IEA SOLAR HEATING AND COOLING PROGRAMME TASK 32: ADVANCED STORAGE CONCEPTS FOR SOLAR AND LOW ENERGY BUILDINGS

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1 Introduction

Single family houses are the pioneer segment for low energy buildings. Low energy houses (40-45 kWh/m2 per year for space heating) combined with solar heat production are becoming more attractive to energy concerned persons, communities or authorities seeking to give a strong name to “sustainable development”. Examples flourish in Germany with the “Passiv Haus” concept and in Switzerland with “Minergie”, which captures already 10% of the segment of the new houses market. France is introducing the concept of “building with positive energy”, that is producing more than it needs, in terms of heat and electricity.

High insulation standards, high quality glass and windows, heat recovery systems, and passive solar devices such as shading devices, help to decrease the need for heating and cooling to a low standard, 4 times less than what was the standard 20 years ago.

However, an efficient and cost effective means for storing solar energy for heating during the winter months is still needed in low energy houses.

The main goal of this “Task”, part of the Solar Heating and Cooling Programme of the International Energy Agency (IEA), is therefore to investigate new or advanced solutions for storing thermal energy in systems providing heating or cooling for buildings.

The objectives of the Task are:

- to contribute to the development of advanced storage solutions in thermal solar systems for buildings that lead to high solar fraction, and up to 100% in a typical 45N latitude climate,
- to propose advanced storage solutions for other heating or cooling technologies than solar, for example heat pumps or fossil boilers in order to reduce cycling and thus to reduce pollutant emissions due to partial combustion.

The ambition of the Task is not to develop new storage systems independent of a system application. The focus is on the integration of advanced storage concepts in a thermal system (solar, heat pump or boiler) for low energy housing. This provides both a framework and a goal to develop new technologies.

Duration

The Task was initiated in July 2003 and was initially planned to be completed in December 2006. Due to unexpected difficulties in setting up laboratory experiments with new materials and developing new models for heat storage modules, the Task has been extended 12 months until December 2007.

2 Task organisation

The Task is organised in 4 Subtasks:

1. Subtask A: Evaluation and Dissemination (Subtask Leader: Switzerland / France)
2. Subtask B: Chemical and Sorption (Subtask Leader : Chris Bales, Sweden)
3. Subtask C: Phase Change Materials (Subtask Leader: Wolfgang Streicher, Austria)
4. Subtask D: Water (Subtask Leader: Harald Drueck, Germany)

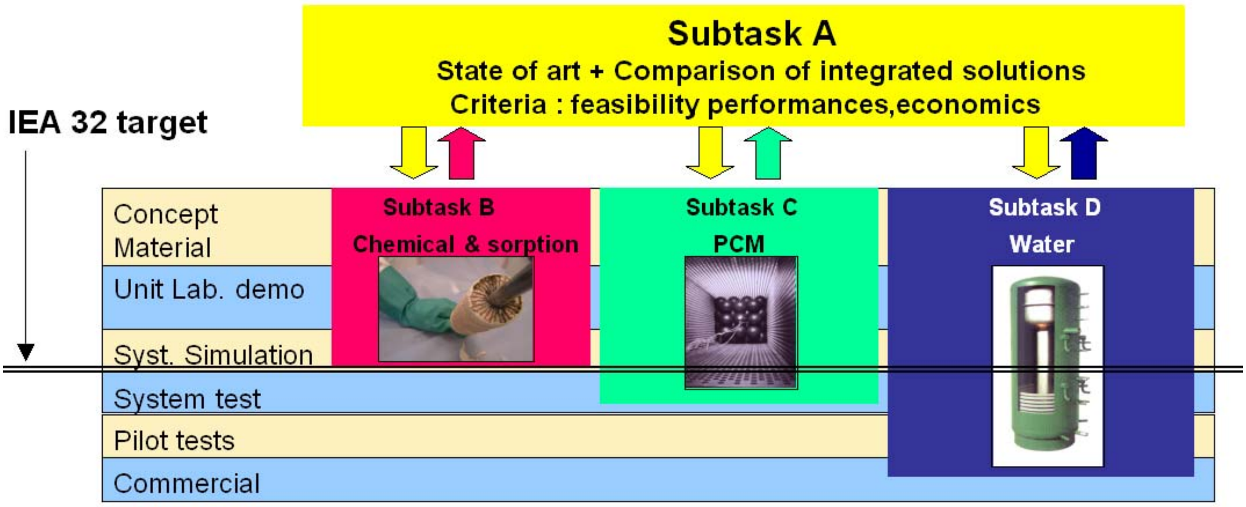


Figure 1 – Task 32 is organised in 4 subtasks and the common target is to reach at least the level of a system simulation for each project submitted by participants

Subtask A prepares the common framework to compare the different designs.

