Medicool European Project
A Demonstrative Example of Smart Solar Cooling/Heating System

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Keywords: Solar Cooling/Heating System, Energy Efficiency, Absorption Chiller, Solar Energy.

Abstract: The main objective of this paper is focused on describing a demonstrative example of a thermal cooling/heating system. The proposed solution has been implemented in the pharmaceutical distribution sector, which involves strict and rigid European and national regulations regarding storage temperature conditions. The developed installation is one of the largest systems ever built in Europe based on solar cooling/heating technologies. It has a collecting surface of 22,500 m^2 by using one of the latest technologies: the Ultra High Vacuum (UHV) collectors. These collectors reduce significantly both convection and conduction heat losses. The proposed system has two absorption chillers of 675 and 855 kW respectively. It is expected to provide an annual energy savings estimated of around 795 MWh, only for the cooling system representing more than 70% of the global energy currently needed for conditioning the selected warehouse. This solution can be easily extensive towards other industrial sectors in areas with similar energy characteristics and thermal requirements: large conditioning spaces and buildings with high cooling/heating power demand during the peak power periods.

1 INTRODUCTION

The decreasing of traditional fossil energy sources, combined with pollutant emission reduction agreements, have leaded most developed countries to propose special tariff systems and tax reductions for renewable energy solutions. In this upcoming scenario, new technologies have a remarkable short-term impact and play an important role towards a sustainable energy system. As an example, PV power plants are proposed in (Valentini, 2008) as a crucial new supply solution. In a similar way, the useful impact of wind farms on power system operators is analysed in (Wan, 2005), showing that load fluctuations even can produce more changes in the interchange than wind power fluctuations. But not only supply-side is proposed to be analysed and modified, in (Kirschen, 2008) is suggested that consumers should be also considered as a genuine demand-side capable of making rational decisions, and not only as a load that needs to be served under all conditions. However, this desired active participation in electricity markets by the demand-side remains minimal, though there is a strong need to increase customer participation in markets to enhance system reliability and reduce price volatility (Kueck, 2001).

With regard to the industrial sector, the cooling/heating power demand is increasing more and more in most developed countries. Moreover, in moderate climates such as most EU member states, this fact usually produces a dramatic increase of electricity power demand during hot summer days, involving undesired increases of both fossil and nuclear energies and, furthermore, threaten the stability of electricity grids. These combined cooling/heating power plants are also becoming popular in residential and commercial sectors, aiming to meet desired thermal and electricity demands.

Since these systems integrate cooling, heating and power generation capabilities at one site, they result in potentially lower capital and operating costs and facilitates ease of maintenance and operation (Wu, 2006). Another remarkable aspect very related with the cooling/heating power demand is energy sustainability. In fact, several political incentives have been already proposed to emphasize their

Molina-García A., García-Egea T. and Moreno M..
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DOI: 10.5220/0004861001630169
In *Proceedings of the 3rd International Conference on Smart Grids and Green IT Systems* (SMARTGREENS-2014), pages 163-169
ISBN: 978-989-758-025-3

importance into the building sector, taking into account the existing potential of energy savings as well as the increased social awareness on energy-related issues. Indeed, in industrially developed countries, buildings are contributing with more than one-third of the total energy consumption, being major contributors to greenhouse gas emissions.

Consequently, and considering cooling-heating requirements as well as building aspects, the use of renewable resources and energy efficiency for space heating and cooling purposes must be considered as a relevant topic of interest for the current industrial sector. In fact, there is a relevant interest in evaluating and assessing the performance of solar thermal solutions for those applications, mainly in countries such as Spain, where the climate offers appropriate opportunities. For these purposes, solar refrigeration is more and more recognized as a priority in developing countries, due to the needs for minimizing the energy expenditure and improvement the thermal requirements. In this context, the use of solar energy for absorption refrigeration research has been one of the hot issues along this last decade (Wang, 2000). According to several authors, refrigeration is particularly attractive as a solar energy application due to the near coincidence of peak cooling loads with the available solar power (Sumathy, 2003). The absorption system is one of the promising solar thermal refrigeration methods, and it is environmentally friendly along with low cost and low maintenance requirements. Furthermore, operating costs are 15% less than conventional air conditioning systems. By installing solar assisted cooling systems in southern European and Mediterranean region, about 40–50% of primary energy can be saved (Balaras, 2007). Under this framework, the present paper is focused on describing a demonstrative project financially supported by the European Union aiming of providing a real example of sustainable solution for cooling large storage or commercial spaces, such as logistic buildings, warehouses, wholesaler… where temperature requirements are very restrictive.

