Energy consumption saving in Municipal Swimming Pools

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Greece - Bulgaria 2007-2013
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Case study

The Municipal Sport Centre of Arkalochori (M.S.C.A.) is located on the east side of the town of Arkalochori in the County of Heraklion Crete. Founded in 2002, it includes the following facilities:

- two outdoor swimming pools, one pool of olympic dimensions 50x20m and one training pool of 25x6m
- one outdoor 8x8 football ground with composite carpet of rubber (calcetto)
- one tennis court
- two basketball-volleyball courts
- one play ground.

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Panoramic view of M.S.C.A.

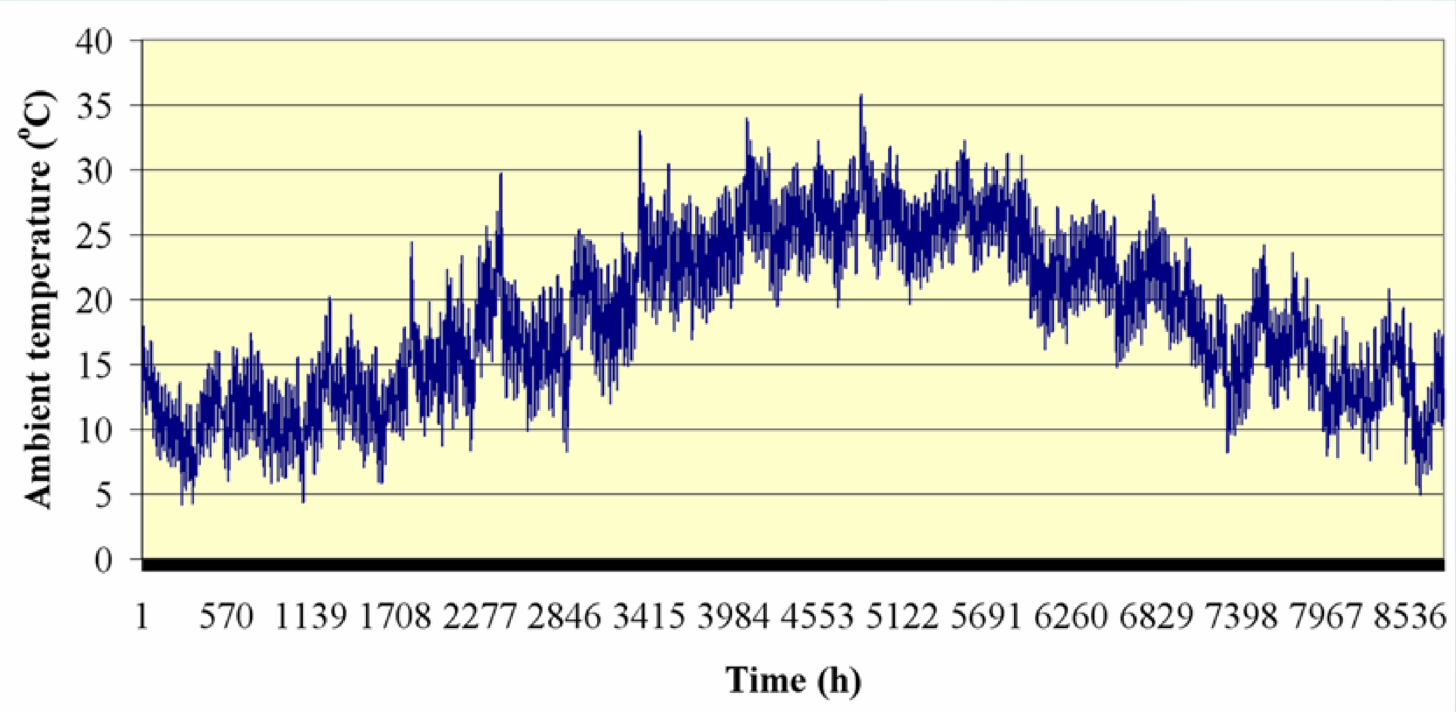
Existing energy consumption in M.S.C.A.

The basic energy consumption that has been recorded in M.S.C.A. is:

- Oil consumption in central burner Golling GL500, of 2.182kW, for water heating in pools.
- Oil consumption in another central burner of 116kW, for interior space heating of the buildings and production of domestic hot water (DHW).
- Electrical energy consumption in MFB and HQI lamps for the lighting of the sport complex.

