Active and Passive Solar Cooling for the European Cities

K. Papakonstantinou, N. Klitsikas and M. Santamouris (NKUA)

A. Gomez-Heras (ATECYR)

P. Rasmussen and N. Gomez-Gil (REHVA)

National Kapodistrian University of Athens, Physics Dept., University Campus, 15784 Athens, Greece

Tel: +30-1-7276847

Fax: +30-1-7295282

ATECYR, Serrano Galvache, s/n. 280833, Madrid, Spain

REHVA, PO BOX 311 NL-3830AJ Leusden, The Netherlands

Abstract

The project nick-named APASCUE-EC and conducted over a period of two years, aims to study and propose global strategies, tools and guidelines to promote efficient and cost effective implementation of advanced passive and active solar cooling systems and techniques for the European cities. To this end, it combines and adapts scientific and technological knowledge with best engineering and architectural practice. It is the first time that such an integrated and global study on new and advanced solar cooling techniques is initiated in Europe.

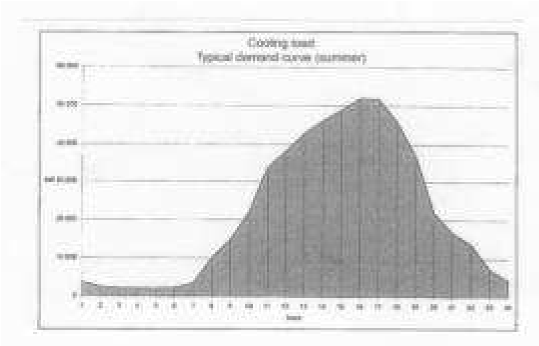
1. Introduction

The buildings sector in Europe accounts for approximately 40% of the total energy consumption, around 70% of which is used in residential buildings. Much of this energy is used for heating and cooling purposes, fuelled principally from fossil sources. It is therefore very important to address this large and diverse sector to identify where energy savings can be made and where clean and more efficient technologies can be incorporated. Such changes will not only contribute to a reduction in the total energy consumption of the sector and an associated reduction in CO_2 emissions, but will also help to provide a better quality of life of citizens by providing a cleaner, more energetically comfortable local environment.

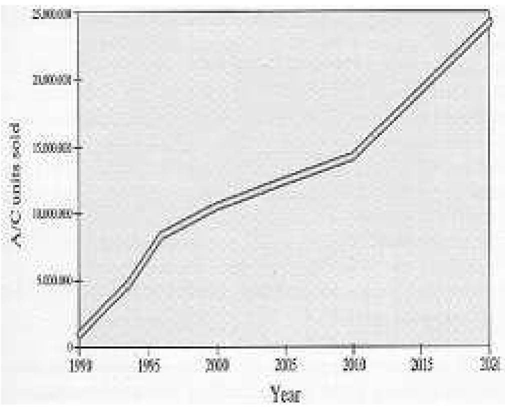
Renewable energy sources are expected to be economically competitive with conventional energy sources in the medium long term. Nevertheless, the penetration of renewable energy sources into Europe"s energy market is still low. In 1996 the renewables contributed less than 6% of the total energy consumption and this was mostly provided by large-scale hydro and by biomass.

It has been concluded that by 2010 renewable energy technologies could contribute an increasing amount to energy supplies in the 15 Member States, especially from the "newer technologies" [1]. The energy demand for cooling is 30kWh/m² in the residential sector in Southern European countries. In the offices and commercial building, the cooling demand is much higher owning to internal heat gains and solar energy gains [2]. In a typical modern office building the amount of energy for cooling purposes is 20% of the total energy [3].

Also during the day in the summer period the maximum cooling loads reach their maximum values of 50000kW between hours 16:00 and 17:00, as is shown in Figure 1.



A much more impressing view of the impact of urban cooling is given in Figure 2, representing the development of domestic A/C sales and their future projections for all the European Union. A peak power of 54 GW will progressively develop in the Union, which is equivalent to the output of 180 power stations, 300Mw each. The above clearly indicates that electrically driven cooling create a severe imbalance to the Union"s power supply strategy, unless new concepts on Urban Cooling, will be applied, as solar energy.



2. The objectives of the project

A technical and financial assessment of the energy saving potential and global impact of cooling technologies when applied to the urban buildings. The assessment considers different financial, operational and energy criteria and characteristics:

- A market study on the sector of air conditioning in buildings assessing the potential to integrate solar cooling technology.
- An assessment of the environmental benefits and impact of solar cooling. The improvement of the urban environment is an increasingly important concern as nowadays more than 85% of the European population is living and working within cities. If good use is made of advanced solar cooling in European cities, the potential

annual energy savings are calculated close to 30 to 50Mtoe. This can reduce CO2 emissions from the building sector up to 8 per cent annually, thus contributing to the objectives set by the EC in the framework of the Kyoto conference, and at the same time save up to 10 G EUR per year.

- A study of the existing legislative framework to better consider solar cooling techniques in urban environment and identification of the possible problems and restrictions. Appropriate codes and regulations will be proposed.
- A development and assessment of specific global scenarios for selected cases studies in Greece and Spain. The scenarios assess the particular technical, financial and environmental potential and limitations of solar cooling systems and propose practical solutions.
- A development of a Reference Manual that will present globally design guidelines, performance criteria and methodologies for best practice implementation of solar cooling techniques. The manual will consider different climatic, operational, energetic and environmental criteria and characteristics. Proposals of a better implementation of measures to improve the penetration of solar assisted cooling in buildings, involving new norms and certification schemes.