The main activity of Subtask A during 2005 has been the publication of a “State of the art” handbook on short term heat storage. The 170 pages book is based on 20 contributions from the experts within the Task and also from 3 external well known international experts. It has been edited by the Operating Agent and printed at the University of Lleida. The content, both scientifical and technical, fills a gap in the current literature on thermal storage.

The method of comparing the "solar performance" of different designs coming from the 3 other subtasks is theoretically defined based on a modified FSC method issued in a previous SHC Task. It needs validation against experimental results from projects.
A list of criteria to evaluate projects has been finalised by Subtask A and will be used for future comparison of storage options.

Criteria for system comparisons

- **Energy performance: FSC'**
- **Economics: indicators**
- **Market Availability**
- **Environnemental impacts**
- **Integration: indicators of quality**

Figure 2 – Classes of criteria considered in Task 32 to evaluate different storage designs and FSC method for the energy performance

The reference conditions for simulating different options with the same framework has been issued by the Austrian team. It is a useful piece of information for comparing systems, ii includes 4 different climates, 3 different types of houses and various heating and cooling options. A reference "solar combisystem" has also been defined so that all teams can simulate their storage solutions within a similar system. TRNSED (a TRNSYS input deck) of the reference conditions and the reference system are available in Beta versions for the Task participants.

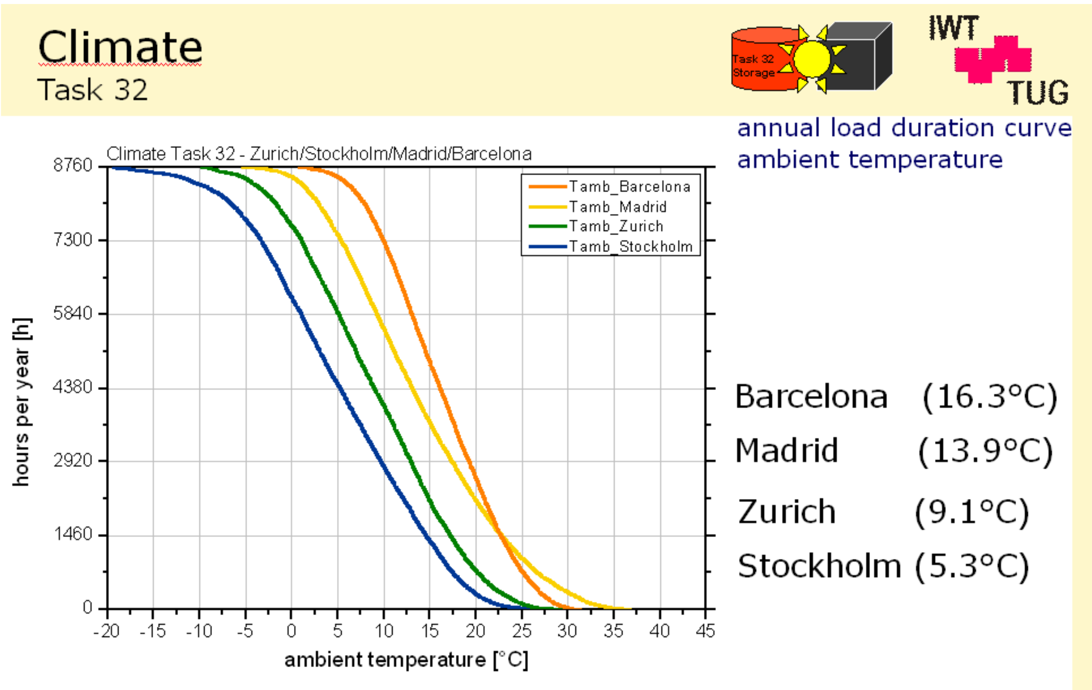


Figure 3 – Four climates are considered in Task 32 to evaluate different storage designs in solar combisystems

The Task web site www.iea-shc.org Task32, has been continuously updated with working documents and is the Task exchange platform with more than 150 documents, presentations at meetings and articles about heat storage available to Task participants.