Existing energy consumption in swimming pool

Meteorological data – Ambient temperature

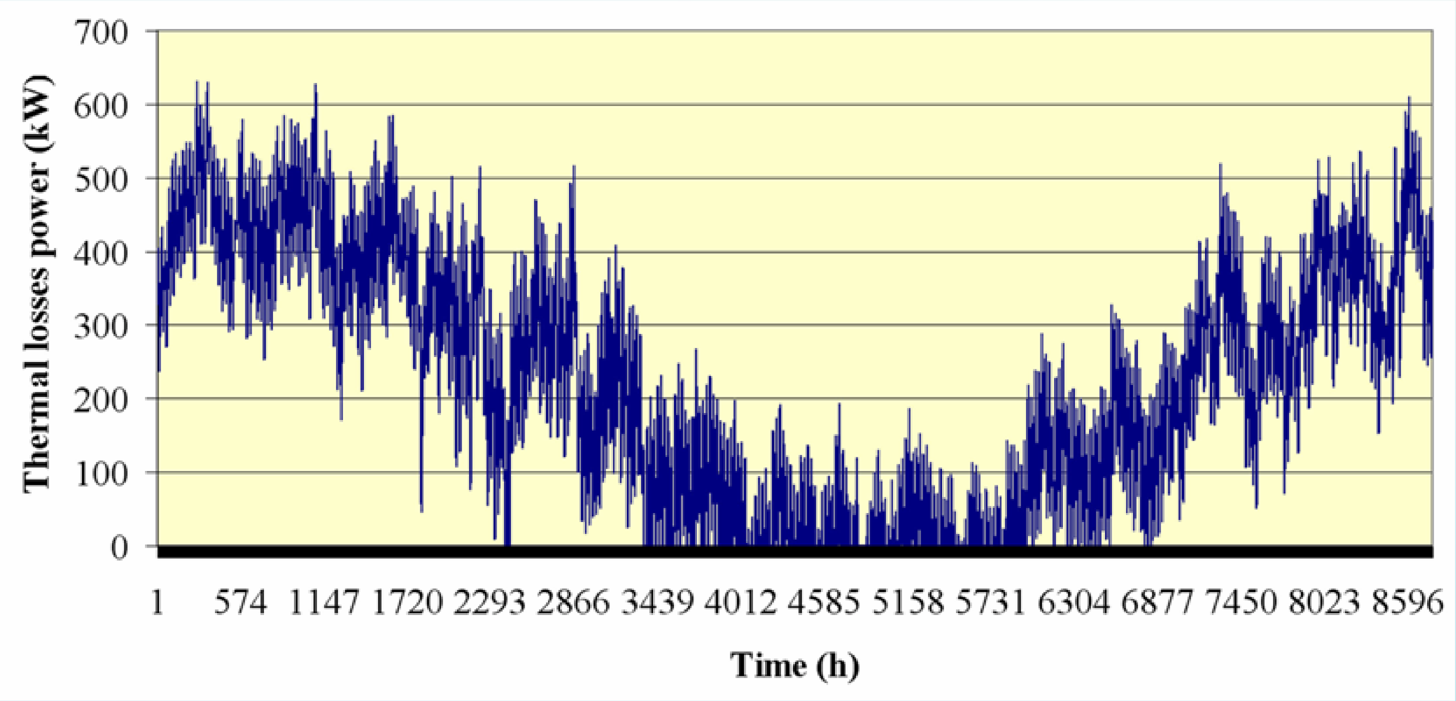


Annual ambient temperature range

Meteorological data – Wind data

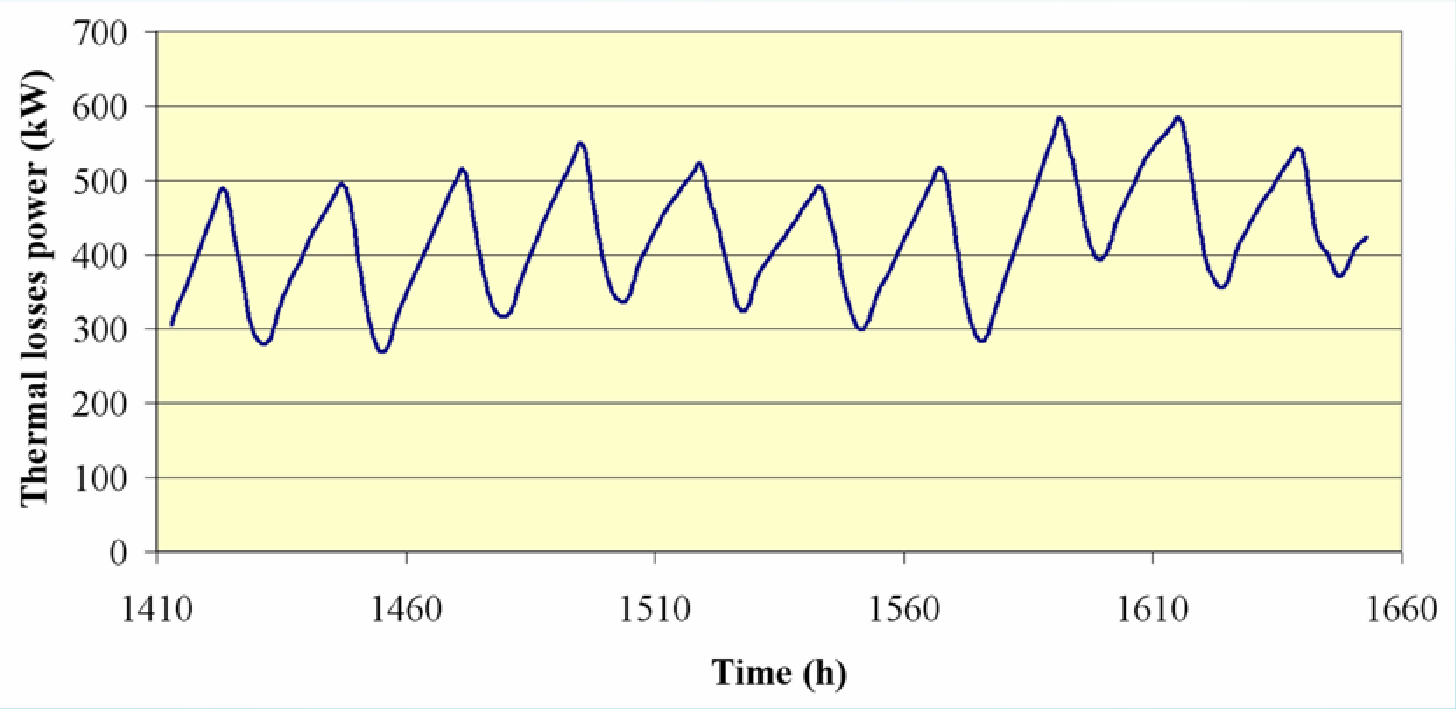
Month	Average wind speed (m/sec)	Main wind direction	C parameter in Weibull distribution (m/sec)	k parameter in Weibull distribution
January	4,79	N – NE – SSE	5,28	1,80
February	4,77	N – NNW	5,58	2,02
March	3,88	N – NNW	4,64	2,06
April	4,39	N – SSE	4,97	2,40
May	4,91	N – NNW – SSE	5,46	1,98
June	5,49	N – NNW	6,20	1,98
July	7,55	N – NNW	8,23	2,80
August	6,85	N – NNW	7,52	2,85
September	4,68	N – NNW	5,08	1,94
October	5,87	N – NNW	6,61	1,85
November	4,44	N – NNW – NW	5,14	1,90
December	6,22	N – SSE	6,99	1,75
Average annual value	**5,33**		**6,00**	**1,81**

Existing thermal losses of the pools



Annual varation of thermal losses of the pools

Existing thermal losses of the pools



Pools thermal losses range from 1/3 until 10/3

Existing annual energy comsumption

	Annual thermal loss energy (kWh)	Annual oil consumption (klt)	Initial thermal energy (kWh)	Original energy (kWh)
Olympic pool	1.705.979	225,883	2.274.638	2.502.102
Training pool	255.897	33,882	341.196	375.315
Total	1.961.876	259,765	2.615.834	2.877.418

Calculation assumptions:

- working hours: 12:00-22:00, six days a week
- desired temperature of pool water: 26^{o}C
- annual system's overall mean efficiency : 75%
- diesel oil lower thermal capacity: 10,07kWh/lt.

