SOLAR VILLAGE in PEFKI of ATTICA.
*“ Retrofitting, Renovation and Optimization of the efficiency of the **Solar Village’ s** energy systems. “*

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1. THE SOLAR VILLAGE PROJECT.

The Solar Village Project has been implemented within the framework of the Agreement on Scientific and Technical Cooperation between the Greek Ministry of Industry, Energy and Technology (nowadays Ministry of Development) and the competent German Ministry of Research and Technology (BMFT), with the participation of the Greek Workers Housing Organization (OEK).

The Programme was a contribution to the international effort for rational use of energy, with increased application of Solar Thermal Technology, in a large-scale housing Project, under real conditions of inhabitation. A housing Project of the Greek Workers Housing Organization in Pefki of Attica was selected, with the consent of OEK, as suitable large-scale settlement for the application of the Solar Village Project. The experimental, researchable and demonstrative character of the Project would encourage the application of solar systems and other energy saving techniques in the field of the social housing and would contribute to their further development.

Both the Greek and German Ministries as also OEK covered the financing of the Solar Village Project. OEK contributed to the total cost of buildings by paying an amount equal to what would be required if a standard (conventional) settlement of equal surface were to be built. The involvement of OEK in the Solar Village Programme was decisive since it provided the opportunity for application of new technologies in the Urban Planning and the Bioarchitectural field as well as of the Active and Passive Energy Systems under real inhabitation conditions.

The sociological approach of the Project has also to be emphasized. To assist the inhabitation of the Village, the inhabitants conducted a parallel sociological survey with the Programme to formulate proposals and implement all necessary measures that would ensure the quality of social life and environment within the community together with the acceptance and use of the applied systems.

The Solar Village Programme consisted mainly of two phases:

a) *August 1984 to June 1988,* the phase in which all designs, technical and sociological studies and the construction were carried out and

b) *July 1988 to December 1991,* the phase in which measuring and evaluation of technical economic and social parameters were being implemented.

2. GENERAL CHARACTERISTICS OF THE SOLAR VILLAGE

The general characteristics of the Solar Village (SV) so as the 8 regions in which it is divided are the following:

Site total area 90 440 m^2

Building area	47 798 m^2
Utilities and landscaping area	35 740 m^2
Community area (schools, kindergarten)	6 902 m^2
Number of apartments (60 – 100 m^2)	435
Flat effective area	33 130 m^2
Apartment Buildings	25 multi storied (with 2 to 6 floors)
Energy Center	1 building
Community Center	3 buildings
Year of the beginning of inhabitation	1989

The various buildings of the SV have been designed and arranged in the space according to the Principles of the Bioclimatic Architecture that is:

- Optimum orientation and arrangement of the buildings.
- Optimized walls, roofs and openings insulation to minimize the thermal losses.
- Large southern and small northern openings.
- Night insulation for the southern openings.
- No openings in the western and eastern directions.
- Well designed thermal capacity of the insulated buildings shell to offset the temperature differences between day and night (both in winter and summer periods).
- Plants and trees by the eastern and southern sides of the buildings for protection against the sun radiation in summertime.

The SV has been divided into 8 energy regions: A, B, C, D, E, F, G, and H. The regions A, B, C, D, E and F have 25 apartment buildings, G has the Energy Center and H has the Community Center. The regions A, C, D, E and F have active energy systems and the region B consists of passive buildings. The active energy systems supply thermal energy for Space Heating (SH) and Domestic Hot Water (DHW.) They include the ***"non conventional"*** part delivering energy from Renewable Energy Sources (RES) either from solar radiation (e.g. through solar collectors of vacuum and flat plate type, air collectors etc.) or environmental energy (through heat pumps) and the ***" conventional"*** part delivering energy through oil burners and electric resistance heaters. Every region has its special features, referred to the following systems:

- Different solar energy collection systems,
- Different systems for distribution of the hot water,
- Different way of storage of the thermal energy,
- Different systems for the energy transfer to the heated space,
- Different backup systems which use conventional energy (oil, electricity)

3. A BRIEF DESCRIPTION OF THE ENERGY REGIONS OF SOLAR VILLAGE

In what follows, it is given a brief description of the energy systems (active and passive ones) used in the 6 regions A to F.