PROJECTS	PROJECTS	PROJECTS
1. S: SERC and Climatewell: TCA	1. DK: PCM study at DTU	1. D: ITW ADStore
2. A: Modestore AEE INTEC	2. A: Pamela slurries	2. DK: comparison of systems
3. CH: Sorption storage SPF	3. A: PCM in tank	3. CH: SPF (pressureless tank)
4. D: Monosorp, ITW	4. D: ITW (Tank + PCM)	4. D: Kassel
5. NL: TCM storage	5. CH: eivd CosyPCM	5. NL: Tank project
6. CH: NaOH, EMPA (if financed)	6. SP: PCM in a solar tank	
7. D: Modestore multi-cycles	7. NL: PCM in tank in 2005	

Figure 4 – 22 projects are listed within the 3 subtasks

3 Water storages (Subtask D)

In 2005, the subtask D issued a report on the possible improvements of water tank storage for combisystems. The trends are: to increase solar energy savings, to better integrate, to improve the thermal performances, to try to use a mixture of water and PCM (Phase Change Material), to use CFD (Computational Fluid Dynamics) tools to better understand the thermal behaviour inside the tank, to look for cost reduction (standardised and simpler systems, polymeric materials), to use pressureless tanks.

In a danish study, three different ways to produce domestic hot water have been studied and lead to recommendations.

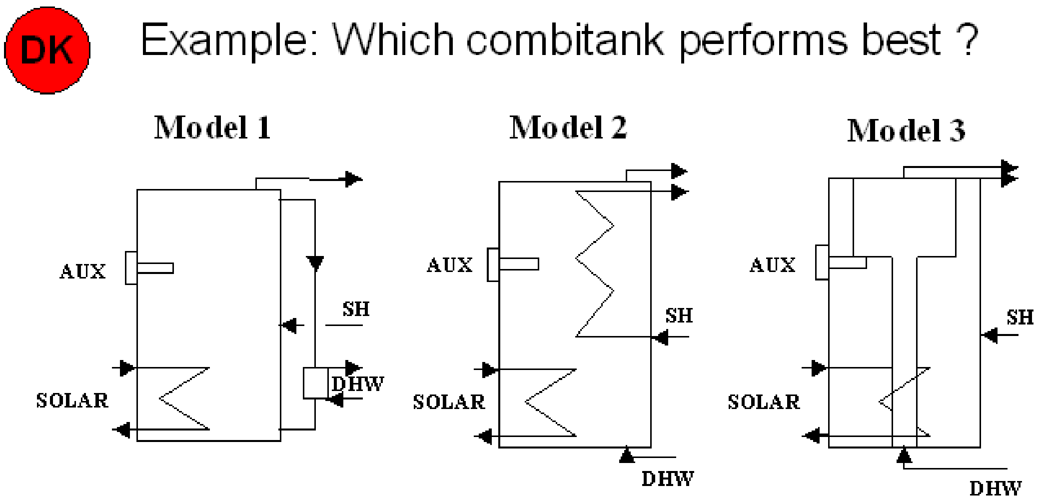


Figure 5 – Denmark: best configuration of DHW preparation is studied through modelling

In Switzerland, 11 different combisystems were compared and the comparison produced detailed results for better designs. Germany will present in 2006 a more deep contribution to subtask C since a new project has been financed for the period 2006-2007 with the cooperation of the Kassel University as a new participant.

Global Design improvements for water tank storage

- Internal vs external boiler and/r heat exchangers
- Stratification enhancers
- Internal vs external DHW preparation
- Pressurized solutions (120-150C) or Pressureless tanks
- True drain back systems
- Variable auxiliary volumes (smart tanks) from DK
- Predictive control strategies
- …

Tank material

- Advanced pipe connection
- CFD simulation of water flows
- …

Figure 6 – Water tank storage possible improvements are being listed in Subtask D

4 PCM Storages (Subtask C)

Six projects are being developed in subtask C. Most of them use sodium acetate as the phase change material. Characterization of the material in different combinations of heat transfer enhancers has been the main work of 2005. The heat transfer coefficient is indeed the limiting factor for a useful PCM storage, and it was shown that the preparation of the samples might induce very different results for the material properties. It is anticipated that this work is also a preliminary work for an international standard on PCM for heat storage.