First important comment

- Based on the 30th maximum value of average thermal losses of the pools per hour (581,917kW) and the total average efficiency of the heating system of the pools which is estimated to be 0,75, the required rated power of the oil burner-boiler should be 775,889kW or 667.591kcal/h.
- It is obvious that installing the existing oil burner Golling GL500, of 2.184kW is excessive, which means that overestimation of the oil burner has been made.

Suggested interventions in saving energy at the swimming pool

Suggested interventions in saving energy

To reduce energy consumption at the swimming pool it is suggested:

1. To construct housing for the two pools:

The housing is suggested to have aluminum frame, which will be seated on steel foundations. The main housing material will be polycarbonate masiv, which is preferred to polycarbonate cellular, because of the much lower thermal conductivity coefficient and higher solar gains' coefficient.

Basic presupposition is the capability of the housing to be removed/open during summer months, so as to avoid high interior temperature, which, combined with high humidity, would make pools impossible to use.

Suggested interventions in saving energy

PC masiv and PC cellular properties

Properties	Test method	Unit	PC masiv	PC cellular
General				
Density	ISO 1183	gr/cm	1,2	1,2
Optical				
Solar gains' factor	DIN 5036	%	86	84
Refractive index	ISO 489		1,585	
Mechanical				
Flexural strength	ISO 178	MPa	>95	
Tensile strength	ISO 527	MPa	60	60
Thermal				
Specific heat capacity	ASTM D2766	J/gr·K	1,17	
Themal conductivity	DIN 52612	W/mk	0,2	3,9-1,4

Suggested interventions in saving energy

Swimming pools housings

Suggested interventions in saving energy

To reduce energy consumption at the swimming pool it is suggested:

2. Installation of surface cover on the top surface in both pools to reduce heat losses.

   The cover is accompanied by wrapping mechanism and is placed on the top surface of the pools when they are not in use.

Suggested interventions in saving energy

Surface cover in swimming pools.

Suggested interventions in saving energy

Cover material thermal properties:

Cover material	Polyethylene
Bubble diameter (mm)	12
Bubbles density (pcs/m^2)	5.750
Weight per surface unit (gr/m^2)	368
Pool cover material radiation emission ratio ε	0,550
Pool cover thermal conductivity coefficient λ (W/m·K)	0,025
Pool cover thickness d (m)	0,020
Pool cover thermal resistance coefficient d/λ (m^2·K/W)	0,800

Suggested interventions in saving energy

To reduce energy consumption in the M.S.C.A. it is suggested:

3. To replace the existing oil burner heating system of the swimming pools with biomass burner, so as to cover the new reduced heat losses for both pools with biomass.

The power of the new biomass burner that will take over the heating of the swimming pools will come up based on the power of thermal losses that will be calculated by the simulation of the annual operation of the swimming pools after applying the suggested interventions that concern reduction of heat losses (swimming pools housing and cover installation).

Suggested interventions in saving energy

To reduce energy consumption in the M.S.C.A. it is suggested:

4. Replacement of the small interior space heating and domestic hot water production burner can be done with the central biomass burner, with the appropriate modification of hydraulic network and installation of automation devises.

The final result that will be achieved with the proposed actions will be the total independence of the pools' operation from the usage of oil and the coverage of thermal losses in pools and interior space exclusively by Renewable Energy Sources (R.E.S.)

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Pools thermal loads after interventions

Calculation of internal temperature of indoor swimming pools

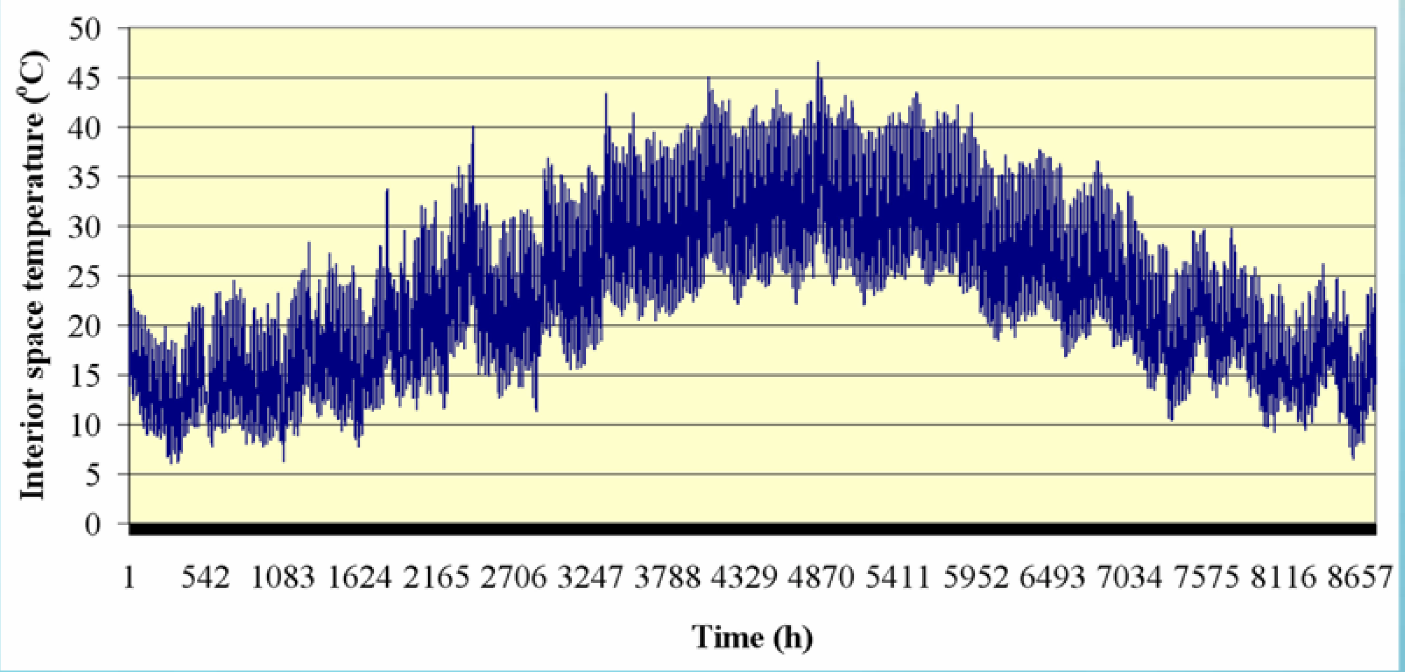
- For the calculation of the thermal loads of the pools after housing and installation of surface cover interventions, the annual variation of the internal temperature of the interior space that will be created above the swimming pools after housing, should be calculated.
- The calculation of the range of internal temperature is very important and depends on:
  - the climate conditions of the region of the swimming pool
  - the orientation of the vertical surfaces of the housings
  - the materials of the housings
  - the ventilation of the interior space of the swimming pool, which is determined the relevant bilbiography.

