Solar cooling potential in tourist complexes in the North Aegean

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ABSTRACT

Heating, cooling and domestic hot water in buildings have high energy demands and they are associated with direct and indirect environmental problems through pollutant emissions. A dramatic increase of the installed air conditioning systems in buildings is observed during the last years. The dominant practice is that air conditioning applications rely exclusively on electrical energy while the exploitation of solar energy is mainly for domestic hot water, with few applications on space heating and very limited on space cooling. This practice is associated with vertical increase of the electricity peak-load during summer months, a fact that is very intense in the islands due to the high tourist season during these months.

Tourism is a very significant development parameter for the islands of North East Aegean but the increased tourist activities are associated with multiple environmental problems, one of them attributed to the increased energy demand.

One of the main building applications that are responsible for the energy demand problems during summer is air-conditioning applications. In the context of this paper, the potential for solar applications, mainly for space cooling but also combined with space heating and hot water are investigated for the tourist sector in the Northern –East Aegean area.

Based on the results of energy audits and calculations of 3 hotel complexes in the Chios island and collection of data about the hotel building stock in the island of Northern – East Aegean, an assessment is made for the potential of economic feasible solar cooling applications in the hotel sector in this geographical area.

1. INTRODUCTION

Tourism is an important lever of development for the islands of the N.E. Aegean sea. However, the increased tourist activity creates multiple problems in the environment. The energy demand in the tourist sector is great and presents peaks especially during summer months. It is especially ascertained that electricity is the most often used source of energy, while oil and liquid gas follow. Up today, renewable energy sources have a very small share in the energy balance of the islands.

Energy consumption data of Greek hotels in the beginning of the 90's, show that the mean total energy consumption is in the order of 273 kWh/m^2, from which 197,9 kWh/m^2, are consumed for heating, 10,7 kWh/m^2 for cooling, 24,5 kWh/m^2 , for lighting and 39,9 kWh/m^2 for appliances (Santamouris et al., 1996). Estimation of the energy needs of thermal insulated hotels in the A and B climatic zone – where the islands of N.E. Aegean sea belong – is expected about 56-67 kWh/m^2 for heating and 145 -150 kWh/m^2 for cooling (NOA, 2003).

Heating, cooling and domestic hot water production, demand large amounts of energy and they result in direct or indirect emissions of pollutants and carbon dioxide, a gas that is responsible for the greenhouse effect, which, in the long run, is associated with the climatic change on the earth.

In the current practice, air conditioning is exclusively based in the use of electric energy, while use of solar energy is limited at heating of domestic hot water and in limited applications for space heating and even fewer for cooling.

This practice creates a vertical increase of the electricity peak load during summer months, a phenomenon that is intensely observed in the islands due to the increased tourist action during these months. The existing, autonomous energy production in every island in several cases is not adequate to meet the increased energy demands.

All these negative effects can be eliminated, in benefit of the national economy, society and environment, with the use of solar thermal energy for space heating and cooling, domestic hot water and in heating of the swimming pools.

Aim of the current work is to assess the potential of solar cooling, combined with space heating and hot water in the tourist complexes of the North-East Aegean sea.

2. SOLAR COOLING

The problems faced by conventional cooling techniques in its long way assisted to the development of an important sector, the "thermally driven cooling machines". A solar air conditioning system includes the solar collectors for the production of heat, one of the different cooling technologies - usually absorption or adsorption chillers - and finally the systems of heat and cooling dissipation in the space. A conventional energy source functions as auxiliary, mainly for the periods when the cooling load is not covered by the produced energy from the collectors. The hot water that is produced by the collectors is used by the chiller for the production of cold water (7 -10 ^{0}C) in the case of space air conditioning (Fig. 1).

The basic principle for production of cold by heat is based on the evaporation technique, a mechanism with which we feel cool when we are wet and the water is evaporated through our body. The basic advantage of solar cooling is, that the greater heat exists, the more cooling is produced, advantage that is excellently synchronized with the requirement for summer cooling in buildings.

