B shows the calculated electricity and other fuel requirements which correspond to these assumptions and to the total energy requirements shown in Table A.

TABLE A

Forecasts of Total Energy Requirements

Alternative (I)		Alternative (II)		Alternative (III)	
Output annual growth rates	Total energy requirements in 10^6 GJ	Output annual growth rates	Total energy requirements in 10^6 GJ	Output annual growth rates	Total energy requirements in 10^6 GJ
1971/75, 7,2 %	1971 = 83,5	1971/75, 7,2 %	1971 = 85,5	1971/75, 7,2 %	1971 = 85,5
1976/90, 8 %	1975 = 109,5	1976/90, 9 %	1975 = 109,5	1976/80, 9 %	1975 = 109,5
	1980 = 150,5		1980 = 156,3	1981/85, 8 %	1980 = 156,3
	1985 = 206,7		1985 = 223,0	1986/90, 7 %	1985 = 214,6
	1990 = 283,9		1990 = 318,1		1990 = 283,9
Average annual rates of increase of total energy requirements 1975-1990	6,6 %		7,4 %		6,6 %

TABLE B

Electricity and Other Fuel Requirements, in million GJ

	Alternative I				Alternative II				Alternative III			
	Assumption 1		Assumption 2		Assumption 1		Assumption 2		Assumption 1		Assumption 2	
	Electricity	Other fuels	Electricity	Other fuels	Electricity	Other fuels	Electricity	Other fuels	Electricity	Other fuels	Electricity	Other fuels
71	12,9	72,6	12,9	72,6	12,9	72,6	12,9	72,6	12,9	72,6	12,9	72,6
75	24,6	84,9	27,4	82,1	24,6	84,9	27,4	82,1	24,6	84,9	27,4	82,1
80	40,4	110,1	50,7	99,8	41,9	114,4	52,6	103,7	41,9	114,4	52,6	103,7
85	56,1	150,6	71,0	135,7	60,5	162,5	76,6	146,4	58,3	156,3	73,7	140,9
90	77,2	206,7	97,7	186,2	86,5	231,6	109,4	208,7	77,2	206,7	97,7	186,2
Annual growth rates 1975/90	7,9 %	6,1 %	8,8 %	5,6 %	8,7 %	6,9 %	9,7 %	6,4 %	7,9 %	6,1 %	8,8 %	5,6 %

On the basis of the above alternative assumptions, the results shown in this table and also in the diagrams attached to the end of the paper indicate that, over the period 1975-1990, electricity requirements are expected to rise at an annual growth rate between 7.9 to 9.7 per cent, as compared to the corresponding rise of the other fuel requirements of 5.6 to 6.9 per cent and to the rise of the total energy requirements of 6.6 to 7.4 per cent. On the other hand, this evolution implies that the share of electricity to total energy requirements is expected to rise from 15 per cent in 1971 to 27-34 per cent in 1990.

V.. CONCLUSIONS

The forecasts of electricity and other fuel requirements by the manufacturing sector of Greece have been obtained for the period 1975-1990 by using an econometric model consisting of two equations. The prices of electricity and the other fuels and also the manufacturing output were the exogeneous variables of the model. Thus, on the basis of assumptions referring to these variables we were able to estimate the values of the endogeneous variables that is, the total energy requirements and the ratio of electricity to other fuel requirements.

Further to the forecasting, the model was used to estimate : First, the speed of the adjustment process of the manufacturing sector towards the desired ratio of electricity to other fuel consumption. In particular, it was seen that the achieved in year t ratio was different from the desired ratio, due to the fact that the adjustment process can not be completed in one year. Second, the short-run and long-run price elasticities. Thus, it was possible to calculate the result of a change in the prices of electricity and/or the other fuels on their quantities consumed not only in the short-run that is, within a year, but also in the long-run that is, for the period needed to pass for the adjustment process which began from the price change to be completed.

In view of these considerations, it can be concluded that the model can be used not only for forecasting purposes but also as an instrument for formulating for the manufacturing sector a proper price policy for energy.

