



INNOSTORAGE

Advances in Thermal Energy Storage
חידושים באגירת אנרגיה תרמית

CONFERENCE PROGRAM



אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev
جامعة بن غوريون في النقب

February 16-18, 2016
Beer-Sheva, Israel

Day 1: Tuesday, February 16

09:00-10:00

Opening Session

Opening remarks	<i>Prof. Gennady Ziskind</i> Department of Mechanical Engineering, Ben-Gurion University of the Negev
Greetings	<i>Prof. Dan Blumberg</i> Vice-President and Dean for Research and Development, Ben-Gurion University of the Negev <i>Prof. Joseph Kost</i> Dean, Faculty of Engineering Sciences, Ben-Gurion University of the Negev <i>Prof. Avi Levy</i> Head, Department of Mechanical Engineering, Ben-Gurion University of the Negev
INNOSTORAGE presentation	<i>Prof. Luisa F. Cabeza</i> GREA Innovació Concurrent, Universitat de Lleida, Spain Coordinator, INNOSTORAGE and INPATH-TES research frameworks

10:00-10:30

Coffee break

10:30-12:10

Session 1: Industrial and domestic applications

Chairpersons: Luisa F. Cabeza (Spain) and Rhys Jacob (Australia)

- Paper 023 Industrial waste heat (IWH) recovery potential assessment in Spain
Lai Miró¹, Sarah Brueckner², Russell McKenna³, Luisa F Cabeza¹
¹GREA Innovació concurrent, Edifici CREA, Universitat de Lleida, Pere de Cabrera s/n, 25001-Lleida, Spain. E-mail: lcabeza@diei.udl.cat
²ZAE Bayern, Walther-Meißner-Str. 6, 85748 Garching, Germany. E-mail: sarah.brueckner@zae-bayern.de
³Institute for Industrial Production (IIP), Chair of Energy Economics, Karlsruhe Institute of Technology (KIT), Hertzstraße 16, 76187 Karlsruhe, Germany. E-mail: russell.mckenna@kit.edu
- Paper 025 MERITS project: a comparative study of shell-and-tube heat exchangers for domestic hot water (DHW) and industrial waste heat (IWH) applications
Jaume Gasia¹, Jan Diriken^{2,4}, Malcolm Bourke³, Johan Van Bael^{2,4}, Luisa F. Cabeza¹
¹GREA Innovació concurrent, Edifici CREA, Universitat de Lleida, Pere de Cabrera s/n, 25001-Lleida, Spain. E-mail: lcabeza@diei.udl.cat
²Flemish Institute for Technological Research (VITO), Boeretang 200, BE-2400 Mol, Belgium
³Glen Dimplex Ireland, Church Road, Portadown, Co Armagh, BT63 5HU, U.K.
⁴Energyville (joint venture of VITO NV and KU Leuven), Thor Park 8300, BE-3600 Genk, Belgium
- Paper 032 A compact multi-stage latent heat store for DHW applications
Jan Diriken^{1,2}, Johan Van Bael^{1,2}, Guy Meynen^{1,2}, Filip Leemans^{1,2}, Robbe Salenbien^{1,2}, Martine Baelmans^{2,3}, Luisa F. Cabeza⁴
¹Flemish Institute for Technological Research (VITO), Boeretang 200, 2400 Mol, Belgium. E-mail: jan.diriken@energyville.be
²Energyville (joint venture of VITO NV and KU Leuven), Dennenstraat 7, 3600 Genk, Belgium
³KU Leuven, Department of Mechanical Engineering, Celestijnenlaan 300A, 3001 Leuven, Belgium
⁴GREA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001 Lleida, Spain

- Paper 059 Old and new concepts in development of PCM thermal energy storage systems
Eli Korin
Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel. E-mail: ekorin@bgu.ac.il
- Paper 055 A review of the connection between material property and performance of PCM in real scale applications
Harald Mehling¹, Camila Barreneche², Aran Solé², Luisa F. Cabeza²
¹Consultant, Weingartenstr. 37, 97074 Würzburg, Germany. E-mail: harald.mehling@gmail.com
²GREa Innovació concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001 Lleida, Spain. E-mail: lcabeza@diei.udl.cat

12:10-13:30

Lunch

13:30-15:30

Session 2: Modeling

Chairpersons: A. Inés Fernández (Spain) and Philip Griffiths (United Kingdom)

