INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING CO_2 EMISSIONS

Beneficiaries:

Partners:

D7.2 - Report on Staff Exchanges

	Name and Institution	Date
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1 Objectives

This report reflects the results of two secondments done at the same time. Prof. Dr. Luisa F. Cabeza from the University of Lleida (Spain) and Assoc. Prof. Dr. A. Inés Fernández from the University of Barcelona (Spain) visited Assoc. Prof. Dr. Frank Bruno at the University of South Australia (Australia) for one month in 2015.

The objectives of the two secondments were:

a) To enhance the collaboration between the three institutions with a long term perspective.
b) To give more visibility to the research on TES at UniSA.
c) To analyse the possibility of using metal alloys as PCM in solar power plants.

Each of these objectives is developed in the following sections.

2 Long term collaboration between UdL-UB-UniSA

2.1 Talks with Prof. Dr. Wasim Saman and with Assoc. Prof. Dr. Frank Bruno

- See possibilities of Australia and Singapore in being involved in H2020 projects
- Interest in waste heat applications for TES, potential collaboration with PhD student in UdL, Laia Miró

2.2 Talks with postdocs and PhD students

Dr. Martin Belusko

- See meeting with Luigi Cirocco
- Discussion about materials selection for piping in metal alloy systems
- Visit to Prof. Stephen Clarke

Dr. Steven Tay

- After his secondment in UdL in 2014, different collaboration points are being done
- NTU-method developed in 2008 together with Assoc. Prof. Dr. Albert Castell, when he visited UniSA is still being improved between UniSA and UdL.
- His dynamic concept for PCM storage is going to be tested at UdL and UniSA. Now the tank for UdL is being designed and its commission is expected to be during the next few weeks. Testing will be done in July-August 2015.
- The testing at UniSA will probably be done in collaboration with UdL when PhD student Jaume Gasia from UdL will carry out his secondment at UniSA.

- Dr. Steven Tay has been invited to collaborate in a paper which is being written by PhD student Harald Pointner from DLR, Germany during his research stay at UdL. Together with Dr. Alvaro de Gracia and Dr. Gabriel Zsembinszki, they will compare different modelling programmes and methods used for PCM in terms of computing accuracy, precision and computing velocity.
- Dr. Tay has the assignment to write a book on PCM for high temperature applications. The approach of the book, contents and potential collaborators were discussed. An editorial was approach to present the paper. UdL and UB were invited to cooperate in the book edited by UniSA.

Dr. Ming Liu

- She is carrying out corrosion of carbonates at high temperature
- She started to work with Assoc. Prof. Dr. Mercè Segarra from UB during her secondment. Within this period we worked on the characterization of corrosion on steel samples. Dr Ming is carrying out a series of cycling experiments using high temperature PCM based in chloride salts in closed crucibles. Unexpected solid is deposited in the lid of the crucibles after several cycles. Samples of this solids will be analysed in UB facilities.
- Potential collaboration for the secondment from Assoc. Prof. Dr. Ingrid Martorell from UdL during her secondment in July 2015
- Potential collaboration in her secondment at UB/UdL in June 2015

Shane Sheoran

- He is finishing his PhD on direct contact PCM storage.
- Interesting for liquid-liquid PCM at low temperature and for liquid-gas PCM for CSP and waste heat
- Potential relation with the project with Auckland University and Abengoa in the proposal in Qatar.

Rhys Jacob

- High temperature encapsulation of PCM with inorganic shells
- Discussion about the encapsulation methods and its feasibility at industrial scale.
- One of the encapsulation methods involves the use of polyvinyl alcohol (PVA) as a binder of the inorganic component former of the shell. Due to the heat treatment needed during the encapsulation process, some experiments were designed and carried out to evaluate the feasibility of using PVA. Chemical characterization of the samples is now running at UB facilities.
- He will probably come to Barcelona to do some testing

Soheila Riahi

- She just started.

