



COOP-CT-2004508462

SoCold

Development and implementation of a cost effective adsorption refrigeration system utilizing high temperature (120°C) solar Compound Parabolic Collectors (CPC)

Instrument: Co-operative Research Project

Publishable Final Activity Report

Period covered: from 1st of September 2004 to 31st of August 2006

Date of preparation: 29th of November 2006

Start date of project: 1st of September, 2004

Duration: 24 Months

Project coordinator name: Johann Bergmair

Project coordinator organisation name: Profactor Produktionsforschungs GmbH

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	



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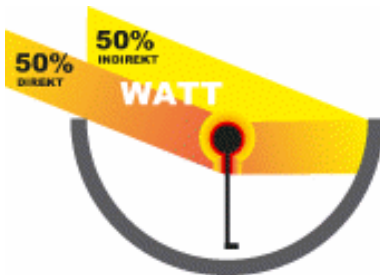
1. Project Execution

Motivation

Despite numerous attempts to reduce the energy consumption of office buildings and residential houses (low or zero energy houses) are air conditioning systems often the sole alternative, to guarantee a comfortable room climate.



Mode of operation of the CPC – collector at vertical solar radiation



Mode of operation of the CPC – collector at flat angle solar radiation

Right now air conditioning of office and residential buildings is more or less exclusively realized by conventional compression refrigeration devices. Ozone layer damaging cooling agents of former days could be widely substituted by CFC – free media, but the significant electric power consumption of compression refrigeration machines stayed. During the last summers the grids of various southern regions collapsed due to high energy consumption. On this account the interest in thermal operated cooling devices, utilizing heat on low temperature level for air conditioning purposes rose drastically.

Especially thermal air conditioning systems for buildings, which are capable of using solar power as operating energy, have to be mentioned in this context.

In this case heavy solar radiation doesn't only mean increased thermal loads and therefore an increased cooling demand, but also a maximum of available operating energy. This obvious correlation nearly commands to press ahead even more intensively with the research activities in terms of solar cold production. The implementation of numerous pilot and demonstration plants shows, that the correct way has already been chosen.

Goals

The performance of a thermal operated cooling device is of course strictly dependent on the particularly used heat source. Therefore the consortium of this project is not only aiming at the development of an adsorption refrigeration machine, but also on the optimization of the appropriate heat source. An advanced flat – plate collector with focusing characteristics

utilizing the so called CPC (Compound Parabolic Concentrator) technology will deliver energy on a temperature level of 120°C. The technology this collector type is based on is brought in as the Know – How contribution of the project partner Solarfocus GmbH.

So far sorption refrigeration devices have been implemented on a high performance level from 80 kW onwards. Those cooling machines have been completely over dimensioned for residential applications and could therefore not be operated in an efficient way. Due to this fact the project SoCOLD takes especially the requirements of “small consumers” into consideration. This implicates, that a preferably cost effective product has to be developed.

Besides the prototype of the collector also two adsorption refrigeration prototypes will be developed, implemented and scrutinized throughout the test stage, which will last several months. The main goal is finding alternative cooling methods for two different temperature ranges. On the one hand air shall be conditioned, on the other hand cold shall be provided on a temperature level of -20°C.

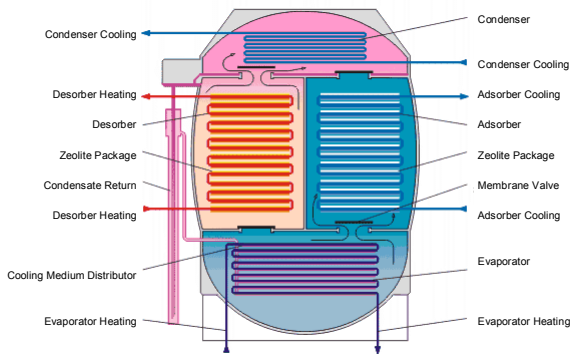


State of the Art

Basically speaking adsorption is the reversible attachment of gas molecules within the pores of a highly porous adsorbent agent, whereby the vapor of the cooling medium is thermally compressed. The sorption agent is assembled within a heat exchanger and alternately – depending on the process stage – charged with either heating or cooling medium. The heat supplied to the system by means of heating medium is used for thermal regeneration of the sorption agent (desorption phase).