- Paper 036 Pumped heat electricity storage
André Thess
Institut für Technische Thermodynamik, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Pfaffenwaldring 38-40, 70569 Stuttgart, Germany. E-mail: andre.thess@dlr.de
- Paper 049 Development and validation of an adsorption heat storage numerical model
Damien Gondre^{1,2}, Kévyng Johannes^{1,3}, Frédéric Kuznik^{1,2}
¹Université de Lyon, CNRS
²INSA-Lyon, CETHIL, UMR5008, F-69621, Villeurbanne, France
³Université Lyon 1, F-69622, France. E-mail: frederic.kuznik@insa-lyon.fr
- Paper 060 Dynamic melting of PCM: An experimental evaluation.
Jaume Gasia¹, N.H. Steven Tay, Rhys Jacob², Martin Belusko², L.F. Cabeza¹, Frank Bruno²
¹GREa Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001 Lleida, Spain. E-mail: lcabeza@diei.udl.cat
²Barbara Hardy Institute, University of South Australia, Mawson Lakes, SA 5095, Australia.
- Paper 051 Implementation and comparison of three enthalpy methods for modelling solid-liquid phase change in OpenFOAM
Andreas König-Haagen¹, Erwin Franquet², Eric Pernot², Dieter Brüggemann¹
University of Bayreuth, Centre of Energy Technology (ZET), Bayreuth, Germany.
E-mail: andreas.koenig-haagen@uni-bayreuth.de
University of Pau & Pays Adour, LaTEP, Pau, France
- Paper 057 One-dimensional analytical model of PCM melting
Vadim Dubovsky, Gennady Ziskind, Ruth Letan
Heat Transfer Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. E-mail: vadimd@bgu.ac.il
- Paper 050 3D modeling of phase change with natural convection using Lattice Boltzmann Method and GPUs
Frédéric Kuznik^{1,2}
¹Université de Lyon, CNRS
²INSA-Lyon, CETHIL, UMR5008, F-69621, Villeurbanne, France

15:30-16:00

Coffee break

16:00-17:40

Session 3: Enhancement

Chairpersons: Maria Browne (Ireland) and Frederic Kuznik (France)

- Paper 019 Working towards solving the rate problem: geometric vs nano-enhanced PCM solutions
Dominic Groulx¹, Ali C. Kheirabadi¹, Louis Desgrosseilliers¹, Moe Kabbara¹, Mohammad Azad¹, Adam Donaldson¹, Alain Joseph², Mary Anne White¹
¹Dalhousie University, Halifax, Nova Scotia, Canada
²Nova Scotia Community College, Dartmouth, Nova Scotia, Canada.
E-mail: dominic.groulx@dal.ca
- Paper 033 Fast thermal energy storage using open-cell aluminum foam
Henk Huisseune, Ben D'Haeger, Michel De Paepe
Ghent University, Department of Flow, Heat and Combustion Mechanics, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium. E-mail: Henk.Huisseune@UGent.be
- Paper 037 Close-contact melting in latent heat storage units with longitudinal fins
Ron Hayat, Tomer Rozenfeld, Yoram Kozak, Gennady Ziskind
Heat Transfer Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. E-mail: gziskind@bgu.ac.il
- Paper 038 Modeling of melting in the presence of solid sinking
Yoram Kozak, Gennady Ziskind
Heat Transfer Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. E-mail: gziskind@bgu.ac.il
- Paper 043 Close-contact melting of nano-enhanced PCMs
Yoram Kozak¹, Yi Zeng², Rabih Al Ghossein², Gennady Ziskind¹, Jeyhoon M. Khodadadi²
¹Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel. E-mail: gziskind@bgu.ac.il
²Mechanical Engineering Department, Auburn University, 1418 Wiggins Hall, Auburn, AL 36849 USA. E-mail: khodajm@auburn.edu

19:30-22:00

Dinner (included) – “Authentic” Restaurant, Beer-Sheva

Day 2: Wednesday, February 17

09:00-10:00

Session 4: Novel Materials and Properties I

Chairpersons: Anna Laura Pisello (Italy) and Mohammed M. Farid (New Zealand)

Paper 058 Novel microencapsulated phase change material for thermal energy storage in building applications

Halime Paksoy, Beyza Beyhan, Kemal Cellat

Çukurova University, 01330, Adana, Turkey. E-mail: beyzabeyhan@gmail.com

Manipulation of phase transition temperatures and supercooling of sugar alcohol based Phase Change Materials (PCMs) by urea

Paper 015 *Johan Göhl¹, Robert Paberit¹, Erik Rilby¹, Jan Swenson², Pär Johansson¹, Helén Jansson¹*

¹Dept. of Civil and Environmental Engineering, Chalmers Univ. of Technology, Gothenburg, Sweden. E-mail: helen.jansson@chalmers.se

²Dept. of Applied Physics, Chalmers Univ. of Technology, Gothenburg, Sweden.

Paper 022 Highly conductive stabilized TCM with graphite

Aran Solé¹, Camila Barreneche^{1,2}, Anabel Palacios², A. Inés Fernández², Luisa F. Cabeza¹

¹University of Lleida, Pere de Cabrera s/n 25001, Lleida, Spain. E-mail: lcabeza@diei.udl.cat

²Department of Materials Science & Metallurgical Engineering, Universitat de Barcelona, Barcelona, Spain. Martí i Franqués 1-11, 08028-Barcelona, Spain. E-mail:

ana_inesfernandez@ub.edu

Paper 012 Thermophysical properties of low cost lithium nitrate salts produced in northern Chile for thermal energy storage

(Proceedings only)

Ángel G. Fernández¹, Judith C. Gomez²

¹Energy Development Center, University of Antofagasta, Av. Universidad de Antofagasta 02800, Antofagasta, Chile. E-mail: angel.fernandez@uantof.cl