3. The work plan of the project

The overall work has been divided and carried out in 8 phases:

- Phase 1: Collection and documentation of the input data.
- Phase 2: Development and assessment of methodologies to better introduce solar cooling techniques to buildings.
- Phase 3: Assessment of the market potential of solar cooling techniques, cost benefit analysis.
- Phase 4: Assessment of the environmental benefits and impact of solar cooling.
- Phase 5: Study of the legislative framework to better consider solar cooling techniques in the urban environment.
- Phase 6: Development and assessment of specific global scenarios for selected cases studies.
- Phase 7: Development of the reference manual.
- Phase 8: Testing the manual in a European workshop.

4. Final deliverables

The final deliverables of the project will be the following:

- A complete Reference Manual ? Handbook presenting design guidelines, performance criteria and methodologies for solar cooling techniques applied to urban buildings.
- A market study on the sector of air conditioning and solar cooling.
- Proposals for better implementation of measures to improve the penetration of solar cooling in buildings.
- A complete assessment of the impact of solar cooling technologies applied in urban buildings.
- Results of a number of test cases where global scenarios to apply solar cooling techniques to buildings will be developed in Greece and Spain.
- The conclusions and the results of a workshop on the application of solar cooling techniques and systems in urban buildings.

5. Presentation of a solar cooling application in Greece

The description and the first results of a solar heating-cooling station installed on an industrial sector in Greece are presented in the following paragraphs. This project is related with the installation of a central air-conditioning system using solar energy for the heating or cooling of the new buildings and warehouses of the Company of Saradis situated in Inofita of Boiotia. The air-conditioning space is 22000 m² ? 130000 m³ where it has been placed a system of flat plate solar collectors extending to an area of 2700m² and which have been constructed in Greece by the SOLE company. This project is the biggest one implemented in Greece and the second one in the whole world. The installed air-conditioned system uses solar flat plate collectors, Figure 3.

The cost of the flat plate collectors is about one third of the cost of the vacuum collectors and therefore the investment becomes more attractive. Besides, the flat plate collectors are constructed in Greece. The solar collectors supply two adsorption coolers with hot water of temperature 70-75 °C and they operate with a coefficient performance of 60%. The two adsorption coolers, Figure 4, use the hot water either as source energy or as a coolant (instead of Freon or Ammonia or Lithium bromide) and produce cool water of temperature 8-10 °C. This is achieved within the condensation and evaporation of the coolant (water) in vacuum. The adsorption coolers don't consist of movable parts and use minimum electric energy for the operation of the vacuum pumps (0.5 KW). The useful power is 350 KW for each one and 700KW for the total. For the coverage of the peak load three conventional electric coolers of 350 KW each of them have been installed. Also two boilers of 1200KW each one substitute the collectors field when there is cloudiness or whenever there is need for air-conditioning during the night.

The boilers use oil fuels that they will be replaced by natural gas in future. During the winter period the solar collectors send round the hot water of 55 °C directly to the heated spaces. The same collectors replace the collectors field in case of overcast. The cold water (during the summer period) and the hot water (during the winter period) is directed to the local air-conditioning units where they cool or heat respectively the ambient air within physical procedures.

A very important benefit of the solar cooling system is that during the summer period its coefficient performance increases as the ambient temperature rises. As a result there is a perfect coincidence of the peak load and the system's performance. This fact is of great significance especially for Greece where the maximum demand of the electric energy concurs with the maximum solar radiation. It is obvious that this system will contribute to the reduction of the electric consumption and the installed electrical power. The budget for the coverage of the total load due to the solar energy is approximately 50-60%. The existing data referring to an operation period of 41/2 months provide a coverage of 67%. However, the monitoring period is very small and doesn't include the peak load months as is July for cooling and January and February for heating. Finally, it is estimated a 50-60% of the total load will be covered on an annual basis.

The project's identity is given in Table 1.

Table 1: The PHOTONIO project identity

Owner	SARADIS
Place	INOFITA BOIOTIAS - GREECE
Air Conditioning Room	$22000m^2$ - 130000^3
System Type	KLIMASOL 2x350
Collector Area	$2700m^2$
System Power	Summer: 700 KW / Winter:1500 KW
First period of operation	15th of August 1999
Exhibition of operation period until	31th of December 1999
Time interval	41/2 months
Problems	None
Yielded Solar Energy	155000 KWHR
Total Load	230000 KWHR
Solar Coverage	67%

6. Conclusion

The APASCUE-EC project provides comprehensive information on the solar cooling technology and proposes measures for the best implementation of solar energy aiming to the cooling of the urban buildings.

ACKNOWLEDGEMENTS

This site was produced as part of ?The Advanced Passive and Active Solar Cooling for the Urban Environment of European Cities project, and funded by the European Commisions's ALTENER programme.

REFERENCES

- "Renewable Energy Report", Joule-Thermie Programme, Directorate General for Energy (DG XVII).
- "Survey for the exploitation of the Renewable Energy Recourses in the southern Aegean, P/V Systems", Ministry of Aegean, Athens, September 1998.
- "Cooling in the cities of tomorrow", Joule-Thermie Programme, Directorate General for Energy (DG XVII).