The rest of the paper is structured as follows: Section II gives detailed information about the proposed solution Innovative aspects of the demonstrative project is discussed in Section III. Preliminary results are described in Section IV. Finally, conclusions are given in Section V.

2 SYSTEM DESCRIPTION: GENERAL OVERVIEW

From the different industrial sector activities, the pharmaceutical distribution network in Europe involves by around 1500 operating sites, delivering more than 6400 hospital pharmacies, 135000 community pharmacies and around 8000 dispensing doctors. They account for more than 80% of the pharmaceutical distribution in Europe, delivering each operating site around 329 pharmacies and 1.11 million people −on average−. This pharmaceutical distribution system can be also considered as a current warehouse for most hospitals, which rely on this system the storage of medicines due to its efficient and safe delivering systems (set by law, up to 5 delivers a day and even instant delivery). Nowadays, there is even a tendency on increasing the number of those warehouses in Europe, since logistic companies are getting into the market and developing the export of medicines by setting logistic warehouses around Europe. Regarding the Mediterranean countries, about 630 warehouses are operating, mainly in Italy, France and Spain, with a surface of about 2 million m^2 and generating the emission of around 62,000 Tons of CO_2. In Spain, there are 192 warehouses with a surface of around 600,000 m^2, with a global energy costs of about 3 million €/year and generating about 18,600 Tons of CO_2/year.

With regard to storage temperature conditions, this industrial sector presents strict and rigid European and national regulations, being necessary to follow properly severe temperature requirements. Indeed, this industrial sector is very sensitive facing environmental and economic problems. The severe thermal conditions (25º C ± 2º C and humidity levels of 60% ±5%) must be fulfilled in every medicine warehouse located in Europe. These storage conditions are set by the Directive 2001/83/EC −amended by Directive 2004/27/EC− and the subsequent national regulations and codes of good practices in each country.

In Spain, the Law 29/2006 about guaranties and rational use of medicines and health products is in charge of regulating these requirements. However, this regulation framework is currently fulfilled at very high economic costs and, in some cases, with no-efficient technological solutions, involving remarkable environmental costs. Under this scenario, the *Medicool* project gives an alternative solution to this problem by applying, testing and validating new industrial processes implemented under real conditions. This demonstrative project gives a real example of the suitability of thermal cooling-heating solutions under severe temperature range requirements. It also offers remarkable results regarding technical adjustments and maintenance tasks.

The specific characteristics and requirements of the pharmaceutical warehouses –large conditioning spaces and buildings with high power demands and strict temperature range requirements to meet usually during peak power demand periods– are very similar to other buildings devoted to different activities, such as services buildings, malls, sport centres, food processing and storage industries, or wine cellars. This conditioning space problem, in terms of quantitative and qualitative energy demand, has at this moment a great interest in Europe. Additionally, there is a remarkable replication potential of the present project in the rest of the Mediterranean countries. Indeed, some pharmacy industries and governments of South-Mediterranean countries have already expressed their interest in the results of the project.

As it can be seen in Figure 1, the selected warehouse for the installation of the present prototype is located in the Region of Murcia, South-East of Spain. It has a surface of about 30,000 m^2 –one of the biggest in Europe–, with a global energy demand of over 4000 MWh/year, energy costs of around 140 m€/year and 932 Tons of CO_2/year generated by the whole installations. The solution provided by this European project involves one of the largest systems ever built in Europe, based on solar cooling/heating technologies. It has a collecting surface of 22,500 m^2 with the main objective of reducing the current cooling time periods that can be varied from 5 hours/day during the winter to 12 hours/day during the summer period. On the other hand, it must be pointed out that this pharmaceutical warehouse is considered as a general pharmaceutical storage, being used by public regional hospitals that are not currently available to be equipped with their own pharmaceutical warehouses.

