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Available online at www.sciencedirect.com
ScienceDirect
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Desalination 220 (2008) 588–591
DESALINATION
www.elsevier.com/locate/desal

Fresh water production by means of solar concentration: the AQUASOLIS project

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Received 26 March 2007; accepted 18 April 2007

Abstract

In 2006, the European Commission approved the specific support action (SSA) "AQUASOLIS" as an instrument for assessing the use of solar trough concentration plants for applications other than heating and cooling, in particular for the production of fresh water for human consumption and for agriculture for Mediterranean countries. The capability of solar trough plants of producing heat at temperatures over ca. 150° permits indeed to envisage the use of solar energy for water purification by distillation. At the same time the high temperature fluid generated by the plant can be used to drive adsorption chillers that can extract water from the atmosphere. The AQUASOLIS project was performed as a parallel investigation to the STREP project REACt which is aimed at the actual development of a heating/cooling solar trough system for Mediterranean countries. The results obtained in the AQUASOLIS project show a high promise of the system to help alleviate the conditions of drought in Mediterranean countries and at the same time boosting the use of renewable energy.

1. Introduction

With fossil fuels in decline and climate change on the rise, it is becoming more and more imperative to switch the world's energy supply to renewables. The amount of energy which can be obtained from the sun is abundant: it is possible to calculate that the solar energy that falls on a Mediterranean country of average insulation, such as Italy, corresponds to one barrel of crude oil per year. Even more energy falls on Southern Mediterranean countries; solar energy is not only abundant but widely available. The problem is to transform it into usable, and more than that storable, forms. Without storage, the diffusion of solar energy remains a marginal element of a system still based on fossil fuels. Storage is the necessary element that can lead renewable energy technologies to lift off and replace fossil fuels.

Agriculture is, of course, the most ancient technology used for harvesting and storing solar energy. Photovoltaics and solar concentration are much more efficient than agriculture in transforming solar energy into electrical power, but, at present electrical power can be stored only

Presented at the conference on Desalination and the Environment. Sponsored by the European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.

0011-9164/08/$– See front matter © 2008 Published by Elsevier B.V.
doi:10.1016/j.desal.2007.04.059

by means of expensive equipment. The crucial question in order to favor the diffusion of renewables is therefore how to transform solar energy into something that has economic value, that is can be stored and used when needed. The AQUASOLIS project is born from this idea; specifically of transforming solar energy into clean water for human consumption or for irrigation. Clean, renewable water can be stored and it gives immediate value to solar energy. A critical concept is that of leveraging production, using renewable plants in multi-mode in such a way to enhance their economic return; in this case using a solar concentration plant in order to provide at the same time heating, cooling, and fresh water. This concept can, in principle, kick-start the widespread diffusion of solar plants and at the same time provide a much needed commodity to Mediterranean countries, threatened by the drought associated to climate change.

Solar concentrating plants based on the solar trough technology are especially interesting for renewable water production. Solar trough plants work on the principle that solar light is reflected by parabolic-cylindrical mirrors onto an adsorber tube containing a diathermal liquid that transports the heat to the applications. In the following (Fig. 1) a schematic image of the principle of linear parabolic solar concentrators.

In the simplest version of the technology, the collector tubes are made out of copper and the temperature that can be reached is of the order of 200°C. This temperature is not high enough for use with thermal engines for the production of electrical power. Higher temperatures can be reached using special equipment such as vacuum collector tubes and molten salts as diathermic liquids; but this technology is expensive and complex; justifiable only for large plants; at present under study. Even without being able to produce electrical power, however, solar trough plants of sizes of the order of a few hundreds of square meters find use in producing hot water and air conditioning.

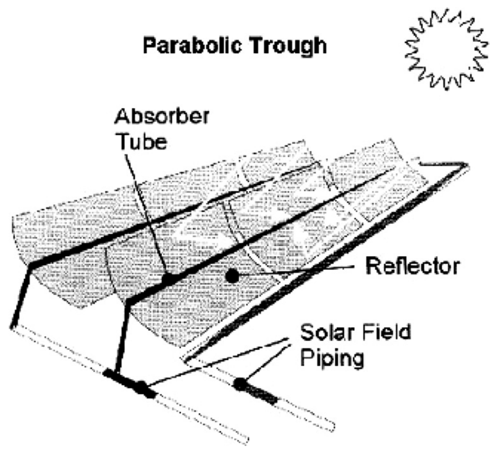

Fig. 1. Linear parabolic collectors.

Crucial to this application is the availability of absorption chillers, equipment able to use heat for the production of cooling. Chillers are machines that transform heat into chemical energy by separating the two components of a mixture. The separated components can then be mixed together again in an entropy driven process which absorbs energy from the surroundings, thereby providing the cooling effect. The process is normally continuous so that the chiller will keep producing refrigeration as long as it is supplied with heat. Typical mixtures used in commercial chillers are ammonia-water and water-lithium bromide.

