THE CLIMATE OF URBAN SPACES AS A DECISIVE ENERGY PARAMETER IN BUILDING DESIGN AND CONSTRUCTION-

ENERGY AND ECONOMIC EVALUATION OF BUILDINGS

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ABSTRACT.This study presents the research on optimum solutions, as far as energy and economic criteria are concerned, for different forms and insulation of the shells of residential buildings in all three climatic zones (C.Z.) of Greece. Measurements in one of the three buildings studied, (one 8- and one 5-storey conventional building and a 2- storey passive solar building) as well as numerous thermal analyses and cost-benefit analyses, constituted the principal methods leading to the verification of the simulation programme and to a series of results and conclusions.
One of the more important conclusions relates to the passive solar building, which verifies the restricted pay-off period (3 years in the cold C.Z.) of the additional investment in the energy saving measures and also evidenced, a very high percentage of energy saving (up to 82%) in comparison with other conventional buildings.

1.Introduction

Numerous energy parameters, based on the principles of bioclimatic architecture design, are considered, which finally influence not only the sensitive thermal balance of the building, but the total life cycle cost as well (cost of energy consumption, construction cost, heating installation cost, maintenance cost). Hence the problem of rational use of energy, a compound problem, is better confronted as an entity, thus evaluating the parameter "energy" as well as the parameter "economy", if, of course, the aim is to determine the optimum solution in each case, using not only thermal but also economic criteria. Based on the above, and assuming that the climate of each area, is one of the most decisive parameters of energy behaviour of buildings (fig. 2), this study investigates the optimum thermal and economic solution in the three climate zones (C.Z.) of Greece and for three types of buildings' . The buildings that were studied were chosen on the basic criterion of form, expressed by the A/V ratio, as well as the existence or not of an energy design.

2. Field of study - Method used

For the purposes of this study, as mentioned above , three residential buildings were chosen: a two-storey passive solar building (fig. 1), house of the architect M. Chrisomallidis, awarded a prize in a Hellenic architectural competition, with an attached green house of 15 m2, A/V: 0.923

(unfavourable form) and dimensions L.7.5*W.7.5*H.7.5 m; a conventional five-storey building (A/V: 0.36 L.20*W.18*H.16.5 m.), and an eight-storey conventional apartment building with A/V: 0.313 (favourable energy form ,L.20*W.14*H.27 m.). These buildings, designed for the cold climate zone of Greece (Thessaloniki) were assumed to be also suitable for construction in the mild climate zone (Athens), and in the warm climate zone (Chania, Crete). The shell of the buildings was considered to have 4,6,8 cm. thermal insulation, (glass-wool) or to have none.The geometric data, the thermal characteristics, and the climate data of the three urban spaces, are presented in table 1.

In the first stage of the study, simulations were carried out for all the climatic cases and all possibilities of thermal insulation of the shell of the three buildings, by using a computer programme in order, to determine their thermal behaviour (fig.2). It should be especially noted that the verification of the programme results was checked by temperature measurements and annual registers of consumption (24 tons oil) in the existing uninsulated 5-storey building. The results from the comparison are considered to be very satisfactory. (deviation in the order of 7%)

The second stage comprised a cost-benefit analysis, for all the alternative cases investigated in the earlier, stage of thermal analysis. The totally uninsulated building was taken as a base of comparison for the calculations. The aim was the evaluation of the solutions also with reference to economic criteria, so that, for each climate zone and building, the optimum solution (table 2) could be proposed. The economic analyses were based on the existing 6 dynamic economic methods, which were applied by means of a special computer programme. In table 2, only the results from the methods " Net Benefits-Benefits Costs- B-C" and "Discount Pay-back D.P.B." are indicatively presented, taking into account all the cash in- and outflows, that come from the energy-saving measures during the life cycle of the building. A sensitivity analysis was also attempted, for the two most unstable parameters ("I" :interest rate, (%),"L": increase of energy cost (%)), by assuming possible alternative values. The shaded areas (table 2) , refer to results, with values of "I" and "L", that are valid today in Greece, based on which the choice of the optimum economic solution could be realized.

