High Solar Fraction Heating and Cooling Systems with Combination of Innovative Components and Methods

- Results from the European research project High-Combi

Technology sheet

Technology

- Solar High Combi System

General information:

- Technology developer: CRES (Centre of Renewable Energy Sources)
- Date of issue (year): 2006

Aims and Objectives:

The proposed project is based on two technologies: Solar combisystems and solar cooling systems. Solar combisystems are solar thermal systems that provide not only domestic hot water but also space heating. This type of systems has been on the market for about a decade. However, they are mainly employed in single-family houses in Central and Northern Europe (Weiss, W. (ed.): Solar Heating Systems for Houses – A Design Handbook for Solar Combisystems, James & James Ltd., London, 2003). Their market share in the single-family house sector is still increasing. In larger applications, e.g. multi-family houses, most solar thermal systems supply only domestic hot water. A few multi-family house applications have been realized but they cover quite low solar fractions in the order of magnitude of 10 %. One reason for this is that larger collector areas that are necessary for higher solar fractions, cause problems during stagnation in summer. This problem is even more prominent in southern European countries with a short heating season where the market share of solar combisystems is still very low. The proposed project will solve this problem by using the surplus energy for cooling. On the other hand, cooling of residential buildings in Southern Europe and of commercial and industrial buildings all over Europe is an increasing and promising market. Approximately 100 solar cooling systems have been installed worldwide so far. Most of them are quite large systems with a cooling power above 100 kW. However, as reported by experts in the IEA-Solar Heating and Cooling Programme's Task 25 (Hans-Martin Henning (ed.): Solar-Assisted Air-Conditioning in Buildings – A Handbook for Planners, Springer-Verlag, Wien, New York, 2004) more knowledge and experience is needed. There is limited simulation and monitoring data and practical design know-how for system optimization available. In addition, very few combined solar heating and cooling applications have been realized and the solar fractions are generally not very high. Therefore, a combination of solar heating and cooling systems is an ideal solution that has the potential to lead to both high solar fractions and economical systems due to double usage of the collector field and other system components. Such systems can make a significant contribution to the energy supply in Europe, as described in the White Paper "Energy for the Future: Renewable Sources of Energy".

A Short Description of the Technology:

The solar demo plant will most probably be built in a residential area (still to be identified) and will provide heat (and cooling) to residential apartments with a total living area of about 700 m^2. The latter is a typical size of a multifamily building, which represents a significant share of the residential buildings in Greece and therefore offers a high replication potential. In the figure below a schematic representation of the plant and its operation mode during summer are given. The apartments are ownership of the Greek Workers' Housing Organisation. The main system components are the solar thermal collectors (selective flat plate), the radiative heating and cooling elements (internal to the walls), the absorption or adsorption-cooling machine and the storage.

The cooling machine receives thermal energy (Q_h) at high temperature (i.e., 70-85°C) from the collectors' field and provides the useful cooling (Q_c) services to the building. As in every heat driven system, the sum of the heat provided for operating the chiller at "high" temperature and of the heat extracted from the building (at low temperature), namely (Q_h+Q_c), has to be rejected at a mid temperature level. Often the external ambient is used as heat sink for the heat rejection (e.g., through a cooling tower). In this HIGH-COMBI system, Q_h+Q_c will be delivered to the boreholes (that are positioned around the water storage tank). Consequently, the earth surrounding the storage will be heated, thus reducing the losses of the water storage tank. When, during summer, there is solar energy available but no need for cooling or domestic hot water, the produced heat will be delivered into the water tank storage. The storage will be heated up to about 90°C in summer. The combination of a good insulation (yellow area in the figure), additional low cost insulation (light blue area) and the surrounding earth heated by the boreholes will maintain the storage high temperatures, so that it will cover a substantial amount of the heating load during winter. Obviously, a part of the heating load will be covered directly by the solar gains during winter.

European Project "Eco-Building International Club for advanced European sustainable energy technology dissemination in Europe and China"

Project partners:

ENEA (IT), ISNOVA (IT), FINCO (IT), ADEME (FR), AIMCC (FR), DTI (DK), DI (DK), CRES (GR), EBHE(GR), GPREC (GR), SEC(B), ZERI (CN), CBEEA (CN)

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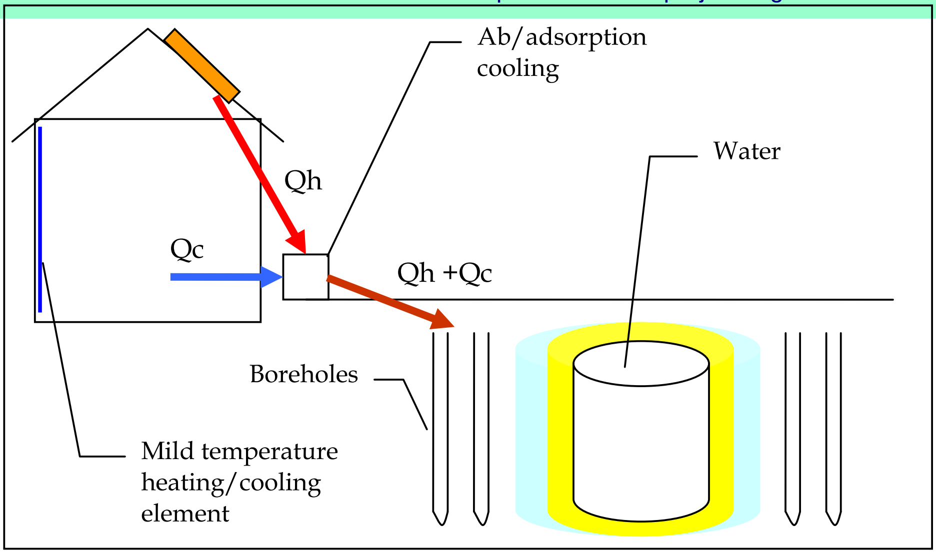