The selected pharmaceutical warehouse provides services to all hospitals and pharmacies in the Region of Murcia (Spain). This pharmaceutical distribution is owned by HEFAME, which is one of the three national leading companies in the sector of pharmaceutical distribution and owns 6 more warehouses, mainly in the Mediterranean regions of Spain (Hefame, 2013). In reference to the storage of pharmaceutical products, and considering the annual cycles of outdoor temperature and humidity in the South-East of Spain, the company presents severe problems to keep the conditioning space temperature below 25 ºC. This temperature requirement has been set by European and national regulations as well as international codes for pharmaceutical products.

Figure 1: Geographical localization of the demonstrative project and general information.

Over the past years, some initiatives have been proposed by different agents to solve the conditioning large space problem. Indeed, this issue has been considered as a high priority by the public administration of the Region of Murcia (Spain), which has also participated actively in this project through the Regional Energy Agency of Murcia. This particular interest is due to there are only a few projects devoted to assess and implement solar cooling/heating systems and, most of them propose smaller systems or prototypes not designed for the industry. Additionally, there are no examples of projects in Europe for thermal solar systems larger than 1MW, being most systems below 100 kW.

3 INNOVATIVE ASPECTS OF THE MEDICOOL PROJECT

The proposed thermal cooling/heating system works as follows: the Ultra High Vacuum (UHV) collectors heat the thermal oil until getting the set-point temperature (<120º C), adapting the flow to maintain this value. Afterwards, a heat exchanger is in charge of heating the water up to 90 ºC. This water is then sent to the absorption chillers, using 1 or 2 machines depending on the thermal power available (Medicool, 2012), see Figure 2. These machines cool the water of the cold circuit from the conventional chillers before water crosses them. These conventional chillers are responsible for the last regulation of the temperature. The energy saving of the system is provided by the cold absorbed by the solar system that is produced with renewable energy source (solar). Conventional cooling backup system and hot water storage are both foreseen to complement the proposed system. Hot water storage is part of the system as well; and its associated benefits are included in the global energy reduction of around 70% of the total energy. Conventional cooling system, already installed in the pharmaceutical warehouse, covers the rest of the cooling energy needs (30%). The final objective of this technological solution is to be able to cover the whole energy requirements without conventional cooling backup systems, since it would make the system more efficient in terms of energy consumption and economically cheaper to install and maintain. The design of the proposed solution involves that all storage centres have these conventional systems already installed and available.

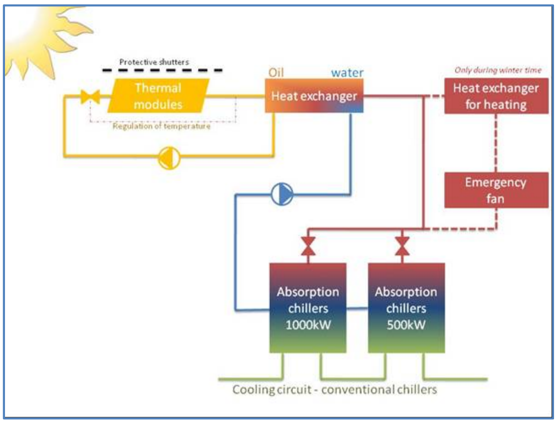

Figure 2: Proposed solution based on solar thermal cooling-heating system.

In reference to the innovate aspects of the proposed demonstrative project, new collectors with the latest technology have been selected, supposing one of the key elements of the system: the Ultra High Vacuum (UHV) collectors. These collectors reduce convection and conduction heat losses. Each collector is provided with a "Getter" pump that assures the vacuum. The collectors are composed by high absorbance (>90%) and low emittance (<7%) elements, which are exclusive for this kind of collectors and have not been provided by any other collectors. This system has been successfully tested at laboratory and pre-industrial level.