TABLE : 1 Geometric data, thermal characteristics of the buildings, and climate conditions of the three climate zones in Greece

	PROJECTS DATA														
	8- STOREY CONVENT. BUILD.					5-STOREY CONVENT. BUILD.					2-STOREY PASSIVE SOLAR BUIL.				
SHELLS THERMAL INSULATION		0cm	4cm	6cm	8cm		0cm	4cm	6cm	8cm		0cm	4cm	6cm	8cm
GEOMETRIC DATA															
			U-VALUE [W/M2K]					U-VALUE [W/M2K]					U-VALUE [W/M2K]		
VOLUME [M3]	7943					5869					353				
FLOOR AREA [M2]	323	3.80	0.54	0.49	0.33	360	3.78	0.54	0.49	0.33	56	2.83	0.59	0.42	0.33
ROOF AREA [M2]	323	2.15	0.52	0.44	0.30	360	2.15	0.52	0.44	0.30	56	2.00	0.54	0.39	0.30
EXTERNAL WALL AREA [M2]	1457	1.78	0.66	0.51	0.39	1044	2.16	0.66	0.51	0.39	188	2.36	0.55	0.40	0.32
WINDOWS TOTAL AREA [M2]	380	5.80	3.02	3.02	3.02	338	5.80	3.02	3.02	3.02	26	5.81	3.02	3.02	3.02
THERMAL CHARACTERISTICS															
TOTAL Um -VALUE [W/M2K]		2.50	0.95	0.85	0.75		2.70	0.97	0.87	0.76		2.30	0.68	0.56	0.49
VENTILATION RATE n:h⁻¹		0.60	0.60	0.60	0.60		0.60	0.60	0.60	0.60		0.60	0.60	0.60	0.60
HEATED VOLUME [M3]	7943					5869					353				
HEATED FLOOR AREA [M2]	2647					1956					113				
NET HEAT LOAD [KWh/M2A]	THESSA	84	34	31	28	THESSA	107	39	36	32	THESSA	227	61	50	44
	ATHENS	47	19	18	17	ATHENS	61	22	21	20	ATHENS	137	34	28	26
	CHANIA	27	11	11	11	CHANIA	37	13	13	12	CHANIA	87	20	17	16

SITE CLIMATE				
		THESSA	ATHENS	CHANIA
LATITUDE		40 37	38 58	36 22
LONGITUDE		23.00	23 43	24.00
AVERAGE AMBIENT TEMP.[C]	JANUAR	5.5	9.4	11.9
	JULI	26.7	27.9	26.9
DEGREE DAYS [days] [base 18°C]		1725.0	1100.0	782.0
GLOBAL IRRADIAT. ON HORIZ	KWh/M2	1403.0	1581.0	1630.0