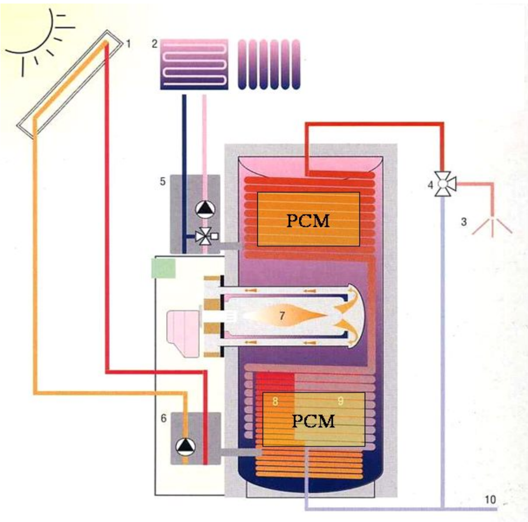


Figure 7 – Switzerland: Where to place a PCM storage in a water tank to improve the storage performance ? Theroretical and experimental studies are carried out

Modelling the subcooling effect is also a difficult topic that is addressed by 2 teams. Models are not completely developed, but first results showed that the number of nodes in the discretization process influence strongly the quality of the results.

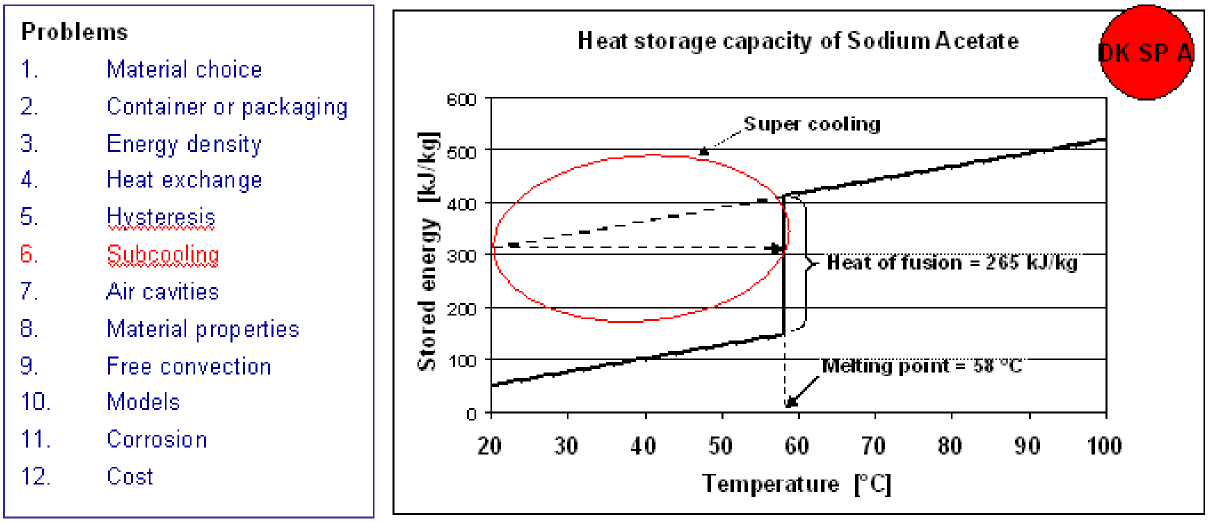


Figure 8 – Main issues of PCM storage and the subcooling effect that must be modelled to accurately predict the performance of a PCM storage

The Danish team showed in a theoretical study with a simplified model that seasonal storage could benefit from this effect by a 30% reduction of the storage.