REGION A (Active systems): It includes 11 buildings with totally 252 apartments. The heat is supplied to the buildings through a **district-heating underground network** and is delivered to each building through a terminal thermal substation (heat exchanger). The energy is produced in the Energy Center G by a boiler 1.34 MW, burning oil. The DHW is produced in central systems in each building. The energy is collected from the sun through vacuum or flat plate collectors installed on the roofs of the buildings. The characteristics of these systems are the short time storage in tanks of 1 and 2 m^3 and the continuous hot water recirculation. The backup system consists of electric resistance heaters.

REGION B (Passive systems): It includes 4 buildings with totally 34 apartments. The 3 out of the 4 buildings of region B have two-storey single-family dwellings with autonomous thermosyphon solar systems supplying the DHW. The fourth building of region B is a three-storey building equipped with a central DHW solar system as in region A. The Space Heating of these houses is achieved through passive (structural) elements of the buildings. A variety of systems and methods have applied to passive houses like:

Glasshouses with water walls
Glasshouses with Trombe walls
Direct Solar Gain with water benches
Indirect Solar Gain with massive Trombe walls or water walls
Systems with heat transfer cycle.

REGION C (Active systems): It includes 2 buildings with totally 9 two-storey single-family dwellings. The heat is supplied to the buildings through warm air recirculation in air ducts via a ventilator. The warm air heats also the DHW through a heat exchanger. **Air solar collectors** heat the air. The conventional system consists of electric resistance heaters heating up the air for SH and DHW, whenever the solar radiation is not sufficient to meet the needs. Every dwelling has each own autonomous air solar collector of 11 m².

REGION D (Active systems): It includes 3 buildings with totally 76 flats. The heat is supplied to the buildings through a system of 2 or 3 electrically driven **heat pumps** air-to-water. The heat pumps, are installed on the roofs of the buildings and feed separately the central systems of SH and DHW. After some few years of operation, the 8 (in total) heat pumps were put out of order, because of their high electric energy consumption and maintenance cost. Thenceforth the needs for thermal energy in the Region D are met through the conventional energy systems, that is an oil boiler for SH and electric resistance heaters for DHW.

REGION E (Active systems): It includes 4 buildings with totally 40 flats. The energy is collected from the sun through vacuum or flat plate collectors installed on the roofs of the buildings. The flats are heated through central systems with floor heating (3 building) and one-pipe fan coil units (1 building). The DHW is also supplied by a central system similar to the ones of Region A. Oil boilers and electric resistance heaters supply auxiliary energy during the winter period.

REGION F (Active systems): It includes 1 building with totally 24 flats and effective area of 1700 m². The solar energy is collected through vacuum heat pipes and is transferred to the DHW installation via a heat exchanger. The excess heat is stored in a well-isolated water tank of 500 m³ capacity. From this **Interseasonal Storage Tank (IST)** the heat is transferred, whenever necessary to the central DHW system, similar to the ones of Region A or to the central SH system. Main characteristic and major advantage of the IST is the collection of solar energy during summer, when the energy balance is positive, and its use during winter. As a result the realized energy saving of conventional fuel is very impressive: Under normal conditions of operation of all the Region F subsystems, the total demand of DHW is covered by a solar fraction of 95 % and the total demand of SH is covered by a solar fraction of 60 %. In other words all the 24 flats of the Region F have not to pay for conventional fuel but 5 % for their DHW consumption and 40 % for their SH consumption.

The following table includes a big part of the technical data of the SV energy systems and regions.