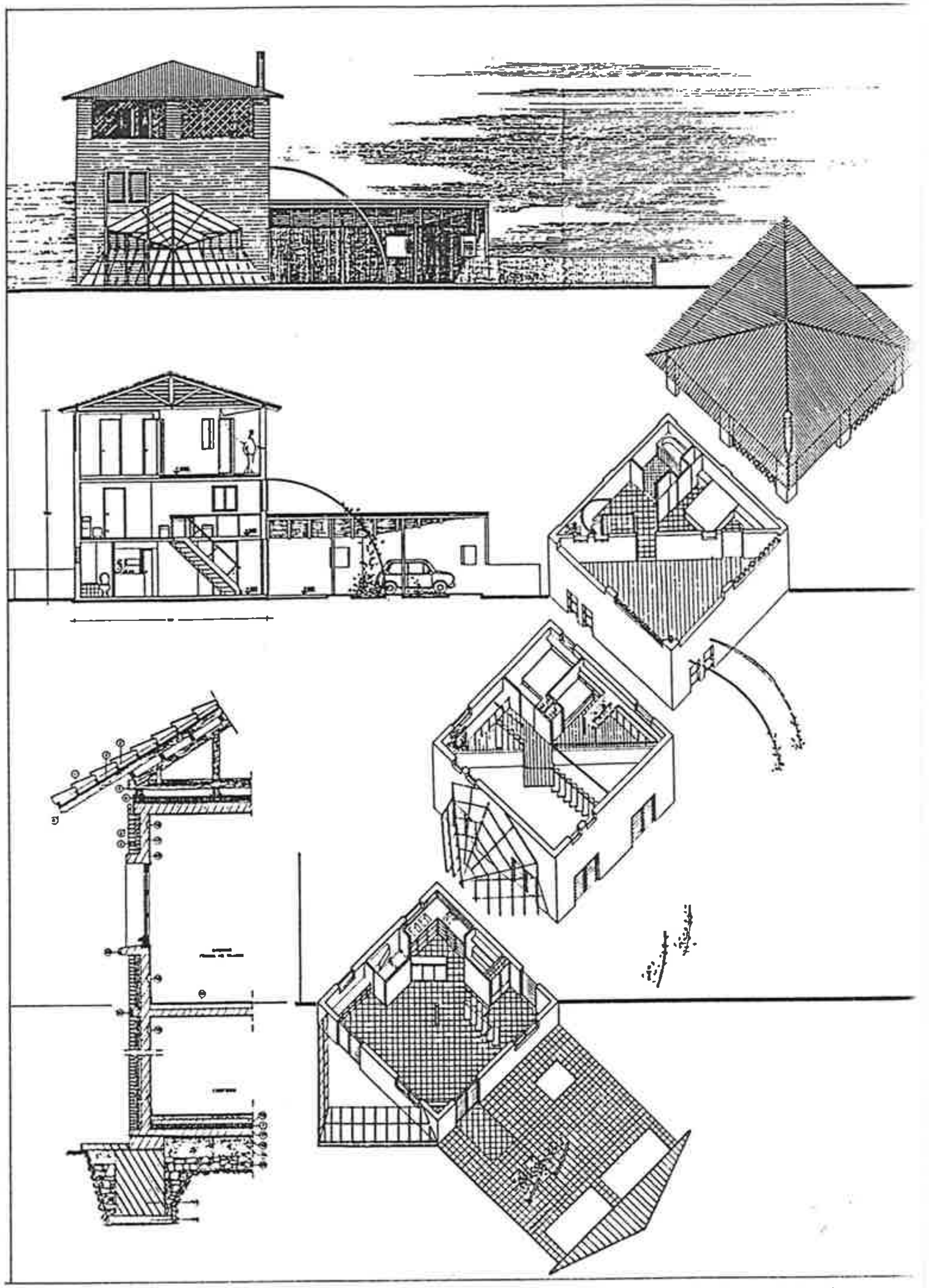

Figure 1   Passive solar 2-storey house, designed for mountain in the cold climate zo