Calculation of internal temperature of indoor swimming pools.

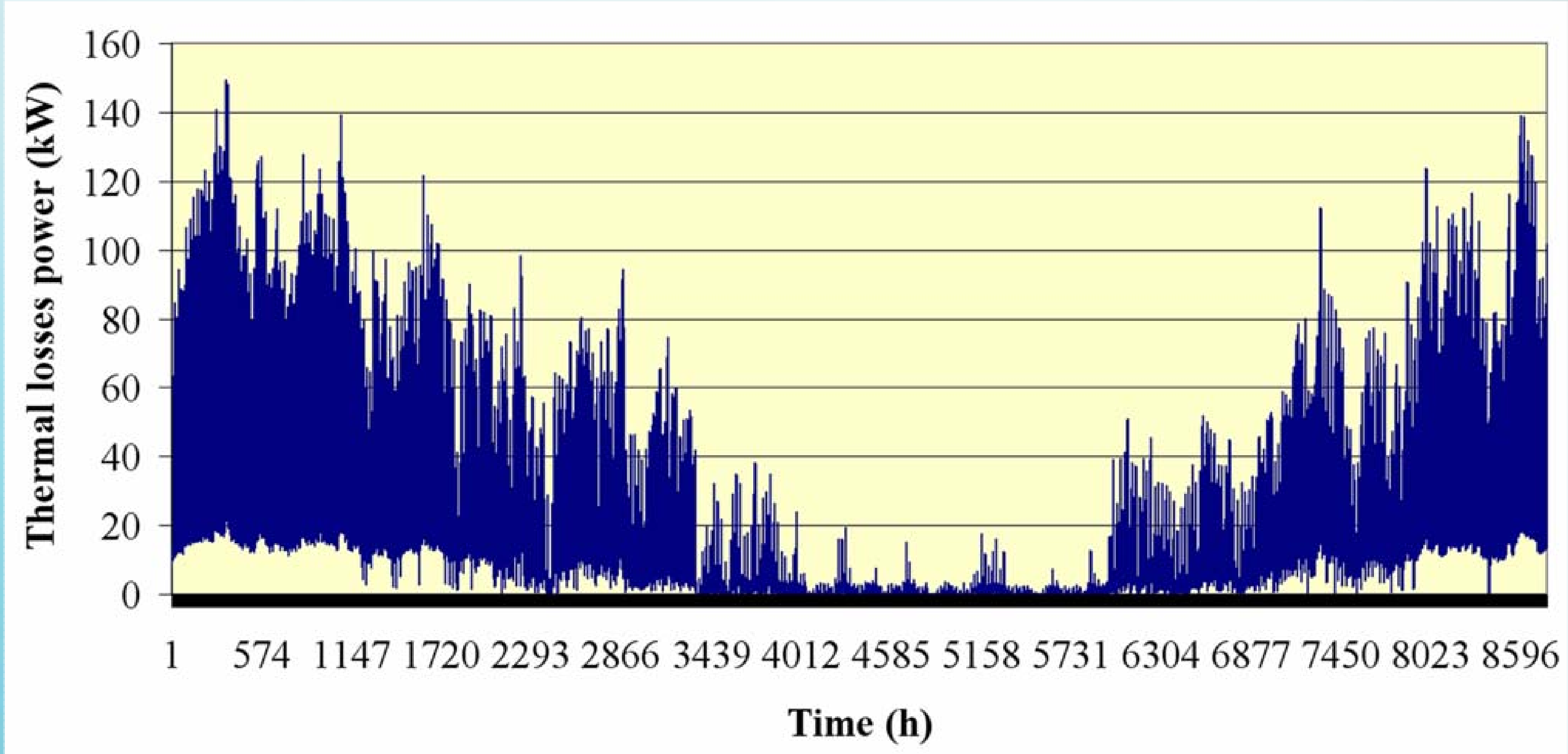
- To maximize the accuracy of calculation, the annual variation of the interior space’s temperature was calculated after the computational simulation of the problem, with the support of specialized commercial software (TRNSYS).
- Calculation assumptions:
  - thermal gains from presence of users were calculated based on the relevant bibliography and Greek standards
  - the considered number of users was 30 and average presence coefficient was 0,58.