The adsorption process itself is exothermic and has therefore to be cooled, in order not to be disrupted.

The most obvious advantage of adsorption refrigeration machines over conventional absorption and compression chillers is due to the fact that no moving parts in the depressurized areas of the device are needed.



Adsorption Refrigeration Machine

Air conditioning with thermal cooling aggregates can be achieved with much lower operating temperatures than 200°C (from 60°C onwards), but this project – as already aforementioned – will deal with both adsorption refrigeration machine for air conditioning and an application for solar cooling below 0°C. The adsorption pair used for the air conditioning process will be Water/Silicagel. In case of the solar cooling device the

adsorption pair will be Methanol/Activated Carbon. Both cooling media – water and methanol – have no increasing impact on the global green house effect or contribute to the destruction of the ozone layer. The low freezing point of Methanol enables Methanol/Activated Carbon units to reach temperatures far beyond 0°C.

Methods of Resolution

The process of adsorption is going to be exactly documented and investigated concerning possible optimization potential by means of laboratory tests. A close cooperation of Profactor, the French institute for industrial utilization of cold at CNAM University, Paris and the Fraunhofer Institute in Freiburg will help to perform this task. The treatment of both adsorption agents and their combination with the active heat exchanger surface will be above all a target for possible innovations. Two prototype adsorption chillers, working on different temperature levels will be constructed and manufactured based on the gained results of these investigations and the end user requirement specifications.

A final assessment of all project results in terms of economical, socio-economic and logistic aspects will be performed by local experts. A simulation tool, describing the whole process will be developed at Profactor's facilities located in Steyr. This tool will help to dimension and design adsorption refrigeration chillers within the near future.

Results of the Project

Adsorption system for air conditioning (AC-Unit)

The SorTech-Adsorption Heat Pump (AHP) produces cold from waste- or solar heat with a minimum of electricity consumption. For an efficient adsorption cycle the required temperature level of the High Temperature Circuit is 75 ... 95°C. In combination with a dry closed and almost maintenance free re-



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cooling circuit the COP reaches 0,53 considering cooled water temperatures of 12 – 14°C which is suitable especially for air conditioning applications.

Basically the Adsorption Heat Pump Prototype (so also in the SoCold Project) consists of one or more heat pump modules, switching unit (pipes and valves), controller and electronic parts. Each heat pump module is divided into the 4 chambers evaporator, adsorber 1 + 2 and condenser, which are connected by self operating steam valves. The external re-circulation leads condensed water permanently from the condenser to the evaporator; so a continuous operation is guaranteed.

With the present development stage one module provides a cooling power of appr. 4 kW. Through a new coating technology and further optimization of the internal construction the performance of SorTech AHP will increase up to 10 kW considering a COP of app. 0,6.

The system has been installed in July 2006 at a school in Sabadell near Barcelona (Spain).



CPC Solar collectors on school roof (Sabadell, Spain)



Installation of the AC system at school



School room with solar cooling



Adsorption system for cooling rooms (FROST-Unit)

In this project, it is intended to use robust systems for solar collection as well as for cold production. It is the reason why the high temperature solar collector of SOLARFOCUS which could provide heat at about 120°C has been selected. This constraint limits the technologies to be used for cold production. Liquid absorption and solid adsorption are two possible candidates for that purpose. The use of ammonia – water liquid absorption with solar heat at 120°C could be a possibility. In that case, a flat plate solar collector unit coupled to absorption ammonia – water cooling unit would be required.

Solid adsorption can as well be used (for example active carbon – methanol or active carbon – ammonia pairs) as a cooling unit coupled to a solar panel system. If this technology is selected, it should be necessary to develop a cooling unit suited to operate with the temperature constraint corresponding to the solar collectors and to the end user's demands. The reason why solid adsorption is selected is two – fold: the units will be more robust than ammonia water units and the costs of adsorption cooling units will be less than that of ammonia water units.

At the present a module was developed with a cooling power of approx. 5 kW which is considered to reach a COP of 0,45.