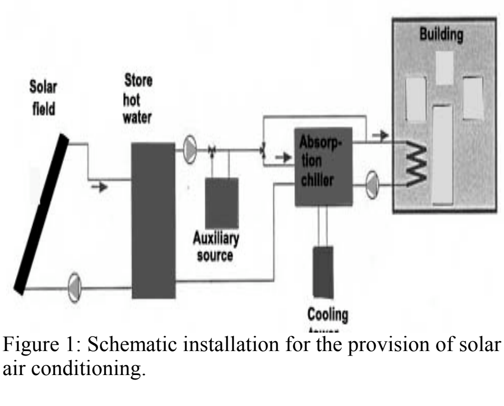

Figure 1: Schematic installation for the provision of solar air conditioning.

Behind the absorption – adsorption techniques a carefully orchestrated ballet of evaporation and condensation is found. The successive phases of cooling are ensured through an absorbent and cooling substance. There is gas absorption from liquid in the techniques of absorption and gas from solid in the techniques of adsorption. On the contrary, in the conventional air-conditioners, there are mechanical methods of compression and relaxation of a cooling fluid with electricity consumption.

In Table 1, the basic operation characteristics of the main solar cooling techniques are summarized. A classification is presented based on the type of thermal cycle - open or closed - and absorption medium.

The greatest exploitation of solar cooling potential is achieved in buildings with high thermal gains during the day and consequently high cooling load. The total attribution of the solar air conditioning installation depends on the type of used solar collectors (flat collectors or vacuum tubes or vacuum collectors), the size of solar field, the cooling load (type of building and use, local climatic conditions) and the used cooling and air-conditioning technique. In order to achieve energy savings, solar cooling installations should achieve a minimum solar cover of about 20% of the load (in absorption and open air cycle cooling based on absorption) and of about 30% (in adsorption cooling) (Henning, 1997).

3. CLIMATIC CONDITIONS IN THE N.E. AEGEAN SEA

The climate of the region is characterized as hot mediterranean, characteristic of the islands of N.E. Aegean sea area. Particularly in the island of Chios, the average annual air temperature is relatively high, about 17 ^{o}C (NWS, 2003). The average absolute high air temperature is observed in July and is about 29.9 ^{o}C while the absolute high temperature was observed in August 1994 with 41 ^{o}C. The average relative humidity is about 67% with a minimum value dur-

Table 1: Characteristics of solar cooling techniques (Henning, 1997)

Method	Closed		Open	
Cooling cycle	Closed circulation of cooling means		Cooling means (water) in contact with the atmosphere	
Principle of method	Cold water production		Air humidification + evaporative cooling	
Absorption mean	Solid	Liquid	Solid	Liquid(1)
Cooling /absorption mean	water/silica gel, NH_3 / salt(1)	H_2O / LiBr, NH_3 / H_2O	H_2O /silica gel, H_2O / LiCl, cellulose	H_2O /CaCl, H_2O /LiCl
Available techniques	Cooling adsorption machines	Cooling absorption machines (one-two stage)	Air-conditioning based on absorption (ABA)	-
Available power (KW)	70-1050 kW	50kW–5MW (A) 250kW–5 MW (B)	20-350 kW (per unit)	-
Coefficient of performance COP	0,3-0,7	0,6-0,75 (A) 1,0-1,20 (B)	0,5-1,0	>1,0
Driving temperature	60-90 °C	80 -110 °C (A) 140-160 °C (B)	45-95 °C	45-70 °C
Solar collector	Vacuum tube, flat plate collector	Vacuum tube, flat plate selective collector	Flat plate collector, air collector	Flat plate collector, air collector

1) Still in development, A = one stage, B = two stages

ing the months of July – August, in the order of 56,5%. The prevailing wind direction is northern and for short periods southern. Cloudness is very low, in the value of about 2,7%. The islands of N.E. Aegean area are classified among the regions of Greece with the greater sunshine duration, having total annual sunshine duration of 2.858 hours or an average of 7,8 hours per day. The highest monthly value of 391,2 hours was observed in July that corresponds to 12,6 hours per day. The ratio of clear to cloudy days is 3,8/1 (NWS, 2003).