These UHV collectors avoid evaporation problems of water by heating oil, reaching higher temperatures with lower pressure, which implies a simpler valve system. Evaporation is a major problem for this kind of installations, since the evaporation of water leads to the breakage of the collectors. In reference to the use of oil in the collectors instead of ordinary water, this solution presents several advantages based on the higher boiling point of oil: over 355°C at normal conditions. In the proposed prototype, UHV panels with a selective treatment of high absorbency and low emissivity collectors, provided with concentrators, have been selected. In these conditions, film temperature can reach higher values and, at these temperatures, exceptionally good thermal stability of the transmitting fluid is required. The proposed mineral oil has bulk temperatures up to 320°C, and the rates of cracking and oxidation are very small, providing an efficient fluid heater with good pump circulation. Moreover, the use of oil decreases considerably the working pressure values, reducing then the exigencies and requirements of the piping, instrumentations and collectors. Due to the extremely high film temperatures in the collectors, the use of water would imply high-pressure values to avoid evaporation processes that may reduce the performance of the system. Figure 3 shows some details about the collecting surface as well as the installation process. Each collector group (126 components) has his own control of temperature on the oil output, managing each group in order to keep the collector group within the temperature set value and avoiding undesired heating or cooling process. The system is provided with 4 oil circuits connected in parallel. This layout allows us to give a higher selectivity in case of breakdown and reduce costs, due to the use of smaller components.

The system is provided with two absorption chillers of 675 and 855 kW cooling capacity, instead of a single one of 1.5 MW cooling capacity. With both absorption chiller machines is possible to fit the capacity of cold production according to the real heat production necessities, being able the system to use 1 or 2 machines. The use of 2 machines makes possible a wider range of uses for the installation and the simultaneous supply of heating and cooling towards different areas of the building. A PV power plant has been also integrated as an additional way to reduce the whole power demand, increasing the whole benefits of the solar energy source. In this case, the PV power plant has 888 *kWp* nominal power rate, using PV modules from Schott monocrystalline 185W (Schott Solar).

Figure 3: Solar thermal cooling-heating system: Installation process and collecting surfaces.

The innovations of the project are focused on management issues as well: while ordinary systems have been provided as an additional support to other classical refrigeration systems, this demonstrative prototype constitutes the base of achieving and maintaining the required temperature conditions. Furthermore, instead of developing a specific system devoted to store the excess heat resulting from the process, the management system is responsible to assure a permanent and accurate supply of cooling. This is a major conceptual difference with other regulation systems: the final regulation goal instead of an initial one. Gas boilers could be considered a solution to make the system simpler, but it would waste most of the saved energy to provide the corresponding security heat store requirements. The proposed control system thus optimizes the cold production with the objective of making the installation able to speed up a response to modifications in demand, reliable in its performance and safe. This fast response is possible due to the maximum reduction of the used oil fluid. Accumulators are not used since they need larger volumes, increasing the size of the installation and the fixed and operating costs. Moreover, they would be used only few time periods and make the system slower in its regulation and considerably less efficient.

The final solution adopted is a system managing in real time, where the output temperature in each closed loop (126 components) is compared with the set-point value, modifying the input valve if it was necessary. Subsequently, the temperature is fitted according to the thermal requirements and the volume of oil changes with the available solar power. An additional regulation system is devoted to control the use of one or two absorption chillers. This system is in charge of selecting how many machines must be connected/disconnected according to the necessities and availability of energy.

Finally, the system also involves sensors to collect a sort of variables, giving a precise management of the system with stored data in real time. This makes possible to take fast and clear responses. In order to increase the global safety of the system, steel shutters have been designed to protect the installation facing abnormal climatic ranges or system malfunctions. These shutters can perform automatically and be used as a regulation tool for the energy output.

4 PRELIMINARY RESULTS

The proposed system is expected to provide an annual energy savings estimated in around 795 MWh only for the cooling system, which represents more than 70% of the global energy currently needed for conditioning the warehouse. It means about 105 m€, expected to increase according to the energy price modifications, and reaching up to 1.13 GWh and 150 m€ if the heating energy savings in the offices were included.

These energy reductions are even more relevant in daily and seasonally energy demand peaks, being the system more productive according to the energy demands are higher. In terms of CO_2 savings, and considering a CO_2 production of 0.233 kg/kWh of CO_2, the proposed thermal cooling/heating system is expected to save between 185 and 263 Tons of CO_2/year. Other types of emissions that can also be reduced are the following (per year): 766 Tons of SO_2, 626 Tons of NO_x, 4140 cm^3 of radioactive residues of low and medium activity, 508 gr of high radioactive activity residues. At the same time, the implementation of this solar thermal technology in other warehouses with the same characteristics and the potential of transferability make these amounts to be much higher. The economic savings have to take into account indirect issues, as the decreases in electricity demand on peak power periods, especially in hot summer days.