3. Results

3.1 THERMAL ANALYSIS RESULTS.

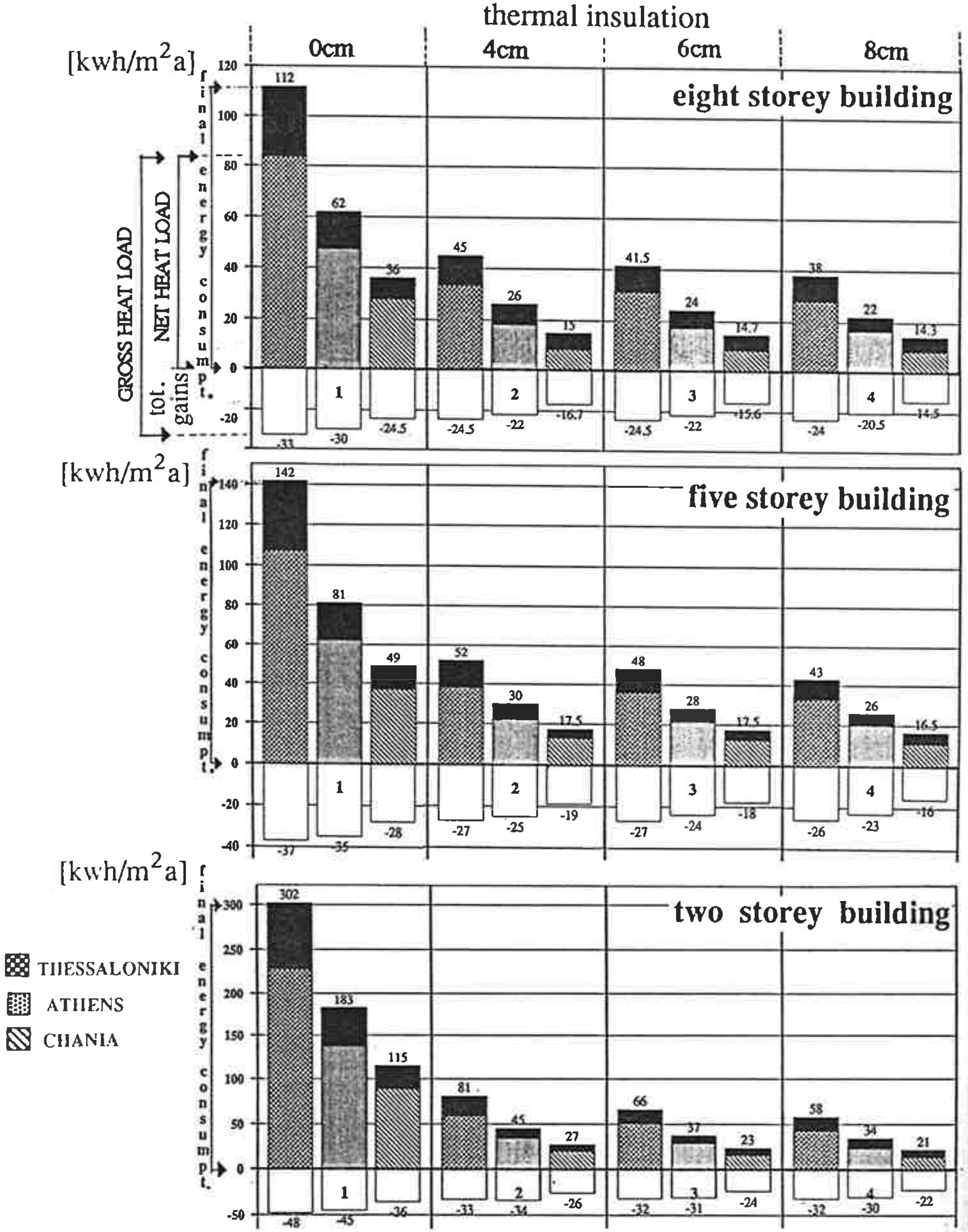

Figure 2. Thermal balance of buildings and final energy consumption, in the three climate zones and with different thickness of shell insulation. (central heating, degree of efficiency of the installation 0.75). Note: The total thermal gains appear higher in the cold C.Z. due to longer heating period (6 months) compared to the mild (5 months) and the warm (3 months) C.Z..