4. HOTEL INFRASTRUCTURE IN THE N.E. AEGEAN SEA AREA

The N.E. Aegean area includes the islands of Lesvos, Chios, Samos, Ikaria and Lemnos. The mild climate of the islands, their natural beauties and their cultural monuments have helped a lot in the growth of tourism and consequently the construction of several hotel units. The number and the category of the hotel complexes in the area are presented in the Table 2.

5. ENERGY MONITORING OF HOTELS

The installation of solar air conditioning was studied in three hotel units of the inland of Chios, representative of the tourist units that exist in the island:

- A hotel, with a restaurant and a bar, of 48 beds capacity and a total conditioned area of 1200 m^2, with a continuous operation throughout winter-summer time.
- A tourist complex with 12 rented apartments of total conditioned area of 800 m^2 that operates only in summertime.
- A tourist complex with 8 furnished apartments of total area of 780 m^2 that operates only in summertime.

The objective of the study was the investiga-

Table 2: Distribution of tourist complexes in each island and hotel category, in 2003 [HCG, 2003].

	Category						
Island	Lux	A	B	C	D	E	Total
Lesvos	1	5	40	52	2	6	106
Chios	-	9	11	1	11	2	34
Samos	1	7	34	108	-	-	150
Ikaria	-	2	3	9	4	9	27
Lemnos	4	3	6	8	3		24
Total	6	26	94	178	20	17	341

tion of the potential of covering the heating – in yearly hotel operation – the cooling and hot water needs of the tourist complexes by a solar system and also the environmental implications.

A detail energy audit was carried out in each of the building, through recording of:

- the constructional and bioclimatic elements of the building,
- the installed energy systems, appliances and lighting,
- the energy consumption,

followed by:

- calculations of the thermal and cooling loads,
- dimensioning of the solar installation,
- choice of a solar chiller.

In each building it was recorded:

- the monthly electricity consumption,
- the oil consumption, and
- the number, the installed power and the hours of operation of lighting systems, appliances, air conditioning units and heating installations.

Calculation of the monthly energy consumption was made:

- in the summer months, based on the installed power of air conditioning units, the hours of operation and the degree of occupation of the hotel,
- in the winter months, based on the heating oil quantity and the corresponding degree of occupation of the hotel.

Based on the selected data and the analysis, the total monitored oil and electricity consumption for the different uses, per building, appear in the following Table 3. The monthly distribution per use of the electricity consumption for each hotel unit is shown in Figures 2, 3 and 4.

Table 3: Monitored specific energy consumption in the 3 hotel buildings.

Fuel (kWh /m^2)	Hotel Building		
	1st	2nd	3rd
Electricity			
Heating	1,024	-	-
Cooling	14,56	11,32	14,18
Lighting	10,04	5,91	6,06
Appliances	31,80	2,27	2,07
TOTAL	57,64	19,50	22,31
Oil	28,05	-	-

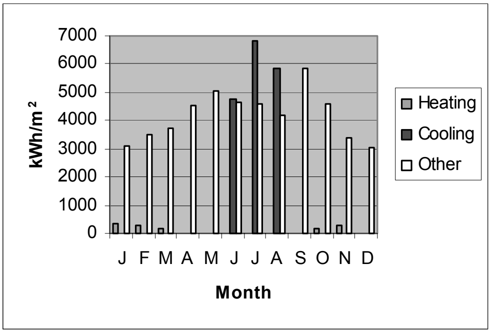

Figure 2: Distribution of the specific electricity consumption at the 1st hotel building.