OEK
SOLAR VILLAGE/PEFKI, ATTICA

TECHNICAL DATA OF ENERGY SYSTEMS AND BUILDINGS

No	REGION	NAME OF BUILDING	NUMBER OF FLATS	FLAT EFF. AREA (m^2)	NUMBER OF INHABITANTS	SOLAR COLLECTORS (CENTRAL SYSTEMS) TYPE	INCLINATION (^{0})	AREA (m^2)	CONSTRUCTOR	USERS NEED	ENERGY TRANSFER FOR SH	WATER TEMPERATURE FEED/RETURN (^{0}C)	HEAT DEMAND FOR SH (kW)	BOILER POWER (kW)	CONSUMPTION OF DHW PER DAY (Theor.) (m^3/day)	ENERGY DEMAND PER DAY (kWh/day)	REMARKS
1	A	UAA	41	2.750	152	VACUUM	50	98	CORNING	DHW	Radiators	67/47	113,50		7,60	266	District Heating
2	A	UAB	24	1.700	91	VACUUM	50	54	CORNING	DHW	Radiators	67/48	74,40		4,55	159	District Heating
3	A	UAC	40	2.960	154	FLAT PLATE	50	128	BP - CALPAK	DHW	Radiators	67/49	124,80		7,70	269	District Heating
4	A	UAD	26	1.770	97	VACUUM	50	63	CORNING	DHW	Radiators	67/50	79,00		4,85	170	District Heating
5	A	UAE	24	1.920	96	FLAT PLATE	50	72	CALPAK CICERO	DHW	Radiators	67/51	83,60		4,80	168	District Heating
6	A	UAF	24	1.700	91	FLAT PLATE	50	72	CALPAK CICERO	DHW	Radiators	67/52	74,40		4,55	159	District Heating
7	A	UAG	30	2.030	112	FLAT PLATE	50	81	CALPAK CICERO	DHW	Radiators	67/53	89,70		5,60	196	District Heating
8	A	UAH	18	1.230	68	FLAT PLATE	50	51	CALPAK CICERO	DHW	Radiators	67/54	56,90		3,40	119	District Heating
9	A	UAJ	8	800	40	FLAT PLATE	50	30	CALPAK CICERO	DHW	Fan Coil Un.	55	36,30		2,00	70	District Heating
10	A	UAK	11	1.100	55	FLAT PLATE	50	40	CALPAK CICERO	DHW	Fan Coil Un.	55	49,70		2,75	96	District Heating
11	A	UAL	6	600	30	FLAT PLATE	50	23	CALPAK CICERO	DHW	Fan Coil Un.	55	27,00		1,50	52	District Heating
12	G	Total:	252	18.560	986			712		SH			809,30	1.335,00			
13	B	UBA	6	600	30	FLAT PLATE	50	24	CALPAK CICERO	DHW	Passive						Autonomous thermosyphon
14	B	UBB	12	840	45	FLAT PLATE	50	33	CALPAK CICERO	DHW	Passive				2,25	79	Central System
15	B	UBC	6	600	30	FLAT PLATE	50	24	CALPAK CICERO	DHW	Passive						Auton. Thermosyphon, 4 m²
16	B	UBD	10	1.000	50	FLAT PLATE	50	40	CALPAK CICERO	DHW	Passive						Auton. Thermosyphon, 4 m²
17	C	UCA	4	400	20	AIR COLLECT	50	44		DHW+SH	Air ducts	35/26					Auton. air collector, 11 m²
18	C	UCB	5	500	25	AIR COLLECT	50	55		DHW+SH	Air ducts	35/26					Auton. air collector, 11 m²
19	D	UDA	36	2.660	139	HP				DHW+SH	Radiators	60/46	114,50	120,00	6,95	243	Heat Pumps electr. Driven (Out of order)
20	D	UDB	30	2.130	114	HP				DHW+SH	Radiators	60/46	93,50	120,00	5,70	199	
21	D	UDC	10	1.000	50	HP				DHW+SH	Fan Coil Un.	45/37	45,10	45,36	2,50	87	
22	E	UEA	24	1.700	91	FLAT PLATE	38	94	CORNING	DHW+SH	Floor Heating	32/28	74,30	85,00	4,55	159	Initialy vacuum collectors
23	E	UEB	8	800	40	FLAT PLATE	50	52	BP - CALPAK	DHW+SH	Fan Coil Un.	32/28	36,30	35,00	2,00	70	
24+25	E	UEC/D	8	640	32	FLAT PLATE	38	40	25% SIEMENS, 25% STIEBEL ELTRON, 50%SET	DHW+SH	Floor Heating	32/28	29,80	34,00	1,6	56	
26	F	UFA	24	1.700	91	VACUUM	50	168	PHILIPS	DHW+SH	Floor Heating	32/28	74,30	119,15	4,55	159	Interseasonal Storage Tank
TOTAL			435	33.130	1.743			1.286					1.277,10	1.893,51	79,40	2.776,00	

ABBREVIATIONS : **DHW:** Domestic Hot Water **SH:** Space Heating **IST:** Interseasonal Storage Tank **HP:** Heat Pump

4. THE PROTOTYPE COST FOR CONSTRUCTION AND OPERATION OF THE ENERGY SYSTEMS.

The selection of the active and passive systems under evaluation in the SV was made with the main objective of having a large variety of different systems, which could be compared. The quantity and large variety of the energy systems created more operating and maintenance requirements, that is cost, than those normally expected.