- Her interest is on CFD of shell in tubes storage tanks with high temperature PCM
- We see potential on CFD simulation of TCM systems due to her background in CFD simulation of combustion processes.

Mahsa Karimpour Aghbolagh

- She is coming to Lleida in August-September 2015
- She will carry out a LCA analysis of the MERITS system which UDL is working on
- She will work with PhD student Aran Solé and with Dr. Alvaro de Gracia

Saleh Naser A. Almsater

- PhD on heat transfer enhancement of PCM at high temperature
- Work on heat pipes
- Addition of fins in PCM, but with HTF in both sides of the PCM. This is very similar to what Dr. Gennady Ziskind is doing at BGU, Israel. (Luisa to put in contact)
- Revision of his experimental set up and his papers approach

Ehsan Shamil Omaraa

- Finishing his PhD proposal on PCM characterisation at high temperature
- He will probably focus on melting temperature and enthalpy with calorimetry and T-history
- To put in contact with Gerard Ferrer, PhD at UdL who is also developing a T-history for high temperature (potential secondment)
- For the calorimetry analysis, the work carried out by Lehigh University, USA, needs to be revised.

Luigi Rocco Cirocco

- Secondment Martin: interest in using cold TES to modulated electricity demand. The objective of the secondment will be to gather data from Spain and implement it in the models they have. The results will then be compared with those obtained in Australia.
- For the first week of June, Luisa will set up several meetings in Lleida:
    - Mr. Joaquim Llop, Endesa, to learn about the tariff system in Spain
    - Mr. Argiles, Nufri, to see the potential of cold storage in a cold storage for fruit facility where PV is available
    - Winery (Raimat and/or Torres), to see the glycol cooling system
    - Dairy, if possible, not very common in Lleida

Sleiman Farah

- He presented his PhD proposal during our secondments
- His PhD is about off-grid net-zero houses
- In this PhD he needs to select a TES technology (and material).

- Potential collaboration in this selection is devised and a potential paper is drafted.

Claudio Dametto

- Enhancement of solidification of PCM

2.3 Talks with other researchers at UniSA

Dr. Stephen Clarke

- We had a meeting with Dr Stephen Clark from the UniSA, chemistry department, with Dr. M. Belushko and the PhD student Rhys Jacob. Dr. Clark and his team have significant experience in silicon compounds, and we discussed several possibilities for using silicon based polymers for the encapsulation of inorganic PCM. Particularly we proposed the idea of encapsulating the high temperature PCM with geopolymers, because of the expertise of the group in formulating geopolymers with coal fly ashes.

Dr. Collin Hall / Dr. Drew Evans

- We visit the facilities at the Materials Science building of the Thin Films Coating group. We discussed some common areas of interest and the possibilities of collaborating in the frame of INNOSTORAGE project.

Dr. David Whaley

- We visited the Lochiel Park development with Dr. David Whaley. He also showed us the zero energy home and the visual monitoring system. We discussed jointly with Dr. Frank Bruno the potential collaboration in the secondment of Dr. Marc Medrano from UdL to work in the analysis of data from this housing development.

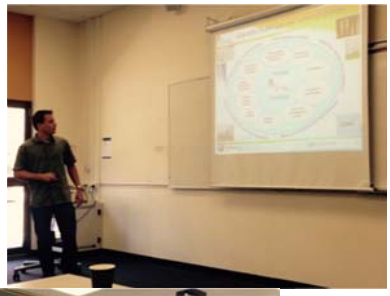
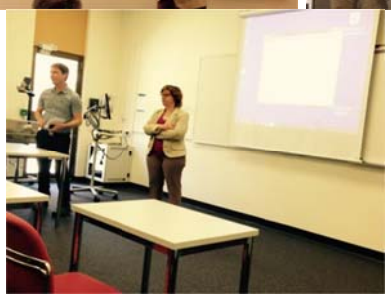
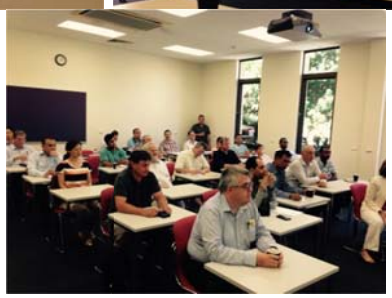
3 Increase visibility to the research on TES at UniSA: outreach activities