Annual range of interior space temperature of the swimming pools

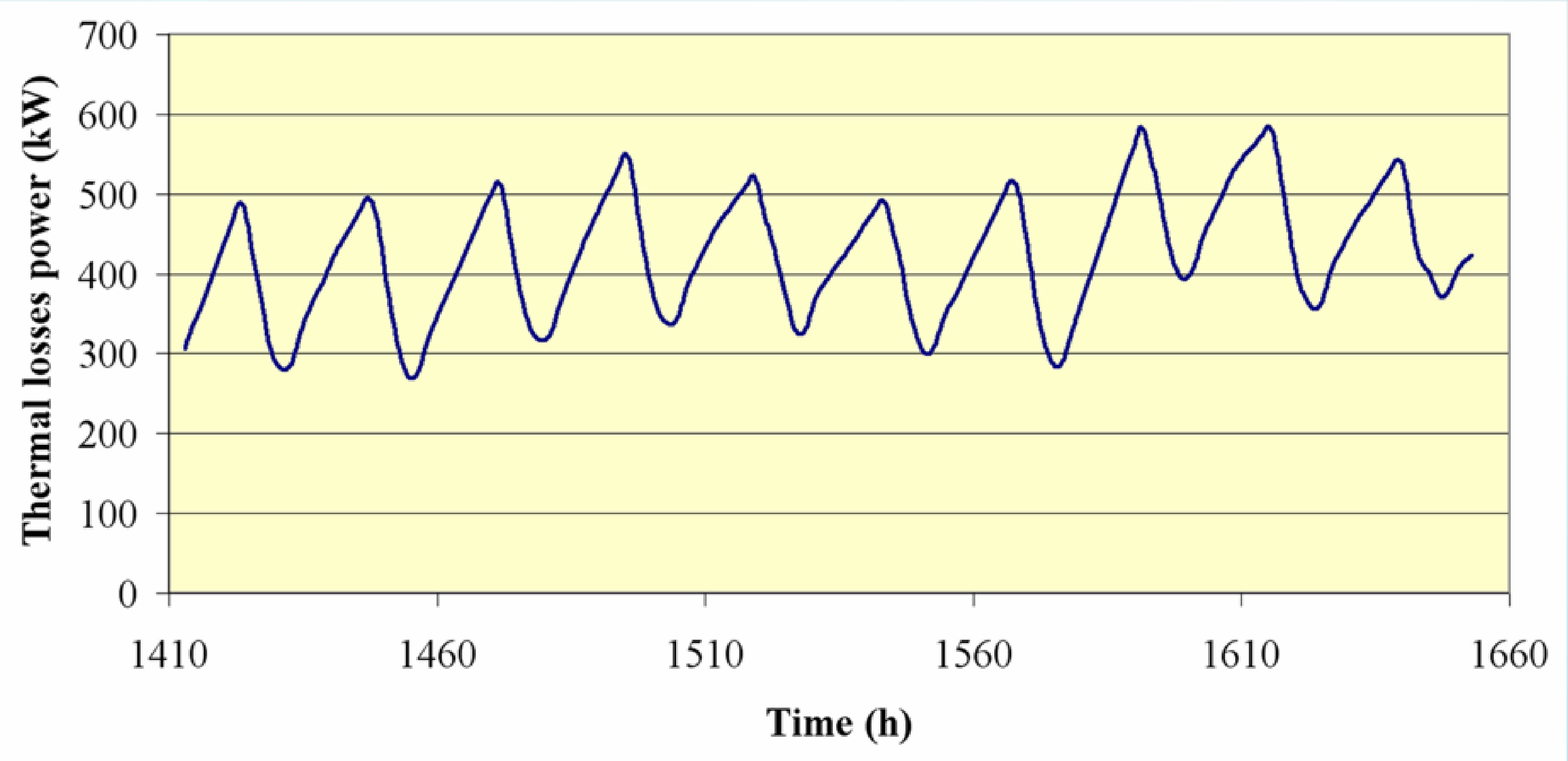
- The diagram come up considering the space permanently housed
- This assumption was made only for the calculation of thermal losses of the space.
- For the calculation of thermal losses of the pools it was assumed that the maximum temperature of internal space can not be higher than 26ºC.
  When this happens, the housing will open.



Annual thermal loads after interventions



Swimming pools thermal losses after interventions



Pools thermal losses variation from 1/3 until 10/3

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Energy saving

Annual energy consumption after interventions

	Annual thermal loss energy (kWh)	Annual oil consumption (klt)	Initial thermal energy (kWh)	Original energy (kWh)
Olympic pool	159.981	21,182	213.307	234.638
Training pool	23.997	3,177	31.996	35.196
Total	183.978	24,360	245.304	269.834

Calculation assumptions:

- working hours : 12:00-22:00, six days a week
- desired temperature of pool water: 26^{o}C
- system's annual overall mean efficiency : 75%
- diesel oil lower thermal capacity: 10,07kWh/lt.

Biomass heating (olive kernel or pellets)

Olive kernel thermal capacity (kWh/kg)	4,054
Pellets thermal capacity (kWh/kg)	5,792
Biomass efficiency	0,750
Annual consumption of olive kernel (tn)	60,509
Annual consumption pellets (tn)	42,352
Biomass initial energy (kWh)	245.304
Gases emission reduction (tn)	759,638

Saving compare charts

	Before interventions	After interventions	Saving	
			Current magnitude unit	Percentage (%)
Annual final heating energy demand (kWh)	1.961.876	183.978	1.777.898	90,62
Annual initial heating energy demand (kWh)	2.615.834	212.937	2.402.897	91,86
Annual oil consumption (klt)	259,765	0	259,765	100,00
Annual olive kernel consumption (tn)	0	60,509	-	-
Annual pellets consumption (tn)	0	42,352	-	-
Annual consumption of origial energy (kWh)	2.877.418	212.937	2.664.480	92,60
Annual gasses emission CO_2 (tn)	759,638	0	759,638	100,00

Biomass burner

Choosing biomass burner

- Based on pools thermal losses calculation after interventions, the maximum loads are estimated to be 140kW.
- Considering average total efficiency of the heating system to be 0,75, the biomass burner should have a rated power of 187kW or 161.000kcal/h.
- Biomass burner of 200.000kcal/h is chosen, so as to cover the loads of space heating and domestic hot water production too.