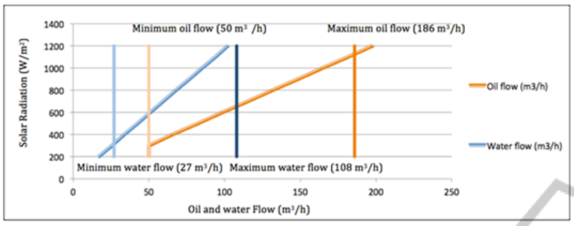

Figure 4: Estimated oil and water flow absorption chiller. 675 kW nominal cooling capacity.

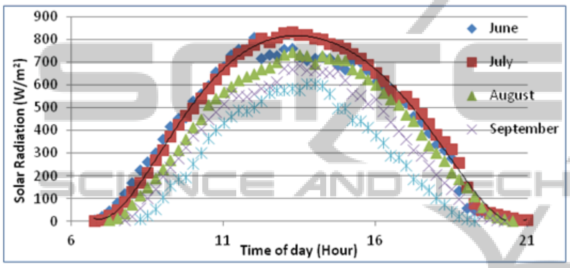

Figure 5: Estimated solar radiation data.

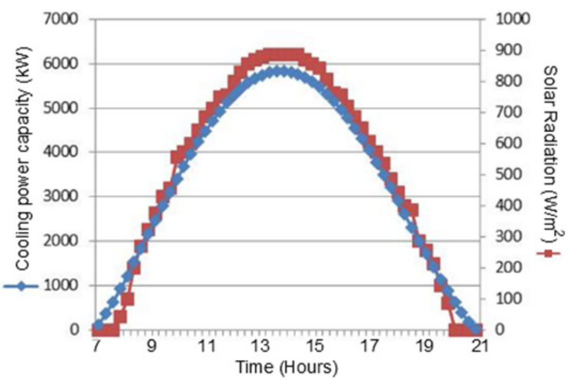

Figure 6: Estimated cooling power capacity (kW).

This fact implies a decrease in the use of fossil and nuclear energy and reduces the threatening to the stability of electricity grids, allowing energy managers to design less over-sized electricity grids. As an example of the estimated absorption chiller performance, Figure 4 and 5 show respectively the flow heat exchanger values as a function of the estimated solar radiation data. As can be seen in Figure 6, significant power reduction can be achieved in comparison with conventional solutions as was previously discussed.

5 CONCLUSIONS

A demonstrative project financially supported by the European Union aiming of providing a real example of sustainable solution for cooling large commercial spaces has been discussed and described in the present paper. This project, called *Medicool*, provides a new solution for the pharmaceutical distribution sector, which presents strict and rigid European and national regulations regarding storage temperature conditions. This solution involves one of the largest systems ever built in Europe based on solar cooling/heating technologies, with a collecting surface of 22,500 m^2 with the main objective of reducing 795 MWh only for the cooling system. This reduction represents more than 70% of the global energy currently needed for conditioning the warehouse. It implies about 105 m€, expected to increase according to the energy price modifications, and reaching up to 1.13 GWh and 150 m€, if the heating energy savings in the offices were included.

With regard to innovative aspects of the proposed system, new collectors with the latest technology have been selected, supposing one of the key elements of the system: the Ultra High Vacuum (UHV) collectors. These collectors reduce significantly both convection and conduction heat losses. The proposed system has with two absorption chillers of 675 and 855 kW each one. For both absorption chiller machines, an additional control system is included to fit the capacity of cold production according to the real heat production necessities, being able the system to use 1 or 2 machines. The estimated energy reductions are even more relevant in daily and seasonally energy demand peaks, being the system more productive according to the energy demands are higher.

In terms of CO_2 savings, and considering a CO_2 production of 0.233 Kg/kWh of CO_2, the proposed thermal cooling/heating system is expected to save between 185 and 263 Tons of CO_2/year. Other types of emissions that can also be reduced are the following (per year): 766 Tons of SO_2, 626 Tons of NO_x, 4140 cm^3 of radioactive residues of low and medium activity, 508 gr of high radioactive activity residues.

Finally, this solution is easily extensive towards other economic and industrial sectors in areas that present similar energy characteristics and thermal requirements: large conditioning spaces and buildings with high cooling/heating power demand during peak power periods.

ACKNOWLEDGEMENTS

The LIFE+ European Program has financially supported this project. (Ref. LIFE10 ENV/ES/456).

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