Its purpose is to provide cold on a temperature level of 0°C to -4°C. The final application area of FROST is the conservation of perishable products like food. The system has been constructed and has been installed in July 2006 at the Asociacion of the Meat Industry of Asturias (Noreña, Spain). It is currently operating under standard conditions.



Building with CPC collectors (Asturias, Spain)



FROST unit, installed at the ASOCIACION



Budget

The overall budget of SOCOLD adds up to 1.7 million €. Grants to the budget will be contributed by the consortium and the European Commission.

The project's duration is 24 months.

Project start: 01.09.2004

Partners

All development, constructing and manufacturing tasks within the project will be performed by an international consortium, consisting of 9 partners.

PROFACTOR GmbH, Austria (Coordinator)

SOLARFOCUS GmbH, Austria

ALTERSUN GRUP S.L., Spain

INDUTHERM S. L., Spain

SORTECH AG, Germany

ASOCIACION, Spain

ITIAM RUAI S.L., Spain

FRAUNHOFER ISE, Germany

CNAM – IFFI, France

Project Coordination

Johann Bergmair

Innovative Energy Systems IES

Profactor Produktionsforschungs GmbH, Steyr



2. Dissemination and Use

Exploitable Knowledge and its Use

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Adsorption technology for air conditioning (AC Unit)	Adsorption chiller	Households and offices	2007	Development is covered in several existing patents	SORTECH, FRAUNHOFER
Adsorption technology for cooling (Frost Unit)	Adsorption chiller	Food industry	2009	---	PROFACTOR, SORTECH, CNAM
New collector design	High temperature CPC collector	Domestic houses, industry	2006	Existing patent Nr. 4021114	SOLARFOCUS

Brief Description of Exploitable Results

The main innovation of this project is the development of two adsorption chiller prototypes working on different temperature levels. One machine will aim at a temperature level suitable for air conditioning and the second machine will be used for food preservation where temperatures around the 2°C are needed.

Both prototypes are designed to fulfil the requirements of small sized cooling devices for the capacity range around 5kW. So far no thermal chiller working on this capacity level has been designed since instrumentation, piping and control of the system are rather complex in comparison to a conventional mechanical vapour compression device. Solar operated thermal chillers in this capacity range do have a broad field of application, especially in Southern Europe, Asia, or Africa.

The very first market penetration will be restricted to Spain and the promotion will be responsibility of the Spanish project partners.

A further innovation of SOCOLD is the optimised CPC collector, which is capable of providing medium temperatures of up to 120°C during operation. This is of great importance for new applications of adsorption chillers within the context of solar air conditioning or cooling. Normal flat plate collectors can't provide high enough a temperature for the regeneration process of the adsorbent. Consequently costly vacuum collectors have to be implemented to run available ab- or adsorption chillers. The new CPC collector offers a good compromise between investment costs and efficiency and is therefore a very important development on the solar thermal market, which will help to boost solar cold production.



Dissemination of Knowledge

Planned/actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
02. – 04.03.05	Poster	Experts and general public	World	900	PROFACTOR, SORTECH, FRAUNHOFER,
19.04.05	Conference	Experts, Industry, Research	Austria	250	PROFACTOR
25.05.05	Conference	Experts, Research	Austria	30	PROFACTOR
	Press release	Experts, Research	Europe		PROFACTOR
	Press release	Experts, Research	Austria		PROFACTOR, SORTECH, FRAUNHOFER
01. – 03.03.06	Poster	Experts and general public	World	900	PROFACTOR, SORTECH, FRAUNHOFER,
23.2. -25.2. 05	Conference	Experts, Research	World	70	SOLARFOCUS
20.10.06	Award	Experts and general public	World	~ 1000	SOLARFOCUS
5.10-8.10. 05	Poster	Experts, Research	Europe	300	SOLARFOCUS and Subcontractor
Ongoing 2005-2006	Trainings	Professionals	Catalonia	200	INTIAM
Feb and Sept 2006	TV-report	Public	Catalonia	100-thousands	INTIAM

Poster concerning SOCOLD's Targets

“World Sustainable Energy Days”, Wels, 02. – 04.03.2005

A poster elaborated by PROFACTOR, SORTECH and FRAUNHOFER has been placed there for the whole duration of the conference. It is an international fair dealing with renewable energies and offers a large spectrum of spectators. Both experts and potential end users do visit this conference.