A cylindrical trough solar plant equipped with chillers is able to provide air conditioning in the same way as it could be done using photovoltaic panels and a conventional, compressor driven, refrigerator. A detailed comparison of the performance of the two approaches is out of scope here, but we can say that a system based on concentrators and chillers may be significantly more efficient than the state of the art photovoltaic panes coupled with conventional refrigerators both in terms of space occupied and monetary cost. In particular, a parabolic trough system may cost as little almost a factor of 2 less than PV panels for the same area. It can collect direct solar radiation and transfer it to the application with an efficiency of about 60% and transform it into refrigeration with a coefficient of performance (COP) of approximately 1. In comparison, PV panels on the market today have efficiencies of about 15%. The higher COP of compressor driven refrigerators (around 3) does not compensate for the lower efficiency of the PV panels and if we add the capability of concentrator plants to provide co-generated heat their economic advantage is evident. This advantage is even more evident in Southern Mediterranean countries, where direct solar irradiation is more abundant than in northern countries.

The capability of solar concentrating plants of providing renewable air conditioning for buildings is interesting but Mediterranean countries are troubled by problems which go well beyond air conditioning; in particular, the climate change presently in progress is expected to reduce rainfall to values that might go up to 30% than the present ones [1]. Mediterranean countries need water and will need more water as time goes by. The traditional methods of desalination are heavily dependent on fossil fuels and therefore new methods based on renewable energy badly need to be developed.

There exist a wide variety of ways in which renewable energy can be used to provide fresh water. It is known that reverse osmosis (RO) treatment of brackish water or seawater is the most efficient method in terms of energy needed. RO can be driven by energy obtained by PV panels, so it can be a renewable method. However, it is not always possible to access seawater or brackish water and transporting it to remote areas may be extremely expensive. In addition, RO is affected by such problems as maintenance of the membranes. Here, solar concentration plants can provide an alternative tool for producing renewable fresh water, both by treatment of brackish water as well as by extracting humidity from the atmosphere. Desalination can be obtained by distillation, utilizing the relatively high temperatures that a solar trough plants can reach. At the same time, chillers can be used in order to condense water from atmospheric humidity [2,3]. This can be done using the cooling effect of the chiller standard cycle, or water can be directly collected from the atmosphere on an absorber substance. The latter method promises to be more efficient, but it is not available commercially yet.

In terms of amount of energy needed, these methods are more expensive than RO. According to Wahlgren [3] extraction of water from air may require 10 to 100 times more energy than the state of the art desalination techniques, in particular those based on reverse osmosis. However, if concentrating plants are used also for different purposes, i.e. for providing heating and cooling, the production of fresh water can be seen as an added value provided by a system that operates anyway; so it can be considered as a “zero cost” method to store energy and provide economic value when there is no need for air conditioned or heat or when the system would be producing an excess of air conditioning or heat. We can also say that the capability of producing fresh water means that the system operates in a “tri-generation” mode. The term “trigeneration” is normally applied to systems that produce heating, cooling, and electrical power. In this case, however, it is to be understood as a system that produces heating, cooling, and fresh water. In any case, the production of multiple outputs increases the overall economic return of the plant.

2. The AQUASOLIS project

The AQUASOLIS project was born as a spin-off of the STREP project REACt which is aimed at the development of solar trough systems for Mediterranean countries. REACt is aimed only at heating/cooling applications whereas AQUASOLIS was conceived as a investigation of new applications of solar concentrating system in the field of water remediation and water extraction from the atmosphere. The concept was of performing a feasibility study for each of the selected applications, assessing the costs and the economic soundness of the innovative technology with respect to the consolidated solutions already in the market.

The countries targeted by AQUASOLIS are the same of the REACt project that is Morocco, Jordan and Lebanon. Entry points for the present project will be the institutions involved in the REACt project: CDER (Centre pour le Développement) in Morocco, ALMEE (Association Libanaise pour la Maîtrise de l'Energie et de l'Environnement) in Lebanon and NERC (National Energy Research Center) in Jordan.

These three countries that are meant to be only an example of the whole Mediterranean area are strongly dependant on oil imports to fulfill the electricity need of their populations. Moreover, the lack of an economical and reliable water sources has driven these countries towards the massive use of fossil fuel powered sea water desalination.

With the present study, alternatives to fossil fuels for powering desalination have been investigated, in particular water solar distillation using the solar heat coming from the concentrators and the condensation of air using the cold produced by the chiller. These two methods, once their feasibility and reliability is proven, can be a significant turnaround in the water sourcing policies of the targeted countries. In May 2007, the AQUASOLIS project will be completed and a report will be filed with the European Commission. The work with the REACt project is going to continue and the field will be further explored.

3. Conclusion

Fresh water, obtained from atmospheric humidity or from desalination using solar concentrating plants can be seen as a way to store solar energy, transforming it into a useful product. Further work is needed for a better understanding of the economic and technical implications of fresh water production from solar concentrating plants. In particular, the safety of distilled water for human consumption should be carefully assessed [4–6]. However, the diffusion of plants that can produce water as an additional economic output to heating and cooling for can be seen as a boost for renewable energy which will kick start the diffusion of solar energy in Mediterranean countries.

Acknowledgement

The author is grateful to Mr. Maurizio De Lucia for his advice on this paper

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