Choosing biomass burner

- Biomass burner should have the capablity to consume any solid fuel of small dimension, such as wood pellets, olive kernel, peels of nuts, almonds etc.
- The biomass burner should be accompanied by:
  - automated ignition system with blower
  - ash removal system
  - fire safety valve
  - fuel feeding tank
  - automated fuel feeding system with screws
  - multi-cyclone chimney filter, especially if olive kernel is used.

Choosing biomass burner

- The biomass burner should be accompanied by:
  - electrical panel with all the required fuses and switches, for the operation of its electrical parts (fans, blower resistor, fuel feeding motor etc)
  - central processing unit, to control and program all the operations and parts of the biomass burner
  - construction, safety and efficiency certificates which are determined by international standards.

Economical indexes of the project

Initial cost

Description	Unit cost (€)	Quantity	Total (€)
Swimming pools (tanks) interventions			
Materials purchase, transfer and installation of the housing	800.000	1	800.000
Olympic pool cover wrapping roller	26.000	1	26.000
Training pool cover wrapping roller	8.900	1	8.900
Olympic pool cover	9.200	1	9.200
Training pool cover	1400	1	1.400
Olympic pool solar cover rail	5,6	100	560
Training pool solar cover rail	5,6	50	280
Olympic pool cover edge driving set	96	20	1.920
Training pool cover edge driving set	96	6	576
		Total 1:	**848.836**

Biomass burner

Description	Unit price (€)	Quantity	Total (€)
Biomass burner			
Biomass burner - boiler	25.110	1	25.110
Burner electrical panel	2.100	1	2.100
Burner fuel store tank	1.000	1	1.000
Store tank basis	700	1	700
Galvanized chimney	3.430	1	3.430
Automated ignition system with blower	900	1	900
Burner fire safety valve	320	1	320
Ash removal system	1.330	1	1.330
Domestic hot water production system	500	1	500
Burner multi-cyclone chimney filter	9.500	1	9.500
		Σύνολο 2:	**44.890**

Initial cost

Swimming pools (tanks) interventions cost (€)	848.836
Biomass heating system cost (€)	44.890
Total interventions cost (€)	893.726

Operating cost reduction

	Existing operation	Olive kernel-used operation	Pellets-used operation
Annual oil consumption (klt)	259,765	0,000	0,000
Annual πυρηνόξυλου consumption (tn)	0,000	60,509	0,000
Annual pellets consumption (tn)	0,000	0,000	42,352
Annual oil cost (€)	363.671	0	0
Annual πυρηνόξυλου cost (€)	0	6.051	0
Annual pellets cost (€)	0	0	14.823

Operating cost reduction
Payback time period

Annual operating cost of swimming pool reduction			
Using olive kernel		Using pellets	
(€)	(%)	(€)	(%)
357.620	98,34	348.848	95,92

Payback time period (years)	
Using olive kernel	Using pellets
2,50	2,56

Calculation assumptions:

- oil price: 1,40€/lt
- olive kernel price: 80€/kg
- pellets price: 350€/kg.

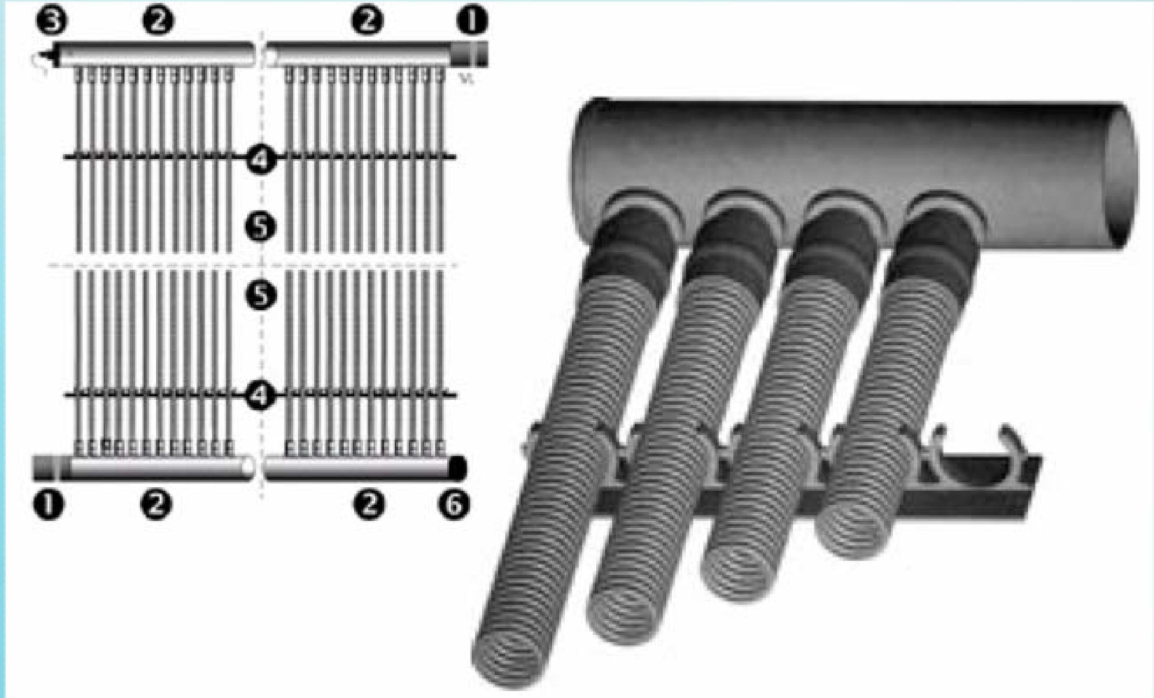
Heating swimming pools with solar collectors

Types of solar collectors

1. Uncovered solar collectors.
2. Flat-plate solar collectors (black painted – semi selective - selective coating collectors).
3. Vacuum tube solar collectors.