Presentation of Market Survey Results

“Effizientes und Solares Kühlen”, Linz, 19.04.2005

Mr. Patterer of PROFACTOR gave a talk concerning the results of the end user requirement specification and their impact on the system design. This conference was aiming especially on potential end users and installers.

Presentation of Solar Cooling and SOCOLD's Targets

“Marie Curie Conference”, Steyr, 25.05.2005

This talk was supposed to give a broad overview over SOCOLD's targets and about solar air conditioning and cooling in general. The talk has been given by Mr. Patterer of PROFACTOR at the Marie Curie Conference held in Steyr.

Article concerning SOCOLD's Targets

For the European Commission



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The European Commission interviewed Mr. Patterer concerning the targets and the expected results of SO-COLD.

Article concerning SO-COLD'S Targets

For the Austrian journal "Umweltjournal", 06/2005

An article describing the targets and the expected results of SO-COLD and solar air conditioning and cooling in general has been published by the "Umweltjournal" entitled "Die kühle Seite der Sonne", which is especially dealing with renewable energies and the latest achievements on this sector.

Poster concerning SO-COLD'S Targets

"World Sustainable Energy Days", Wels, 01. – 03.03.2006

A poster elaborated by PROFACTOR, SORTECH and FRAUNHOFER has been placed there for the whole duration of the conference. It is an international fair dealing with renewable energies and offers a large spectrum of spectators. Both experts and potential end users do visit this conference.

Flyer concerning SO-COLD'S publishable summary

For the Austrian Research Promotion Agency (FFG), Spring 2006

The publishable project summary was printed on a flyer and is being used as "Best practice CRAFT-project" in promotion reports and professional conferences of the FFG.

Article concerning SO-COLD'S Targets

For the Spanish Journal InfoPower Solar, April 2006

An article describing the targets of SoCold was published. Title: "Proyecto SoCold: Refrigeración por adsorción utilizando colectores solares de alta temperature".

Poster and demonstration units concerning SO-COLD'S solar cooling system

"PowerExpo", Zaragoza, 19. – 21.09.2006

A poster elaborated by PROFACTOR and all project partners was presented there for the whole duration of the conference. SORTECH presents a transparent model of the adsorption system and SOLARFOCUS the CPC collectors including 2 flyers of the products. It is an international fair dealing with renewable energies. Both experts and potential end users do visit this fair.

Presentation of the Objectives concerning the new CPC – Collector that will be developed during the SoCold project.

SOLAR HEAT FOR INDUSTRIAL PROCESSES

SHC Task 33 / SolarPACES Task 4

Madrid, Spain, February 23 -25, 2005

Venue: CIEMAT, Avd. Complutense, 22, 28040 Madrid

Submission to "Energy Globe Award"

Nomination for Upper Austria and winning of 7th place, presentation of CPC Collector at stage during Award Gala, 20.10.05



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Poster concerning the SO-COLD Market Survey Austria

European Conference and Cooperation Exchange on Sustainable Energy Systems for Buildings and Regions 2005, Vienna, Oct 5th-8th, 2005

Trainings courses during the project period performed by INTIAM including brief presentations of SoCold's solar cooling system

Sabadell 2005-2006

TV-report on 4th chapter of "L'art de Viure amb les Renovables", shown by 26 local TV broadcasting stations

Catalonia, Feb and Sept 2006

SO-COLD's webpage

www.solar-cooling.info, www.solarekuehlung.org, www.refrigeracion-solar.es

The webpage serves as platform for general information about solar cooling, linked with other relevant pages. In particular the content and the results of the project will be documented for information of interested target groups.

Further activities, such as presentation of posters and speeches at various conferences are planned for the period after the project by several partners.