TABLE 1

Manufacturing Sector of Greece : Electricity, other fuels and total energy consumption. Ratio of electricity price index to other fuel price index. Output value in 1963 prices

Years	Electricity consumption in million GJ	Other fuel consumption in million GJ	Total energy consumption in million GJ	Ratio of Price Indices	Output value in thousand million Drs. in 1963 prices
1963	3,91	39,44	43,35	1.000	42,98
1964	4,46	43,29	47,75	1.049	44,76
1965	5,67	46,20	51,86	0,999	51,45
1966	7,15	50,83	57,97	0,975	56,98
1967	8,30	54,87	63,17	0,893	60,10
1968	9,07	56,92	65,99	0,861	65,31
1969	10,32	60,44	70,77	0,863	72,55
1970	11,16	66,11	77,27	0,895	87,08
1971	12,85	72,64	85,49	0,875	95,00

Note : This table was constructed from data used in the paper, «Enegry Input in Relation to Labour and Output Trends in the Manufacturing Sector of Greece», submitted by Pr. Efthymoglou and D. Xirskostas to the «Symposium on the Role of Electric Power in Meeting Future Energy Needs and on International Cooperation in this Field», E.C.E. of the UN, Greece May 1975, No EP/SEM.3/R.61.

FUTURE ENERGY REQUIREMENTS BY THE MANUFACTUPING SECTOR OF GREECE

ASSUMPTIONS : a. ANNUAL OUTPUT GROWTH RATE 1975-1990, 8 %.
b. RATIO OF ELECTRICITY TO OTHER FUEL PRICE INDICES 1974-1990, 0.60

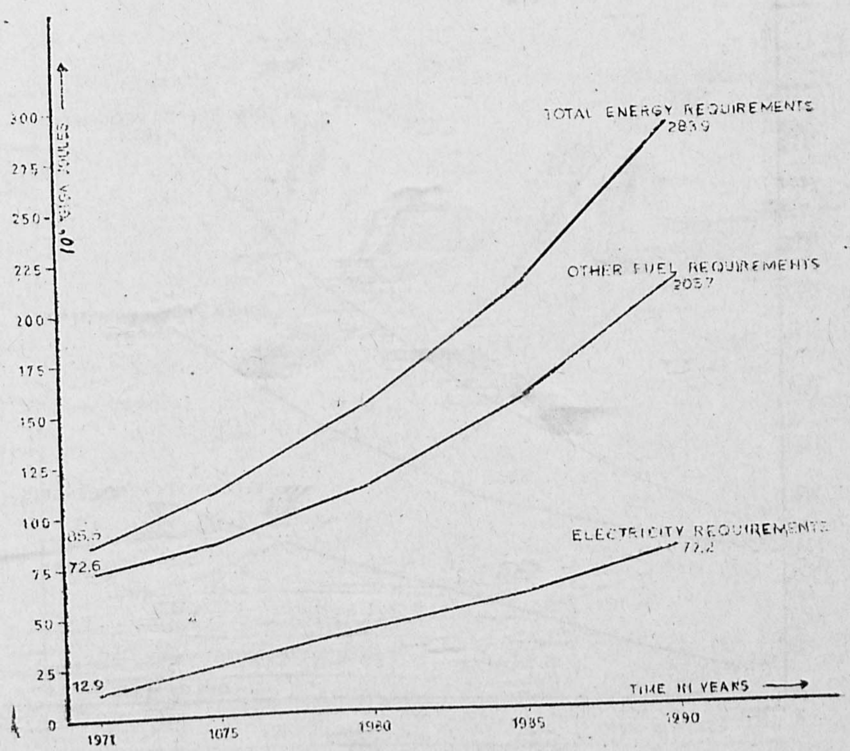

Diagram 1

ANNUAL GROWTH RATES, 1975-1990 :

a. TOTAL ENERGY REGUIREMENTS 6.6 %
b. ELECTRICITY REQUIREMENTS 7.9 %
c. OTHER FUEL REQUIREMENTS 6.1 %

FUTURE ENERGY REQUIREMENTS BY THE MANUFACTURING SECTOR OF GREECE

ASSUMPTIONS : a. ANNUAL OUTPUT GROWTH RATE 1975-1990,8 %
b. RATIO OF ELECTRICITY TO OTHER FUEL PRICE INDICES 1974, 0.60 1975-1990, 0.50