3.2 COST-BENEFIT ANALYSIS RESULTS

		THESSALONIKI			ATHENS			CHANIA		
8-STOREY BUILDING										
		4cm	6cm	8cm	4cm	6cm	8cm	4cm	6cm	8cm
I:14%-	L: 8%	11.982.100 [4.0]	12.505.700 [4.4]	12.492.500 [5.0]	3.783.470 [10]	3.776.150 [10.5	3.175.060 [12.4	0	0	0
	L:14%	27.882.100 [3.8]	29.313.600 [4.0]	30.188.700 [4.5]	12.500.500 [7.9]	12.944.900 [8.2]	12.729.000 [9.3]	4.558.030 [15]	4.153.600 [16]	3.272.260 [18]
	L:20%	70.476.900 [3.5]	74.340.900 [3.7]	77.595.500 [4.2]	35.852.700 [6.8]	37.507.200 [7.0]	38.323.400 [7.6]	18.228.600 [11]	18.002.700 [12]	17.383.200 [13]
I:18%-	L: 8%	7.373.860 [4.4]	7.634.250 [4.6]	7.363.620 [5.4]	1.257.030 [12.6]	1.118.790 [13.5]	406.042 [17.5]	0	0	0
	L:14%	16.044.300 [4.0]	16.799.800 [4.2]	17.013.500 [4.8]	6.010.500 [9.0]	6.118.590 [9.5]	5.615.920 [11]	758.743 [20]	304.709 [22]	0
	L:20%	37.243.000 [3.7]	39.209.100 [3.9]	40.607.100 [4.4]	17.632.500 [7.5]	18.372.900 [7.8]	18.353.800 [8.7]	7.562.370 [13]	7.197.180 [14]	6.373.370 [16]
I:22%-	L : 8%	4.698.270 [4.8]	4.805.870 [5.0]	4.385.770 [6.0]	0	0	0	0	0	0
	L:14%	9.836.250 [4.3]	10.237.300 [4.5]	10.104.200 [5.2]	2.607.010 [11]	2.538.730 [11.5	1.885.640 [14]	0	0	0
	L:20%	21.252.500 [3.9]	22.305.400 [4.0]	22.810.100 [4.6]	8.865.840 [8.5]	9.121.890 [8.8]	8.745.410 [10]	2.430.280 [17]	1.998.070 [18]	1.075.970 [22]
5-STOREY BUILDING										
		THESSALONIKI			ATHENS			CHANIA		
		4cm	6cm	8cm	4cm	6cm	8cm	4cm	6cm	8cm
I:14%-	L: 8%	13.420.900 [2.9]	13.681.300 [3.3]	13.456.000 [4.0]	5.379.030 [6.8]	5.185.420 [7.6]	4.384.810 [9.7]	1.231.320 [15]	685.574 [18]	0
	L:14%	29.454.900 [2.8]	30.441.100 [3.0]	31.049.500 [3.7]	14.351.700 [5.8]	14.489.000 [6.4]	14.026.000 [7.7]	6.731.450 [11]	6.224.470 [12]	5.245.130 [15]
	L:20%	72.409.000 [2.7]	75.339.300 [2.9]	78.181.200 [3.5]	38.388.900 [5.2]	39.412.700 [5.6]	39.853.900 [6.6]	21.465.900 [9]	21.062.800 [10]	20.406.000 [11]
I:18%-	L: 8%	8.773.740 [3.0]	8.823.890 [3.4]	8.356.880 [4.3]	2.778.490 [7.7]	2.488.970 [8.8]	1.590.530 [12]	0	0	0
	L:14%	17.517.300 [2.9]	17.963.200 [3.2]	17.950.800 [4.0]	7.671.390 [6.4]	7.562.320 [7.0]	6.847.950 [8.8]	2.636.500 [13]	2.100660 [15]	1.031.650 [20]
	L:20%	38.894.800 [2.7]	40.308.300 [3.0]	41.407.500 [3.6]	19.634.300 [5.6]	19.966.400 [6.0]	19.702.100 [7.3]	9.969.600 [10]	9.485.440 [11]	8.577.000 [13]
I:22%-	L : 8%	6.075.590 [3.2]	6.003.610 [3.5]	5.396.300 [4.6]	1.268.600 [9.0]	923.395 [11]	0	0	0	0
	L:14%	11.256.900 [2.9]	11.419.400 [3.3]	11.081.500 [4.2]	4.168.070 [7.0]	3.929.800 [8.0]	3.083.630 [10]	489.014 [17]	0	0
	L:20%	22.769.400 [2.8]	23.453.000 [3.0]	23.713.700 [3.8]	10.610.500 [6.0]	10.609.800 [6.7]	10.006.000 [8.2]	4.438.120 [12]	3.914.980 [13]	2.885.420 [16]
2-STOREY BUILDING										
		THESSALONIKI			ATHENS			CHANIA		
		4cm	6cm	8cm	4cm	6cm	8cm	4cm	6cm	8cm
I:14%-	L: 8%	2.220.200 [1.0]	2.202.120 [1.9]	2.097.360 [2.9]	1.226.960 [2.5]	1.127.800 [4.0]	948.594 [6.0]	643.612 [4.9]	491.977 [8.4]	313.006 [12.7]
	L:14%	4.472.400 [1.0]	4.605.460 [1.8]	4.580.470 [2.8]	2.623.060 [2.3]	2.604.430 [3.8]	2.484.460 [5.4]	1.547.350 [4.5]	1.432.810 [6.9]	1.270.020 [9.5]
	L:20%	10.505.900 [1.0]	11.043.800 [1.8]	11.232.600 [2.7]	6.363.100 [2.3]	6.560.220 [3.6]	6.535.590 [4.8]	3.968.380 [4.0]	3.953.240 [6.0]	3.833.800 [7.8]
I:18%-	L: 8%	1.567.450 [1.0]	1.505.560 [1.9]	1.377.680 [3.0]	822.332 [2.5]	699.833 [4.4]	533.957 [6.9]	381.684 [5.4]	219.296 [10.]	35.635 [18.]
	L:14%	2.795.600 [1.0]	2.816.130 [2.0]	2.731.750 [2.8]	1.583.640 [2.4]	1.505.060 [4.0]	1.358.590 [5.9]	874.500 [4.7]	732.343 [7.7]	557.506 [11]
	L:20%	5.798.360 [1.0]	6.020.410 [1.8]	6.042.380 [2.7]	3.445.000 [2.3]	3.473.790 [3.7]	3.374.770 [5.2]	2.079.410 [4.3]	1.986.720 [6.6]	1.833.460 [8.8]
I:22%-	L : 8%	1.188.460 [1.0]	1.101.140 [2.0]	959.830 [3.0]	587.401 [2.6]	451.351 [4.7]	279.485 [7.9]	229.607 [5.9]	60.975 [13]	0
	L:14%	1.916.250 [1.0]	1.877.760 [2.0]	1.762.230 [3.0]	1.038.540 [2.4]	928.515 [4.2]	768.150 [6.5]	521.643 [5.0]	365.001 [9.0]	183.846 [14]
	L:20%	3.533.330 [1.0]	3.603.370 [2.0]	3.545.110 [3.0]	2.040.940 [2.4]	1.988.740 [3.9]	1.853.930 [5.6]	1.170.530 [4.5]	1.040.520 [7.0]	870.986 [10]