- An "Energy Week" takes place in Barcelona in the first October week of 2006. On the 5th of Oct. 2006 on-site visits of innovative solar units will be performed by INTIAM and ALTERSUN. There will be about 50 professionals.
- A training for Solar Installers will be performed on Nov, 15th including a training visit of the AC unit
- A workshop in Sabatell presenting the AC unit is planned in spring 2007 (INTIAM and ALTERSUN)
- The presentation of at least a poster is planned at the INMOSOLAR in Oct. 06 in Almeria, Spain (INTIAM)
- The presentation of results of the project is planned at the "World Sustainable Energy Days" in Wels in March 2007 (PROFACTOR)
- The presentation of results of the project is planned at the international Solar-Cooling conference in October 2007 in Tarragona (FRAUNHOFER)

Publishable Results

SO-COLD's webpage

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ARTICLE IN SPANISH MAGAZINE: INFOPOWER, APRIL 2006

Proyecto SoCold: Refrigeración por adsorción utilizando colectores solares de alta temperatura

El Proyecto SoCold tiene como objetivo desarrollar y testar dos sistemas diferentes de refrigeración solar: uno para la producción de frío a unos $-2\text{ }^{\circ}\text{C}$, denominado FROST, y otro con aplicación para producción de aire acondicionado, denominado AC, basados en la tecnología de adsorción. Es un proyecto internacional con un presupuesto aproximado de 1,7 M€, con una duración de 2 años y que finaliza el próximo otoño. En este proyecto participan junto con el Instituto alemán Fraunhofer, varias empresas europeas como Profactor, Solarfocus, Protecma Energía y Medioambiente, Intiam Ruai, Indutherm, Sortech, Termosun, y La Asociación de Investigación de Industrias Cárnicas de Asturias.



El sistema SoCold persigue el desarrollo de un sistema rentable de pequeño tamaño (5 kW) de refrigeración solar, basado en la tecnología de adsorción y que emplea como captador unos nuevos colectores parabólicos compuestos (CPC) de alta temperatura. Los captadores CPC fueron desarrollados por la empresa austriaca Solarfocus en el marco de un proyecto europeo previo.

La idea es llevar a cabo el mecanismo de adsorción de forma escalada, de tal modo que requiera solo una décima parte de la energía necesaria en los sistemas actuales. El consorcio combina el conocimiento y experiencia de todos sus integrantes: fabricantes de colectores solares, Ingeniería del gas y máquinas enfriadoras térmicas, al igual que instaladores y potenciales usuarios finales de la tecnología de refrigeración solar. Estas firmas cuentan con científicos e ingenieros procedentes de Instituciones en Austria, Francia y Alemania.

El proyecto consiste en dos líneas de trabajo diferentes, una para aire acondicionado, AC, y otra para producción de frío, FROST. Los



dos prototipos, que se están desarrollando en el marco de este proyecto, se probarán en España. El prototipo FROST en Asturias, en la Asociación de Investigación de Industrias Cárnicas, y el AC en el Instituto de Educación Secundaria "Agustí Serra" de Sabadell (Barcelona). Estas instalaciones serán puestas en marcha entre los meses de mayo y junio.

El consorcio que está desarrollando el proyecto no solo persigue el diseño de un sistema energéticamente eficiente, sino que también tiene como objetivo el desarrollo de un producto con un precio competitivo, para aplicaciones domésticas o en pequeñas industrias, que pueda lanzarse al mercado una vez finalizado el proyecto.

Una de las medidas más importantes a tener en cuenta para el buen funcionamiento de estos sistemas será el perfil de la gestión que se lleve a cabo. Sin atender a aspectos económicos, los sistemas de refrigeración solar solo pueden ser aplicados a escala mundial si se demuestra que usan favorablemente la energía (durante su fabricación, instalación y explotación) en comparación con las tecnologías de refrigeración más tradicionales. Profactor utilizará la experiencia adquirida a través de su participación en otros proyectos europeos, para desarrollar una máquina que garantice la máxima optimización de la eficiencia energética.

Si el proyecto SoCold se configura económica y medioambientalmente competitivo, las empresas participantes anticipan una demanda significativa de esta tecnología, especialmente entre propietarios de casas y

pequeñas industrias en el sur de Europa. El cambio climático, junto con la creciente presión para el reemplazo de fuentes de energía tradicionales por otras renovables, podrían hacer de la refrigeración solar y del sistema SoCold una tecnología realmente factible.

Además, disponer de este tipo de tecnología permitirá conseguir una mejor utilización de los sistemas solares convencionales para la producción de ACS y calefacción.