Uncovered solar collectors

1. Tube's gasket
2. distribution tube
3. temperature sensor
4. tubes' distances regulator
5. twisted tube
6. seal.

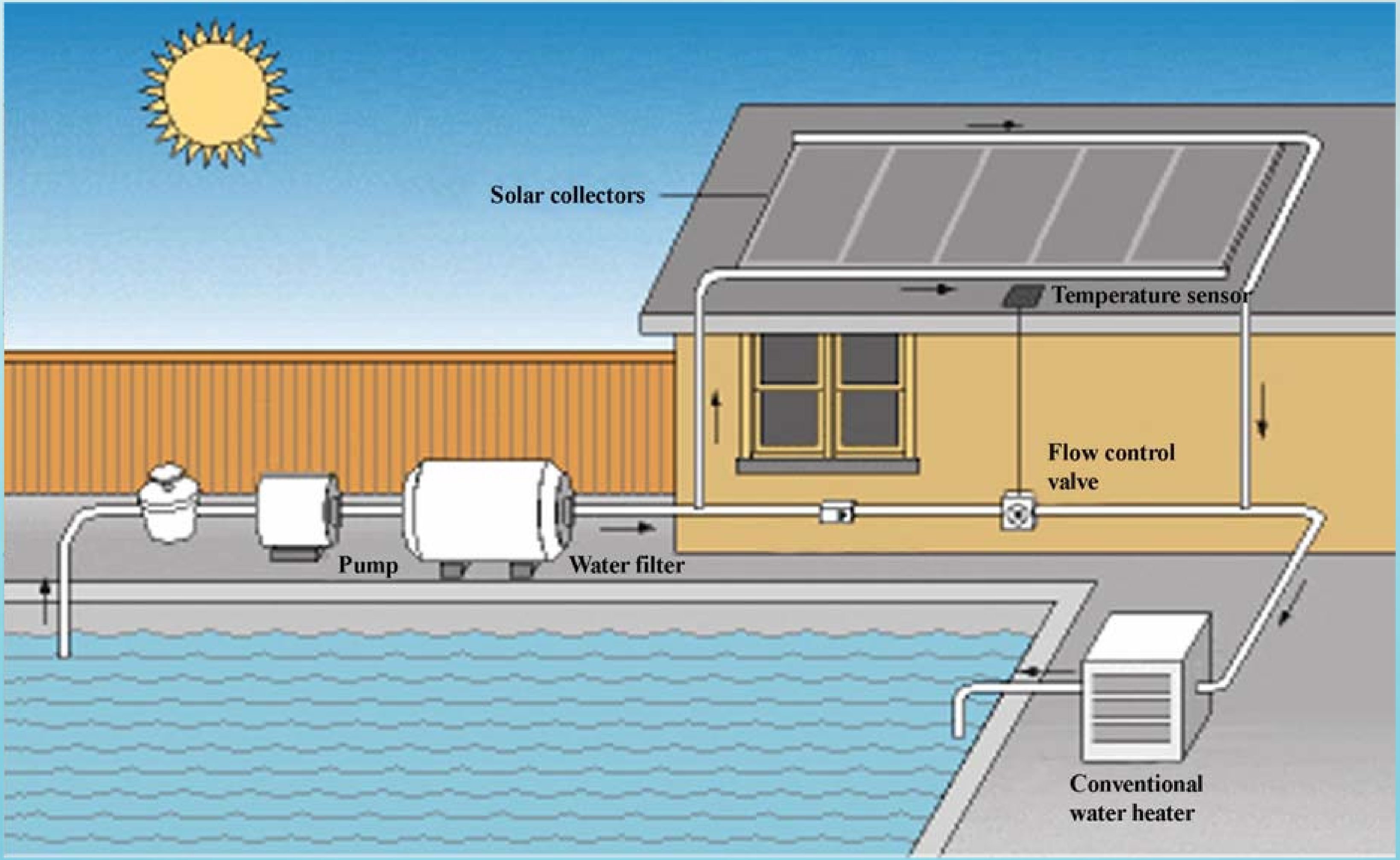


Uncovered solar collectors

- Advantages
  - No additional equipment is required (for example store unit, heat exchangers) that raise the budget.
  - Low purchase and installation cost (approximately 100€/m^2, payback time period 1-5 years.
  - the aesthetic impact of solar collectors in the system is extremely smooth.

- Properties
  - integration only in amateur swimming pools, where the desired temperature is relatively low (26°C), just to prolong for 2-3 months the annual time period usage.
  - required area of solar collectors $m^2 = 0{,}8 \cdot m^2$ of the pool (Greece).

Pool heating application



Pool heating by solar collectors

A system of pool heating by solar collectors consists of:

- **Collectors:** Can be either flat-plate ones or uncovered solar collectors.
- **Heat exchangers:** They are used in flat-plate collectors case so that the chemically treated water of the pool does not enter the collectors and erodes them.
- **Automated systems:** They are used to control the operation of the system.
- **Circulators:** They ensure the water circulation in the circuit of solar collectors.

Pool heating by solar collectors

- **Temperature sensors:** Detect when heat is available and when water heating is needed. When such need is detected, the water circulates in the solar collector, is heated by the sun and afterwards, passes straight into the swimming pool. Temperature sensors are placed:
  - at the exit from solar collector
  - In the water circuit of the pool, usually before the heat exchanger, so as to measure the temperature difference between circuit of the solar collectors and the pool water.

Pool heating collectors compare chart

Collector technology	Cost (€/m^2)	Annual specific production of final energy (kWh/(m^2·year))	Average annual efficiency (%)
Uncovered collectors	100	300	15 – 20
Flat-plate collectors (black painted)	140	650	35 – 40
Flat-plate selective coating collectors	170	700	40