During this period, different outreach activities have been done:

- Participation in the P22 ASTRI project monthly meeting
  We were invited to participate in this teleconference meeting, where we had the chance to learn more about the activities carried out in Australia about TES for CSP. We also had the opportunity to present ourselves to all meeting participants. The agenda of the meeting can be found in the Annex of this document.

- Seminar at UniSA
  At the time of these secondments, also Assoc. Prof. Dr. Kévyn Johannes was doing his secondment at UniSA. Therefore, we prepared a seminar at UniSA for all the School of Engineering, where the work at the three universities in Europe could be presented. Moreover, the project INNOSTORAGE was also presented. The announcement of the seminar can be found in the Annex of this document.

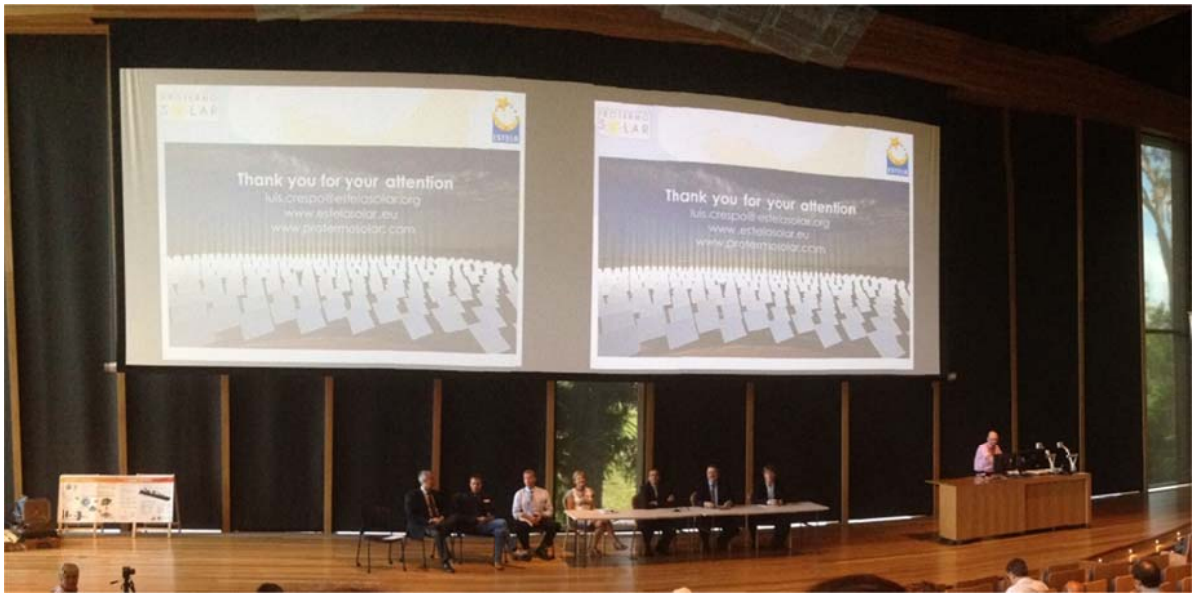


- Visit at the Queensland University of Technology, Brisbane
  On February 9th we visited QUT, where we could see all the infrastructures available there. Dr. Geoffrey Will and Dr. Stuart Bell hosted us; Dr. Ming Liu from UniSA joined us, together with a PhD student and Yanping Sun from CSIRO.

- Participation at Australian Solar Thermal Research Initiative (ASTRI) Workshop in Brisbane

  We had the opportunity to participate in the ASTRI Annual Workshop that was celebrated in Brisbane. We had the opportunity not only to learn all the research that is being carried out in Australia, but also to meet all researchers and project managers, such as Dr. Manuel Blanco, director of ASTRI and Wes Stein, project manager at CSIRO. The agenda of the meeting can be found in the Annex of this document.