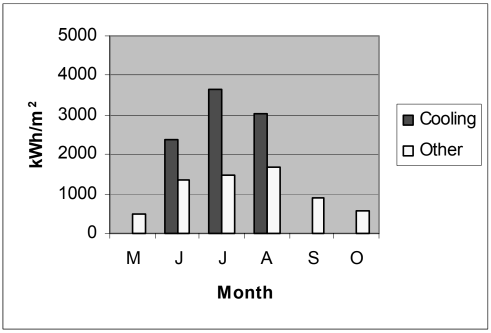

Figure 3: Distribution of the specific electricity consumption at the 2nd hotel building.

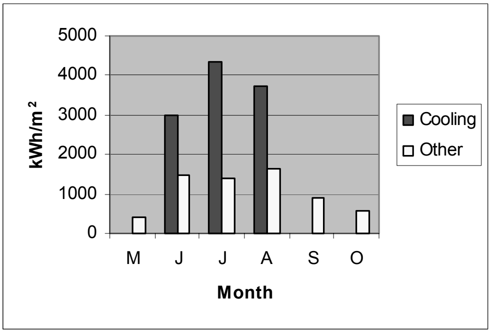

Figure 4: Distribution of the specific electricity consumption at the 3rd hotel building.

For the dimensioning of the solar system, the following assumptions were made:

- 60% solar cover of the thermal load and
- 100% of domestic use hot water

in the winter period, and

- 100% solar cover of the cooling load and
- 100% of domestic hot water of use

in the summer period.

Dimensioning of the system was based on calculated heating and cooling load of each building.

6. ECONOMIC EVALUATION

Assuming that the cost of the solar air conditioning installation comes up to € 7.337 per cooling tonne (CRES, 2003) and the purchase cost of electric power comes to € 0,067 per kWh, the simple pay-back period of the investment in the three buildings of study, under different scenarios of solar installations use, are summarised in Table 4.

From the previous analysis it clearly appears that the more the solar thermal energy exploitation is limited, the more the pay-back period of the investment increases.

An environmental analysis was performed on the basis of the energy savings achieved by replacing conventional energy systems with a solar installation and the resulted reduction of pollutant emissions was calculated. The use of a solar installation in the three studied buildings can result to a reduction of a total 71.427 kWh per year. This energy savings are associated with a total avoidance of pollutant emissions which are presented in the following Table 5.

7. ENERGY AND ENVIRONMENTAL BENEFITS AT THE HOTEL SECTOR IN THE N.E. AEGEAN AREA

As it appears at the Table 1, in all the five islands of the N.E. Aegean area there are totally 341 hotels, covering all the categories, and in their majority are small and very few are big.

Table 4: Pay-back period of the solar energy investments in the 3 hotel buildings.

Building	Operation scenario	Pay back period (years)	
		0% subsidy	50% subsidy
1	A	18	9
	B	25	12,5
	C	36	18
2	B	18	9
	C	23	11,5
3	B	18	9
	C	23	11.5

A. Space heating, space cooling, summer & winter DHW
B. Space cooling, summer DHW
C. Space cooling

Table 5: Amounts of gas emissions reduction.

	Kg / year
CO_2	75.890
SO_2	1.386
CO	13
NO_8	108
HC	3,45
Particles	72

Based on the monitored results of the three studied hotels, it is assumed an average annual energy consumption of 20.000 kWh for air conditioning and domestic hot water. If these needs are covered with the use of solar thermal energy, then energy saving will be achieved, in the order of:

→341 * 20.000 = 6.820.000 kWh/year.

This in turn will result to a reduction of pollutant emissions, which is quantified in Table 6.

In the installations of air conditioning, up to a little time ago nothing better existed than a simple installation of a conventional air conditioning with all the limits that characterize it with regards to the comfort, management costs, the required volume, health and hygiene.