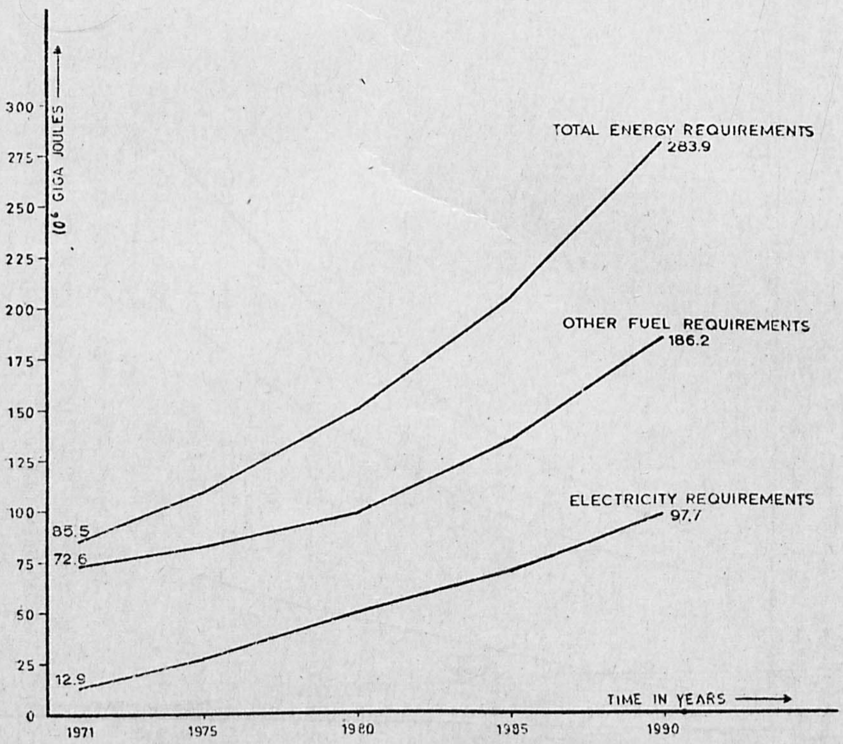

Diagram 2

ANNUAL GROWTH RATES, 1975-1990 :

a. TOTAL ENERGY REQUIREMENTS 6.6 %
b. ELECTRICITY REQUIREMENTS 8.8 %
c. OTHER FUEL REQUIREMENTS 5.6 %

FUTURE ENERGY REGUIREMENTS BY THE MANUFACTURING SECTOR OF GREECE

ASSUMPTIONS : a. ANNUAL OUTPUT GROWTH RATE 1975-1990, 9 %
b. RATIO OF ELECTRICITY TO OTHER FUEL PRICE INDICES 1974-1990, 0.60