Sistema de climatización

El desarrollo del sistema de aire acondicionado AC, dirigido por el Instituto de Investigación alemán Fraunhofer-Gesellschaft, se basa en el proceso de adsorción usando agua como fluido refrigerante y gel de sílice como material adsorbente. El objetivo es enfriar el aire por debajo de los $18\text{ }^{\circ}\text{C}$.

El sistema que se va a instalar en el Instituto de Educación Secundaria "Agustí Serra" de



Sabadell (Barcelona), incorporará 14 captadores de 2,7 m² de superficie efectiva cada uno del tipo CPC mejorados, inclinados 35° sobre la horizontal y orientados hacia el sur sobre cubierta plana.

El sistema de captación trabajará a temperaturas entre 85 y 95 °C sobre un depósito de inercia de 1.500 litros de agua para asegurar una hora de funcionamiento continuado del sistema de enfriamiento.

La máquina enfriadora que la empresa Sortech ha diseñado y está fabricando es un prototipo evolucionado, de tercera generación, de adsorción que utiliza Zeolitas. La potencia del prototipo será de entre 5 y 8 kW con unas temperaturas de agua enfriada alrededor de los 16 °C para su uso en climatizadores tipo fancoil.

Este sistema climatizará dos aulas-taller del mencionado Instituto de Sabadell. El COP esperado de la máquina estará entorno al 0,5 ya que el objetivo no es tanto superar el rendimiento de otras formas alternativas de refrigerar sino el de tener una opción económica.

La firma Intiam Ruai es la encargada de monitorizar los resultados de funcionamiento de la unidad de aire acondicionado que se instalará en el instituto de enseñanza. La instalación de este sistema correrá a cargo de la firma Termosun, que tendrá los derechos de comercialización del sistema.

Refrigeración a temperaturas bajo cero

La mayoría de las máquinas térmicas pueden ser usadas para aplicaciones de aire

acondicionado, utilizando agua como refrigerante, de manera que la temperatura de evaporación está limitada a 5 °C. Sin embargo, algunas áreas de aplicación de estas máquinas, como la industria química o de la alimentación, requieren temperaturas entre los 5 y -5 °C. El prototipo desarrollado para el sistema FROST utiliza metanol como refrigerante y carbón activo como adsorbente, lo que permite alcanzar temperaturas de evaporación muy por encima del punto de congelación, a un coeficiente COP razonable.

El Conservatoire National des Arts et Métiers francés (CNAM) está llevando a cabo experimentos para ver si es posible usar esta combinación para alcanzar temperaturas inferiores a -20 °C, suficientemente frías como para conservar los alimentos. Esta parte del proyecto supone el primer intento de usar energía solar térmica para aplicaciones que requieran temperaturas bajo cero, utilizando la tecnología de adsorción.

Indutherm, CNAM y Profactor han desarrollado conjuntamente el prototipo para este proyecto. Protecma Energía y Medio Ambiente, apoya a Profactor para llevar toda la monitorización y apoyo a los socios españoles. El objetivo de Protecma es promover este tipo de proyectos en colaboración con socios como Profactor y el Instituto Fraunhofer para el mercado español.

Colectores mejorados

Al emplear carbón activo y metanol como par adsorbente, se necesitan temperaturas de regeneración de aproximadamente 110 °C.



colector CPC de Solarfocus

Los colectores planos convencionales no tienen capacidad suficiente para suministrar energía a dicho nivel de temperatura, y por esto se hizo necesario desarrollar una fuente de calor ajustada a los requerimientos del prototipo de máquina de adsorción. Esta tarea ha sido llevada a cabo por Solarfocus, fabricando para el proyecto una versión modificada de sus paneles CPC estándar, que además han sido analizados en España bajo condiciones de campo. Esta tecnología es capaz de capturar eficientemente la energía solar y suministrar temperaturas de alrededor de 120 °C para la deshumidificación del material adsorbente.

Las mejoras introducidas en los captadores han sido:

- Mejora de la geometría de la óptica reflectiva.
- Introducción de aislamiento posterior.
- Incorporación de una lámina de aislante transparente frontal bajo la cubierta vidriada.

Termosun, distribuidor en España de Solarfocus, será el responsable del control a largo plazo de estos colectores solares adaptados y del sistema de refrigeración integrado.