4 Use of metal alloys as PCM in solar power plants

The aim of this chapter was to work on a common scientific paper to be submitted preferably in the journal Solar Energy Materials & Solar Cells.

4.1 Introduction and state of the art

Phase change materials (PCM) have been used in thermal energy storage (TES) for many years, but usually at lower temperatures than 150 ^{o}C. At this stage, interest in PCM for high temperature applications, such as for concentrated solar power (CSP) and waste heat recovery in industry, is growing. In this context, interest in metal and metal alloys used as PCM has appeared. Many reviews published list a few metals and metal alloys as potential PCM, and most of them agree that have not yet been seriously considered.

Table 1 shows a list of all materials published as PCM with their thermophysical properties.

Table 1. Metals and metal alloys considered in the literature as PCM for high temperature applications.

Material	Melting point (ºC)	Latent heat		Density (kg/L)	Cp (sol) (kJ/kg·K)	Cp (liq) (kJ/kg·K)	Thermal conductivity (W/m·K)	Volume expansion (10^{-6}/K)	Type
		(kJ/kg)	(kJ/L)						
52Zn-48Mg	340	180	---	---	---	---	---	---	---
53.7Zn-46.3Mg	340	185	851	4.600	---	---	---	---	Eutectic
51Zn-49Mg	342	155	442	2.850	0.73	---	75	---	Eutectic
96Zn-4Al	381	138	916	6.630	---	---	---	---	Eutectic
Zn (commercial purity, high grade, min 99.9%)	419	112	---	7.140	0.39	0.48	---	93.5	---l
59Al-35Mg-6Zn*	443	310	---	2.38	1.63	1.46	---	---	---
60Al-34Mg-6Zn	443	312	---	2.380	1.63	1.46	---	80.1-93.5	---
60Al:34Mg:6Zn	450.3	32.1	---	---	---	---	---	---	---
60Mg-25Cu-15Zn	452	254	---	2.80	---	---	---	---	---

52Mg-25Cu-23Ca	453	184	---	2.00	---	---	---	---	---
86.4Al-9.4Si-4.2Sb	471	471	---	---	---	---	---	---	Eutectic
34.65Mg-65.35Al	497	285	615	2.155	---	---	---	---	Eutectic
60.8Al-33.2Cu-6.0Mg	506	365	111.3	3.050	---	---	---	---	Eutectic
64.1Al-5.2Si-28Cu-2.2Mg	507	374	164.4	4.400	---	---	---	---	Eutectic
54Al-22Cu-18Mg-6Zn	520	305	---	3.14	1.51	1.13	---	---	---
68.5Al-26.5Cu-5.0Si	525	364	106.9	2.938	---	---	---	---	Eutectic
64.3Al-34.0Cu-1.7Sb	545	331	132.4	4.000	---	---	---	---	Eutectic
66.92Al-33.08Cu	548	372	133.9	3.600	---	---	---	---	Eutectic
83.14Al-11.7Si-5.16Mg	555	485	121.3	2.500	---	---	---	---	Eutectic
87.76Al-12.24Si	557	498	126.5	2.540	---	---	---	---	Eutectic
49.1Cu-46.3Al-4.6Si	571	406	226.0	5.560	---	---	---	---	Eutectic