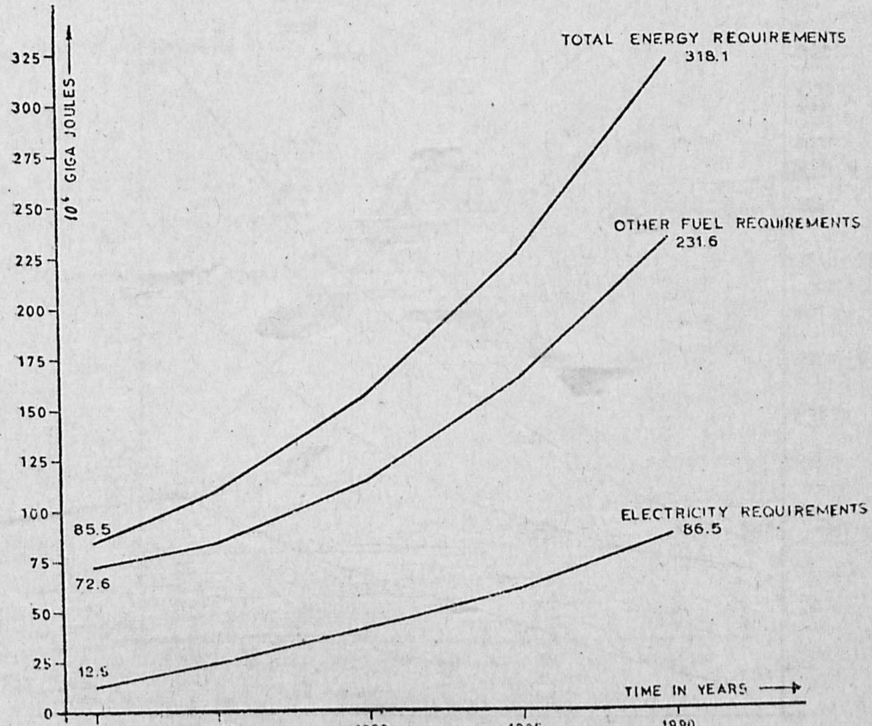

Diagram 3

ANNUAL GROWTH RATES, 1975-1990 :

a. TOTAL ENERGY REQUIREMENTS 7.4 %
b. ELECTRICITY REQUIREMENTS 8.7 %
c. OTHER FUEL REQUIREMENTS 6.9 %

FUTURE ENERGY REGUIREMENTS BY THE MANUFACTURING SECTOR OF GREECE

ASSUMPTIONS : a. ANNUAL OUTPUT GROWTH RATE 1975-1990, 9 %
b) RATIO OF ELECTRICITY TO OTHER FUEL PRICE INDICES 1974, 0.60 1975-1990, 0.50

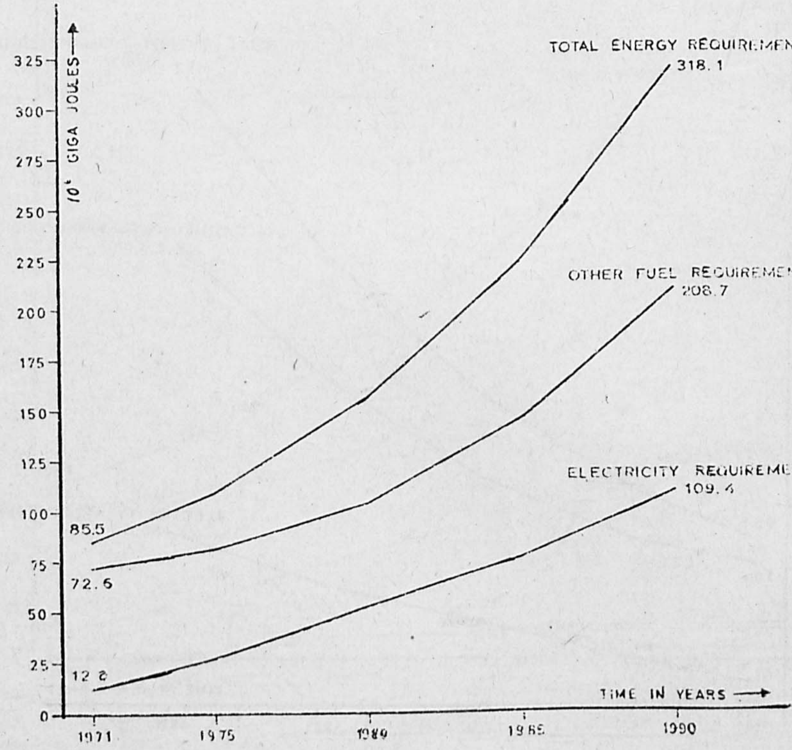

Diagram 4

ANNUAL GROWTH RATES, 1975-1990 :