Follow some basic information on the system sizing and cost of the Greek and the other demo plants:

- Collectors area: about 150 m^2 flat plate collectors
- Type and size of storage: Seasonal storage - Volume: about 400 m^3 (tank only will be about 250 m^3 surrounded by boreholes; their exact number and depth will be specified during optimization). Indicative data for the storage are following:
- Water storage: buried, cylindrical, either concrete or steel with a radius of about 3.5 meters and height of about 7 meters.
- Boreholes: U-shape plastic tubes, surrounded by concrete, about 8 meters in depth, with a distance among them in the order of 1 meter. The boreholes number will be in the order of a few tenths.
- Cooling heat driven machine power: 70 kW (absorption or adsorption).
- Estimated solar fraction: 80% of total load (i.e., sum of DHW, space heating and cooling load)
- Budget: 190 k€, including the monitoring equipment.

Results and Achievements:

Preliminary calculations have shown a sound economy of High-Combi plants. In particular, the range of simple payback time for typical High-Combi systems, in the near future, is estimated to be between 7 and 13 years (depending on the climate conditions, the load and the plant configurations), while their lifetime is over 20 years. In case of ESCOs agreements, the IRR (Internal Rate of Return), from the ESCO's side, can often be higher than 8%. It is worth mentioning that the above estimations are "on the safe side" as they do not take into account any of the following possible advantages:

- Possible increases (over the inflation rate) of conventional fuels and electricity prices.
- Subsidies for High-Combi plants.
- The cost reduction that will occur when High-Combi systems will have a substantial penetration into the market.
- The added value for the houses (or buildings in general) where High-Combi systems are installed.

With the above considerations, it is obvious that the High-Combi systems could be promising option for the European and worldwide heating and cooling market.

An estimation of the payback time for the Greek High-Combi plant is following.

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Main data (almost all data are specific, i.e. per m^2 of collector area):
Solar yield: 800 kWh/m^2

Energy provided to space heating and domestic hot water: approximately 400kWh/m^2

Energy provided to the solar cooling machine: approximately 400kWh/m^2

Cost of the solar plant (without the extra monitoring equipment): 800 €/m^2

Clarifications for the cost: the total budget for the plant to be constructed is 190 k€ from which the monitoring equipment will cost approximately 40 k€. Therefore, the cost for the plant without monitoring is approximately 150 k€ which corresponds to 1000 €/m^2. However, it is clear that this price is particularly high since the plant is a prototype with a lot of innovations. It is expected that even in the first market steps, the price will not be higher than 800 €/m^2, with many possibilities for further reduction.

According to the above, the conventional energy savings are as follows:

The savings in thermal kWh are about 500 kWh/m^2 if we consider the boiler efficiency approximately equal to 80 %. This corresponds to 50 litres of oil or to approximately 35€ (always per m^2 of collector area) by assuming an oil price of 0,7€/l.
On the other hand, assuming a Cop (coefficient of performance) of the cooling machine equal to 0,9, the cooling energy delivered to the load will be 360 cooling kWh/m^2. If we assume that this corresponds to half electric kWh of savings and a price for electricity of 0,165 €/kWh, the resulting savings are about 30 € (always considered per m^2 of collector area).

Thus the total savings are 65€ per m^2 of collector and year. With the above assumptions the simple payback time of the plant is about 12,3 years (without taking into account any subsidy). This value is inside the estimated range for "High-Combi" plants (from 7 to 13 years), while the lifetime of the plants is more than 20 years. It is also worth mentioning that this system is particularly expensive due to the seasonal storage and that a similar configuration with short term storage would have been far less costly.

Possible application area:

Office buildings residential buildings restaurant and leisure buildings

Reference:

SIXTH FRAMEWORK PROGRAMME 6.1 Sustainable Energy Systems

Priority Title: Cost effective supply of Renewable Energies

Project acronym: High-Combi

Project full title: High Solar Fraction Heating and Cooling Systems with Combination of Innovative Components and Methods

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Eco-Building Club: an innovative RTD&D results' promotion approach

Different from common market promotion approaches, where market operators are only simple message receivers, the project proposes an innovative approach: Eco-Building Club is a virtual round table, around which building market operators will be main actors for market penetration of research and demonstration results, through the following actions:

- determining what are more appropriated innovative RTD&D results for local market transferring;
- demonstrating the feasibilities of the research and demonstration results on real cases.