65Al-30Cu-5Si	571	422	---	2.73	1.30	1.20	---	---	---
86.4Al-9.4Si-4.2Sb	575	471	127.2	2.70	---	---	---	---	Eutectic
88Al-12Si	576	560	---	2.70	1.038	1.741	160	---	Alloy
88Al-12Si	576	560	---	2.700	1.04	1.74	---	63.9	Metal
88Al-12Si	576	560	---	---	---	---	---	---	Alloy
88Al-12Si	577	462		---	0.939		181		Alloy
Zn_2Mg	588	230	---	---	---	---	---	---	---
Mg (commercial purity)	648	365	---	1.740	1.27	1.37	---	87	Metal
Al (commercial purity, 1-0 wrought)	661	388	---	2.700	0.90	0.90	---	80.1	Metal
49Zn-45Cu-6Mg	703	176	---	8.67	0.42	---	---	---	---
91Cu-9P	715	134	---	5.60	---	---	---	---	---
69Cu-17Zn-14P	720	368	---	7.00	---	---	---	---	---
74Cu-19Zn-7Si	765	125	---	7.17	---	---	---	---	---

56Cu-27Si-17Mg	770	420	---	4.15	0.75	---	---	---	---
84Mg-16Ca	790	272	---	1.38	---	---	---	---	---
47Mg-38Si-15Zn	800	314	---	---	---	---	---	---	---
80Cu-20Si	803	197	---	6.60	0.50	---	---	---	---
83Cu-10P-7Si	840	92	---	6.88	---	---	---	---	---
Mg_2Cu	841	243	---	---	---	---	---	---	---
49Si-30Mg-21Ca	865	305	---	2.25	---	---	---	---	---
56Si-44Mg	946	757	---	1.90	0.79	---	---	---	---
Cu	1077	71	---	---	---	---	---	---	---

4.2 Challenges on the use of metal alloys as PCM at high temperature

The use of metal alloys, and even metals, as phase change materials (PCM) at high temperature has some challenges:

- Most metal alloys applicable for TES are compositions close to the eutectics, therefore the implications in the microstructure has to be taken into account.
- The quantity of energy needed to form the different microstructures in metal and metal alloys change.
- In the preparation, most metal alloys after the solidification require a heat treatment to reach the desired microstructure. This is mainly due to the required mechanical properties of these alloys in used. If this mechanical performance is not needed, we may think on not doing this heat treatment, but then the different heating and cooling cycles in their use as PCM may produce segregation or formation of insoluble precipitates.
- The formation of precipitates or oxides due to the change in cycling rates (which may be a requirement of the storage system) may change the alloy characteristics, therefore melting and solidification temperatures and enthalpy may change. In each metal alloy selected as PCM, the extent of this effect needs to be evaluated to see if this is a problem.
- Conduction heat transfer coefficients are very high in alloys. The possibility of the HTF to cope with that needs to be evaluated.
- The oxidation of metal alloys can be avoided with inert atmospheres, but each gas has a different influence on the alloy that needs to be considered and revised.
- Possible undesired reactions (reactivity and solubility with the container/coil/pipes/… metal) should be investigated.
- Difficulties in the selection of container/coil/pipes/… material due to the high working temperature. Mechanical properties of materials at those temperatures are bad, which may require expensive alternatives.
- If there is a leakage of the PCM in the system, which reactions may happen with the HTF?

5 Outcomes or future work

It is expected that these secondments will produce journal papers as a result of the collaboration with the different researchers. Particularly, the paper on metal alloys is being prepared in these two months after the secondment.

Nevertheless, the most important outcomes are all the future and possible links.

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7 Assessment

7.1 Assessment from Luisa F. Cabeza

Being my second visit to the University of South Australia and for a long period such as one month, this visit has been of high interest for me and my research team at the University of Lleida. I have had the opportunity to enhance the collaboration between both universities, but being the visit together with Dr. Fernández from the University of Barcelona, the exchange has been even better to improve our collaboration.

7.2 Assessment from A. Inés Fernández

This has been a great opportunity for me to learn from the different researchers at UniSA group. The meetings and talks with PhD students and postdoc researchers were very fruitful and I wish I can contribute to their researches from my perspective as a materials scientist. The experience was excellent, as I had the possibility of knowing another way of working, trying to soak all possible skills experiencing research and knowledge sharing.

8 Annex

ASTRI P22 meeting agenda

UniSA Seminar announcement

Brisbane workshop agenda