The solar air conditioning in the hotel units of the N.E. Aegean area is an important application field of the use of solar thermal energy, because the sunshine of the region is in very high levels. Various techniques are available but there is still need for technological improvements in order to become widely applicable. Of course, up to this day there is limited experience for the installation and operation of solar air conditioning systems

As it was realised by the three examined case studies in the present work, the use of thermal solar systems in the hotels of the N.E. Aegean area for space heating, cooling and domestic hot water can create the following economic and environmental profits:

Table 6: Estimated gas emissions reduction by application of solar installations at tourist complexes in the N.E Aegean.

	Kg/ year
CO_2	7.246.250
SO_2	132.308
CO	1.228
NO_8	10.230
HC	341
Particles	6.820

- Remarkable energy savings during winter and more important during summertime.
- Reduction of pollutant emissions.
- Reduction of the peak electricity load, especially during summer, a very important aspect for the islands of the N.E. Aegean area that is supported by autonomous power stations. Solar cooling will decrease the electricity peak loads during summertime and it will smooth out load curves, thus, resulting in important investment savings for the construction of new power stations and remarkable environmental benefits.
- Promotion of a green identity of the hotels of the N.E. Aegean area in the wide public as well as their picture of social sensitivity which will also result in increase of their purchasing value.

However, the hotel units of the N.E. Aegean area, in their great majority, are relatively small and the cost of investment is high enough. In addition, the lack of information about the available technologies and the limited economic motives that are provided through national and european programs, as well as their long payback period are some of the main obstacles.

The more general actions which are proposed in the frame of a strategy for the promotion of solar air conditioning in the hotel units of the N.E. Aegean area are:

- Demonstrative projects must be made in order to make explicit to the directors and the hotel owners that solar air conditioning is indeed applicable and beneficial.
- Analytical research must be carried out with regard to the energy consumption for air conditioning in the hotel units using the existing conventional technology and the saving of energy that will result with the use of solar technology.
- New specifications must be established for the construction of new hotel buildings, for the wider, if not obligatory for some hotel sizes, use of thermal solar energy with regard to the heating and cooling of spaces, the production of domestic hot water and heating of swimming pools.
- Information dissemination must be organized regarding the new energy technologies and the existing effective financing mechanisms.
- Financing of feasibility studies for the new investments must further promote their application.
- Subsidy of the interest-rate for the loans that concern investments in new energy technologies.
- Indirect economic interventions like reduction of V.A.T. and other taxes.
- Programmes for "return of money" to be worked out, with subsidy of the efficient energy technologies (renewable energy sources).

As the number of tourists with increased environmental consciousness increases, classification of hotels, depending on their environmental behaviour will constitute an advantage for the hotels and the tourist regions. This system of hotel classification depending on their energy efficiency and their environment performance should be promoted sufficiently worldwide.

8. CONCLUSIONS

The character of Greek tourism is seasonal. This means that the problems of peak loads that are presented in the electric network in the summer period in the islands, which have autonomous production power stations, are exclusively due to the intense tourist movement.

In order to avoid the phenomena of frequent interruptions in the electrification, with the so negative consequences in the image of the country to the visitors, there are two choices:

- The first is to increase the installed power in the systems of electricity generation, which is economically disadvantageous with obvious damage to the environment of these regions and hence to the tourist movement itself.
- The second is the reduction of the hotel building heating - cooling loads through their right energy design and cover of it – part or all – together with the heating of domestic water though solar technologies. This will reduce or eliminate the problems of peak electricity load, it will protect the environment and strengthen the green picture of the tourist sector in the wide public.

As it was realised by the case studies of the present work, the use of thermal solar systems in the hotels of the N.E. Aegean area for heating, cooling and hot water it creates appreciable economic and environmental benefits.

Also, the investment pay-back period decreases as the sectors of exploitation of solar thermal energy increase.

An obstacle of course for the investment is its high cost. Besides Greece, has been committed, according to the objective that has been placed by the Community Directive 2001/77/EC to increase by 2010 the rate of production of energy from renewable energy sources to 20 %.

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