Application example in Arkalochori swimming pool

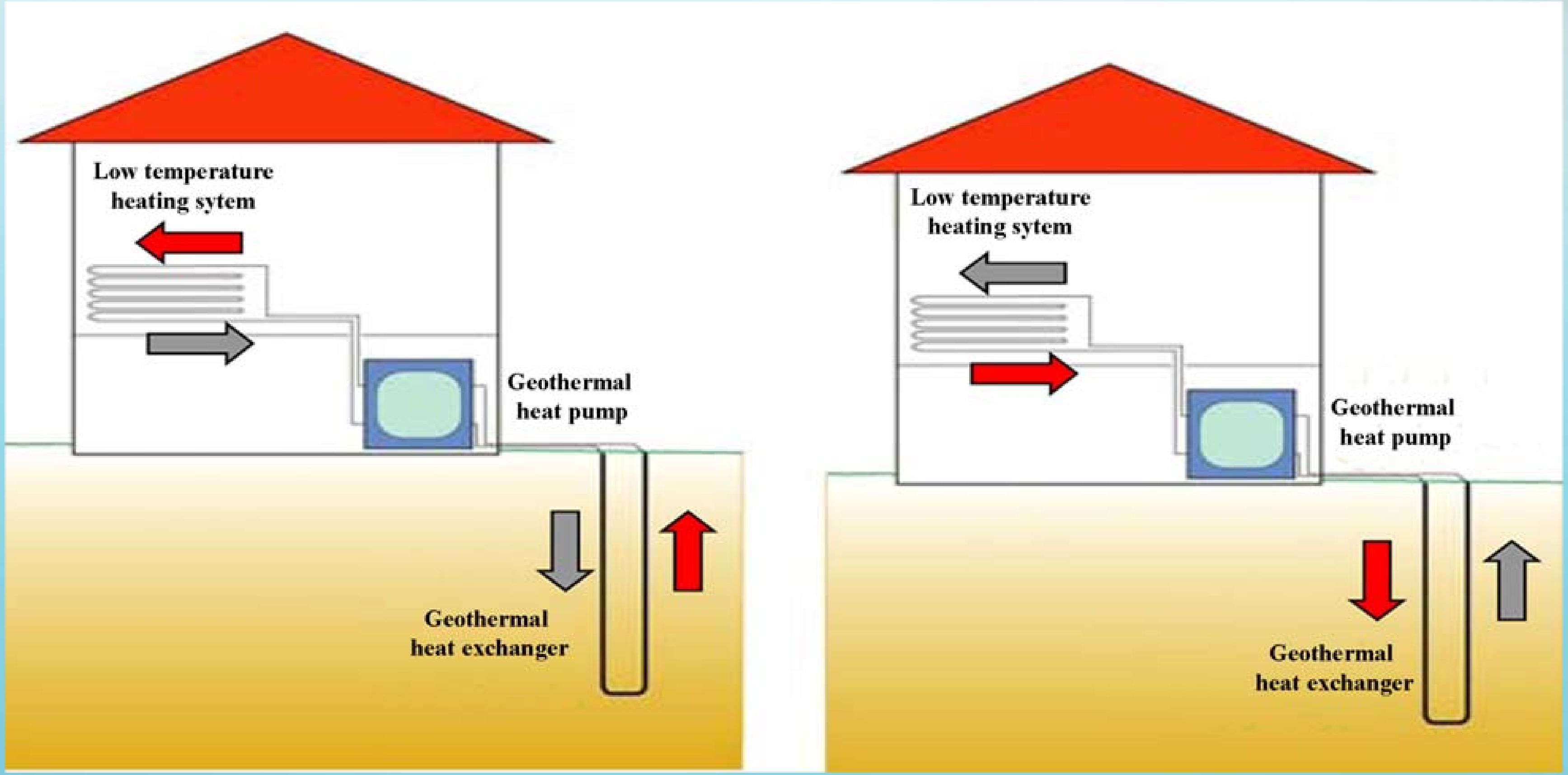
- The specific production of final thermal energy during heating period of the pool (January – April and October – December) is estimated to be:
  - 120kWh/m^2 for uncovered collectors
  - 280kWh/m2 for flat-plate collectors.
- For the production of 183.978kWh of final thermal energy are required:
  - 1.533m^2 uncovered collectors area (cost 153.300€)
  - 657m^2 flat-plate collectors area (cost 91.980€).
- It is given that, even by the before shown areas of solar collector, because of stochastic availability of solar radiation and of non temporal coincidence with the thermal load, usage of a burner is going to be required , even if for small annual percentage (20%).

Swimming pools heating using geothermal heat pumps

Operating principle

Winter – Heating

Summer - cooling



Pool's heating using vertical geothermal loops

- Adopting a specific methodology defined by ASHRAE and taking into account all the available meteorological and operational data that concern the specific swimming pool in Arkalochori, we conclude in the following results regarding the dimensioning of the fundamental geothermal heating system's components:
  - type of loops' installation: vertical (to maximise the system's efficiency)
  - total wells' length: 7.100m
  - number of wells: 40m
  - well's depth: 178m
  - diameter / width of geothermal pipe: Φ32mm / 3mm
  - total geothermal pipes length: 14.200m
  - nominal power of heat pump: 150kW
  - heat pump's nominal Coefficient of Perfmormanc (C.O.P.): 4,5.

Pool’s heating using vertical geothermal loops

Annual final thermal energy demand (kWh)	183.978
Heat pump’s nominal C.O.P.	4,5
Annual electricity cinsumption (kWh)	40.884
Annual electricity purchase cost (€)	4.714
Project’s estimated set-up cost (€)	650.000

Electricity price: 0,11529€/kWh

Presented systems’ comparative results

Comparative economic results

	Olive kernel usage	Pellets usage	Solar collectors – pellets	G.H.P.
Total set-up cost on swimming pools interventions (€)	848.836	848.836	848.836	848.836
Thermal production system set-up cost (€)	44.890	44.890	150.000	650.000
Total set-up cost (€)	893.726	893.726	998.836	1.498.836
System's annual operating cost (€)	6.051	14.823	3.500	4.714
Annual operating cost reduction compared to the existing one (diesel oil usage) (€)	357.620	348.848	360.671	358.957
Payback time period (έτη)	2,50	2,56	2,77	4,18

Comparative energy results

	Olive kernel usage	Pellets usage	Solar collectors – pellets	G.H.P.
Annual final thermal energy demand (kWh)	183.978	183.978	183.978	183.978
Annual initial biomass energy consumption (kWh)	245.304	245.304	49.061	-
Annual electricity consumption (kWh)	-	-	-	40.884
Annual original energy consumption (kWh)	245.304	245.304	49.061	118.564
Annual CO_2 emission (kg)	0	0	0	117.259

End of presentation

Thank you for your attention

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