a. TOTAL ENERGY REQUIREMENTS 7.4 %
b. ELECTRICITY REQUIREMENTS 9.7 %
c. OTSER FUEL REQUIREMENTS 6.4 %

TOTAL ENERGY REQUIREMENTS AS A FUNCTION OF OUTPUT IN THE MANUFACTURING SECTOR OF GREECE

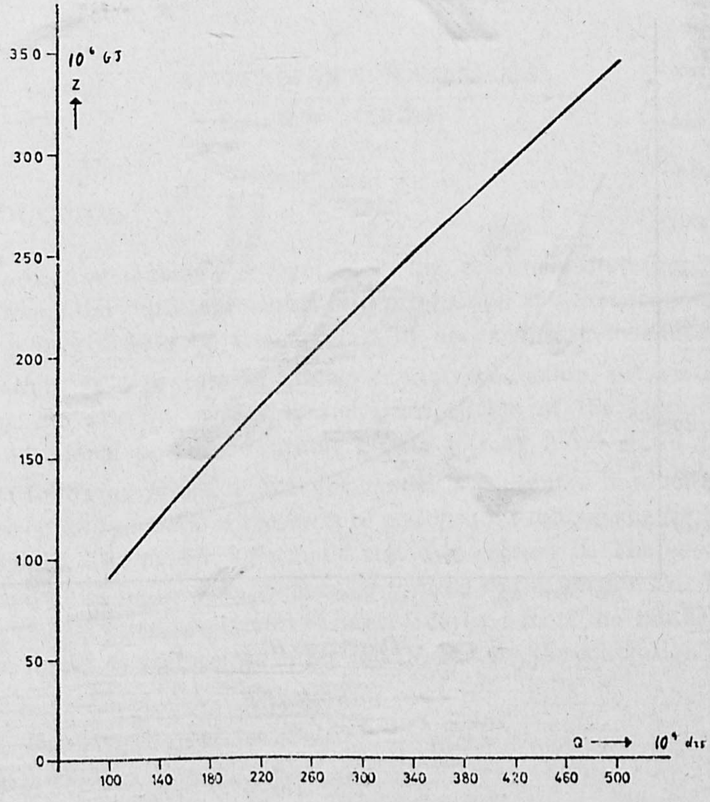

Diagram 5

DESIRED RATIO OF ELECTRICITY TO OTHER FUEL CONSUMPTION AS A FUNCTION OF THEIR RELATIVE PRICE CHANGES

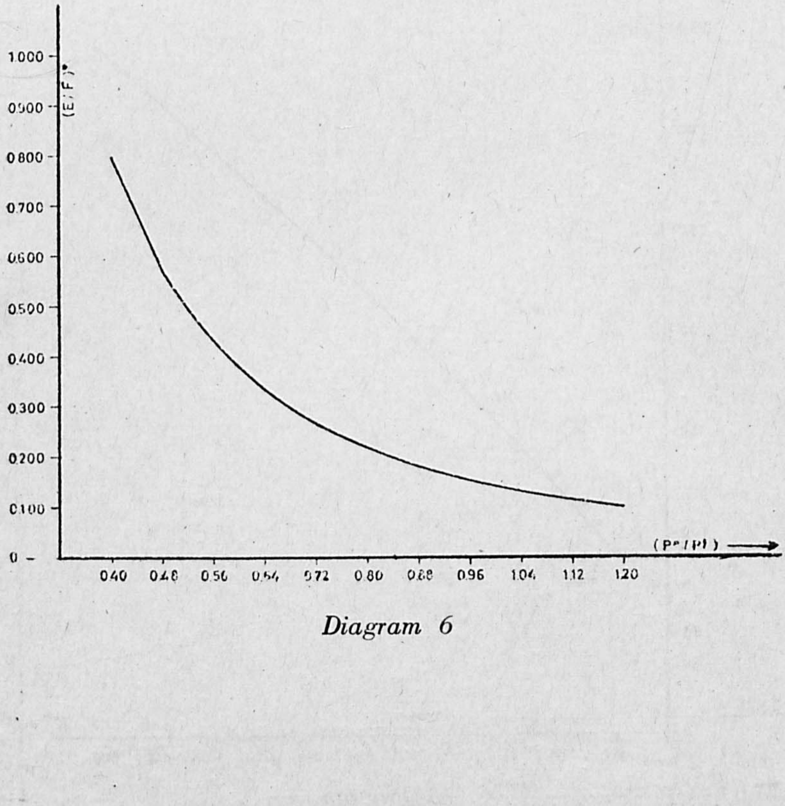

Diagram 6