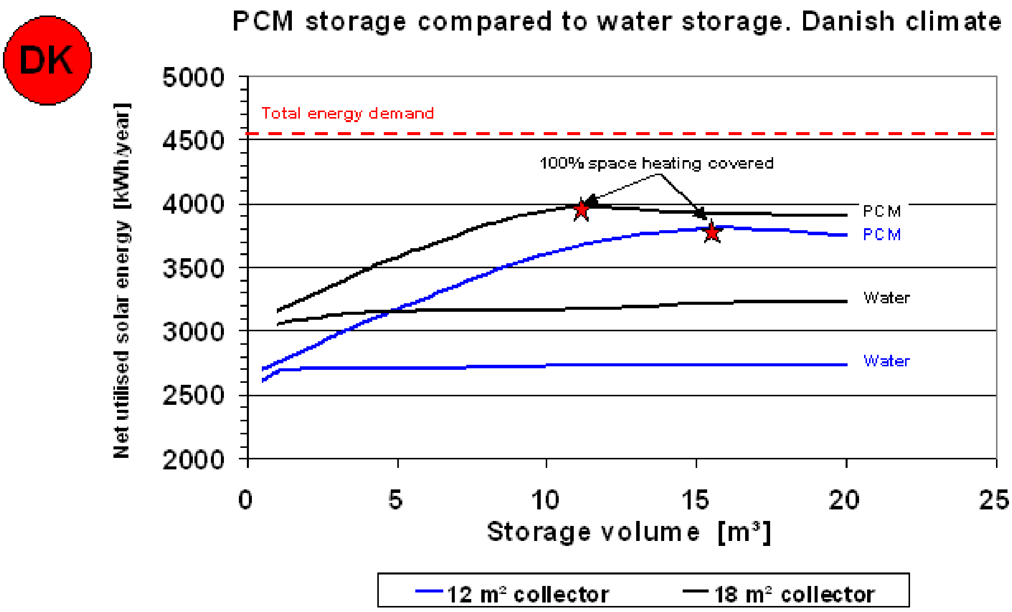


Figure 9 – Denmark: The subcooling effect might be an advantage for seasonal storage according to preliminary simulations

Computational Fluid Dynamics (CFD) tools have also been used to better understand the convection effects in a PCM within a bottle placed at the top of a water tank. Comparisons with a Trnsys model have been undertaken, and show that convection has to be taken into account even in simple models. This is still a challenge.

5 Sorption and Chemical Storages (Subtask B)

Five projects are being investigated and two others could be brought into our Task depending on national financial support.
Sorption storage solutions appear to be complex and more suited to heat pump systems where both heating and cooling could be achieved, than to pure solar systems.
In Sweden, the Thermo Chemical Accumulator (TCA) from the company Climate well is based on a sorption principle with a concentrated solution. The device can produce both heat and cold and is best suited for south European climate. Several prototypes have been tested by different research centers to reach reliability of the product.
Zeolite is still an option but the driving force needed during unloading is still a limiting factor.

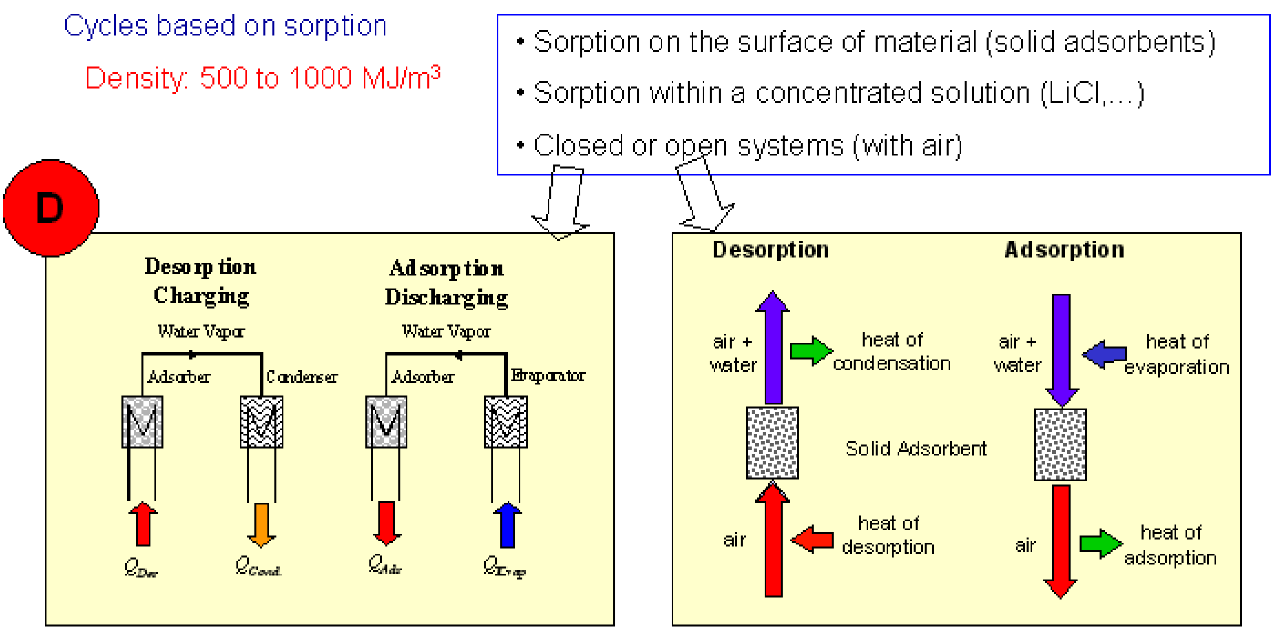
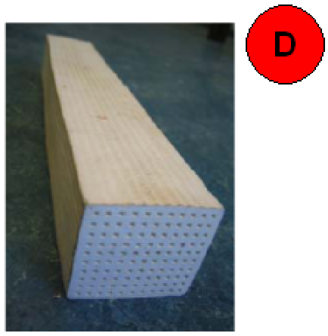