Table 2. Net benefit (in drachmas) during the life cycle of the building and pay off time (in years-values in the parentheses) of the extra-cost for the application of energy saving measures.Base of comparison is the uninsulated building. The optimum solution for countries with different values of interest rate "I" and different increase of the energy price "L"can also be determined from this

4. Conclusions

4.1 CONCLUSIONS FROM THE THERMAL ANALYSES (fig.2 , tab. 3)

Table 3.Indicative summary results.The shaded area refers to the base of comparison.

	8-STOREY BUILDING											
	THESSALONIKI				ATHENS				CHANIA			
1	0cm	4cm	6cm	8cm	0cm	4cm	6cm	8cm	0cm	4cm	6cm	8cm
2	[103] +0.00	[48] -53%	[45] -56%	[42] -59%	[66] +0.00	[31] -53%	[29] -56%	[27] -59%	[41] +0.00	[20] -54%	[18]-57%	[17] -61%
3	32%	51%	53%	56%	45%	70%	73%	75%	56%	84%	84%	84%
4	0.00	60%	63%	66%	0.00	59%	59%	61%	0.00	59%	59%	61%
	5-STOREY BUILDING											
2	[126] +0.00	[54] -57%	[50] -60%	[46] -63%	[83] +0.00	[35] -57%	[33] -60%	[30] -64%	[55] +0.0	[22] -59%	[21] -62%	[20] -65%
3	29%	50%	53%	56%	42%	71%	73%	76%	51%	85%	85%	86%
4	0.00	63%	66%	69%	0.00	63%	65%	68%	0.00	64%	64%	66%
	2-STOREY BUILDING											
2	[254] +0.00	[79] -69%	[67] -74%	[61] -76%	[167] +0.00	[53] -68%	[45]-73%	[40] -76%	[110] +0.0	[35] -68%	[29] -74%	[26] -76%
3	19%	42%	48%	52%	27%	64%	70%	74%	32%	78%	81%	84%
4	0.00	74%	78%	81%	0.00	75%	80%	82%	0.00	77%	80%	82%
	1.thermal insulation [cm]			2. total losses [kwh/m2a] -[%]				3.total gains % of the tot. losses				
					4. energy conservation [%]							

The thermal analysis results confirm what is already known , that
-the more favourable the outdoor climate conditions are
-the stronger the passive protection of the shell is and
-the more favourable the form of the building is, from the energy aspect,
the greater the percentage cover of the total thermal losses, by the thermal gains,(with conductivity and ventilation). (tab.3 ,8-storey building., row 3, 8cm.therm.insul., in the 3 C.Z.)

Therefore, in mild and warm zones, energy autonomous buildings could be very easily achieved.. In cold zones the total gains can cover 42-56% of the gross thermal load,(total losses and energy consumption for use of warm water), a percentage that can be increased with the use of passive solar systems of southern orientation.

The energy saving, with respect to the degree of insulation of the shell and independent of the climatic zone, is, in the conventional 8-storey and 5-storey building, between 59%-68%, whereas in the passive solar 2-storey building it is between 74%-82%. (tab.3)

4.2 CONCLUSIONS FROM THE COST -BENEFIT ANALYSES .(tab.2)

In many cases, and especially in the multistory buildings, in the warm climatic zone the uninsulated building shows a lower life cycle cost compared to the insulated one, and hence result negative benefit values. (0 in table 2).

Using the "I" and "L" values valid for Greece today, and for all the three buildings, the economical optimum solution for the cold climatic zone is shown to be the strong insulation of 8 cm, for the mild climatic zone 6 cm, whereas for the warm climatic zone 4 cm of shell insulation.

In multistory buildings particularly, the discounted pay-back period increases, successively from the cold to the warm C.Z., hence the optimum solution must be determined with the additional consideration of the results by the "B-C" method.

The passive two-storey building shows a very restricted pay-off period, especially in the cold C.Z. (up to 3 years in the most unfavourable case), an encouraging factor for making additional investment in energy-saving measures in buildings of this scale, and especially for the application of passive solar systems.