The two Ministries covered the extra cost of construction, corresponding to the so-called non-conventional cost of the Project, while OEK, as previously mentioned, covered the so-called *conventional cost* of the Project. The cost for operation and maintenance of the energy systems during the phase of Measurement and Evaluation was covered in part by OEK, who kept the ownership of the energy systems, and in part by the inhabitants-users of the energy systems. The inhabitants were and are yet charged with part of the operation and maintenance cost, so that they are not burdened with the extra costs resulting from the demonstrative character of the Project.

An important undertaking of the SV Programme towards to the inhabitants was the gradual simplification of the conditions of operation of the energy systems. This simplification is possible to be achieved either by simple adaptations and control actions or by modifications and/or replacement of some installations. All these interventions and simplifications aim finally to the greatest possible reduction of the cost for Operation & Maintenance.

5. THE PROBLEM WITH THE PROPERTIES DOCUMENTS OF THE INHABITANTS OF SV.

As it is explained previously, the great variety and complexity of the energy systems and consequently the high operation and maintenance cost, due to the experimental character of the SV Project, have guided OEK to an insuperable obstacle and finally to a deadlock: It is impossible for OEK to vest its beneficiaries – inhabitants of SV with their final properties documents, while OEK has to continue covering the operation and maintenance year to year ongoing cost. The problem becomes more and more sharp, because of the natural aging of the equipment and machinery, the deterioration of their efficiency and finally the increase of the energy cost.

OEK making every effort to give a solution to that problem, decided to proceed to an extended revision of the energy systems and further to the realization of the whole proposal. OEK and CRES (Center of Renewable Energy Sources) in cooperation have already worked out a relevant study, based on a full inspection of the SV energy systems. The study has been designed, taking into account the following parameters:

- The experience got within the 18 years of continuous and uninterrupted operation of the energy systems.
- The extended damage of the equipment and machinery.
- The new Solar Technology, which has been improved considerably during the last 20 years.
- The demand of the inhabitants for cheaper energy and also for more simplified energy systems. Thereby, OEK can give the final properties documents for the apartments **including** the energy systems to the beneficiaries.

The financing of the intended new Project of retrofitting, renovation and Optimization of the efficiency of the SV energy systems will be carried out by OEK, using his own funds. It is also under question the possibility of financing of the Project through European funds.

6. THE INTENDED RENOVATION WORKS ON THE SV ENERGY SYSTEMS.

The intended new Project of retrofitting, renovation and Optimization of the efficiency of the SV energy systems, includes different actions on the existent installations, which in outline are described as following:

1. Other up-to-date collectors of high efficiency will replace all old installations of solar collector panels. Selective coatings will coat all absorber plates of the collectors. The steel staging of the solar panels are in good situation so they will not be replaced.

2. The Heat pumps on the roofs of the Region D three buildings will be substituted by central solar collector systems, covering the demand for SH and DHW of the apartments.

3. Oil and in part electric energy, that is the conventional fuel, will be substituted by natural gas, with obvious advantages in operation, environmental pollution and cost.

4. A new Interseasonal Storage Tank will be installed, to cover the SH needs of the Regions B and C (passive houses with autonomous thermosyphon for covering the DHW demand).

5. A new modern and top-tech control, measurement and automation system (full computerized) will substitute the old, obsolescent and in part damaged existing one in all energy systems installations. In other words a full Building Management System (BMS) will be installed.

6. A complete, and extended maintenance and/or repair of all the energy systems installations will be acted out. This group of works will include all the installations that will be kept up in operation and specially: piping, storage tanks, machinery, isolation, instrumentation etc. If necessary, replacements of damaged elements or equipments will be realized.

7. In parallel, in the frame of all these works concerning to the energy systems, maintenance and repair works of the waterproof insulation of the roofs and walls or ground floor of the buildings will be also included, because of the bad performance of the existing insulation.

8. CONCLUSIONS.

Main intentions of the suggested Project are the following:

- The simplification of all energy system installations
- The improvement of the energy systems efficiency,
- The significant decrease of the conventional fuel consumption,
- The minimization of gas pollution,
- The minimization of the operation and maintenance cost,
- The OEK possibility to give to the beneficiaries-inhabitants of SV their property documents,
- Finally, the ameliorating of quality of life of the inhabitants of SV.