Figure 10 – Germany: Principle of a sorption storage in closed (left) or open (right) systems during charging and discharging phase

A new idea from Germany for a seasonal storage based on Zeolite (8m3 for a one-family house) has been proposed theoretically in 2005 and will be studied during 2006.
In Austria, a 1000 kg storage tank filled with silica gel has been installed during 2005 in a combisystem for a solar house and will be monitored during 2006.

Problems sorption storage

1. Open or closed ?
2. Energy density
3. Heat exchange
4. Bed size
5. Delta T
6. Pressure drop in bed
7. Mastering vapour transport in bed
8. Low grade heat regeneration in winter needed
9. More suited for heat pump than storage
10. Models
11. Cost



MONOSORP, D

Figure 11 – Sorption storage concepts need still R&D work to overcome several problems that Task 32 has addressed. The german project Monosorp might be a good answer to the seasonal storage with a zeolite bed.

Task 32 is unfortunately lacking chemical projects although some options might be very well suited for long term storage as defined in a dutch theoretical study. Financing storage projects is in all countries a difficult task although all countries recognize the “need for storage” as the number one topic for the development of solar heat in the future !

Problems chemical storage

1. Reaction choice: Na OH, MgO
2. Stability
3. Reversibility
4. Life time
5. Reactor pressure (vessel)
6. Corrosion
7. Toxicity
8. Container
9. Cost
10. ….
11. Not much R&D budget

$$AB + E \leftrightarrow A + B_g$$

Solid or Liquid ↔ Solid or Liquid + Gas

Figure 12 – Chemical storage concepts could be promising but R&D work is not supported enough in IEA countries. In Switzerland a NaOH storage concept is being experimentally tested at EMPA.

6 Conclusion

Task 32 is addressing ways to improve the storage of heat in thermal installations.

Storage of thermal energy is a fundamental topic to increase the productivity of solar systems. PCM combined with water is at present the most promising option.Competing with water in solar combisystems is a difficult challenge and the objective to increase the capacity of the storage by a factor 3 compared to water will be difficult.
Water tanks have also a potential for improvements that is worth looking at.

New storage techniques might improve the efficiency of combustion cycles.
New machines for delivering heat and cold might benefit from the R&D effort on storage.

The IEA framework makes it possible to confront ideas and results on a very important topic for the development of solar energy and more efficient heat distribution techniques.

7 Literature

IEA ECES Annex 17 (2005)**: www.iea-eces.org The Task final report is available**

IEA SHC Task 26 (2004)**: Solar Heating Systems for Houses - A Design Handbook for Solar Combisystems,** W. Weiss and al., James & James, 2004, 313 pages

Bales C., Hadorn J.-C., Drück H., Streicher W. (2005), Advanced storage concepts for solar houses and low energy buildings, ISES 2005.

Hadorn J.-C. editor, (June 2005), Thermal energy storage for solar and low energy buildings - State of the Art, Printed by Servei de Publicacions Universidad Lleida, Spain, 170 pages ISBN 84-8409-877-X, available through Internet www.iea-shc.org Task32

REPORTS PUBLISHED IN 2005 by Task 32 (some reports are not yet freely available)

- Report A1: Book: State of the art – June 2005.
- Report A3 Method of comparison and criteria.
- Report B1 Identifications and selection of projects.
- Report B2 Thermal properties and laboratory analysis.
- Report C1 Identifications and selection of projects.
- Report C2 Thermal properties and laboratory analysis for PCMs
- Report D1 Review of advanced concepts and dream systems for tank storage.

REPORTS PLANNED FOR 2006

- Report A2 Boundary conditions and reference conditions.
- Report B3 Laboratory prototypes of storage units (Sorption)
- Report C3 Laboratory prototypes of storage units (PCM)