²National Renewable Energy Laboratory, 15013 Denver West Parkway 80401, Golden, Colorado. USA. E-mail: judith.gomez@nrel.gov

10:00-10:30

Coffee break

10:30-12:30

Session 5: PCM Applications I

Chairpersons: Marilena de Simone (Italy) and Harald Mehling (Germany)

Paper 016 Design evaluation and improvements of a latent heat based thermal energy storage system

Pepe Tan, Pär Johansson, Angela Sasic Kalagasidis

Dept. of Civil and Environmental Engineering, Chalmers University of Technology, Gothenburg, Sweden. E-mail: pepe.tan@chalmers.se

Paper 017 Natural convection melting in a high temperature flat plate latent heat storage system: Parameter study of enclosure dimensions

Julian Vogel¹, Jonina Felbinger², Maike Johnson¹

¹German Aerospace Center (DLR), Pfaffenwaldring 38-40, Stuttgart, Germany,

²University of Stuttgart, Stuttgart, Germany.

E-mail: julian.vogel@dlr.de

- Paper 018 Performance characteristics of thermoelectric generator (TEG) with PCM module
Maciej Jaworski, Marta Bednarczyk, Marcei Czachor
 Institute of Heat Engineering, Warsaw University of Technology, Nowowiejska 21/25, 00-665 Warsaw, Poland. E-mail: mjawo@itc.pw.edu.pl
- Paper 024 Experimental evaluation of a cooling radiant wall coupled to a ground heat exchanger
Joaquim Romani¹, Alvaro de Gracia², Luisa F. Cabeza¹
¹GREA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida, Spain. Email: lcabeza@diei.udl.cat
²CELiMIN, Universidad de Antofagasta, Campus Coloso, Av. Universidad de Antofagasta, 02800 Antofagasta, Chile
- Paper 034 Multipurpose characterization of cool roof membrane with paraffin based PCM inclusion
Anna Laura Pisello^{1,2}, Elena Fortunati³, Samantha Mattioli³, Camila Barreneche⁴, Franco Dominici³, Cristina Piselli², Veronica L. Castaldo², Luisa F. Cabeza⁴, Franco Cotana^{1,2}, Luigi Torre³, José M. Kenny³
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- Paper 014 Experimental evaluation of PCMs for heat storage in solar cooling systems
Vincenza Brancato, Andrea Frazzica
 CNR - Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano", Via Salita S. Lucia sopra Contesse 5, 98126 Messina, Italy. E-mail: andrea.frazzica@itae.cnr.it

12:30-13:30

Lunch

13:30-15:30

Session 6: PCM Applications II

Chairpersons: Halime Paksoy (Turkey) and Maciej Jaworski (Poland)

- Paper 040 Analysis of a multi-PCM latent heat storage unit
Moran Ezra, Yoram Kozak, Gennady Ziskind
 Heat Transfer Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. E-mail: gziskind@bgu.ac.il
- Paper 045 The up-scaling of a Photovoltaic/Thermal (PV/T) system with integrated phase change material
Maria C. Browne, Sarah J. McCormack
 Department of Civil, Structural and Environmental Engineering, Trinity College, University of Dublin, College Green, Dublin 2, Ireland. E-mail: brownema@tcd.ie

- Paper 052 Experimental and theoretical study of cold storage with PCM
Yoram Kozak¹, Mohammed Farid², Gennady Ziskind¹
¹Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel. E-mail: kozaky@post.bgu.ac.il
²Department of Chemical and Materials Engineering, The University of Auckland, Auckland, New Zealand. E-mail: m.farid@auckland.ac.nz
- Paper 030 Fire reaction behavior of coated microencapsulated PCM
Camila Barreneche^{1,2}, Anabel Palacios^{1,2}, Refat Al Shannaq³, Jamal Kurdi⁴, Mohammed M. Farid³, Luisa F. Cabeza², A. Inés Fernández¹
¹Department of Materials Science & Metallurgical Engineering, Universitat de Barcelona, Barcelona, Spain. Martí i Franqués 1-11, 08028-Barcelona, Spain. E-mail: ana_inesfernandez@ub.edu
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³Department of Chemical and Materials Engineering, University of Auckland, Auckland, New Zealand. E-mail: m.farid@auckland.ac.nz
⁴College of the North Atlantic, Doha, Qatar
- Paper 041 A novel latent heat storage unit with a helical fin
Avi Rozenfeld, Yoram Kozak, Tomer Rozenfeld, Gennady Ziskind
Heat Transfer Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. E-mail: gziskind@bgu.ac.il
- Paper 042 Prediction of charging and discharging performance for a domestic scale phase change thermal energy storage system with different heat exchanger designs.
Philip Eames
Centre for Renewable Energy Systems Technology (CREST), Loughborough University, UK.
E-mail: P.C.Eames@lboro.ac.uk

15:30-16:00

Coffee break

16:00-18:00

Session 7: Novel Materials and Properties II

Chairpersons: Helen Jansson (Sweden) and Dominic Groulx (Canada)

- Paper 026 Methodology for specific heat capacity determination by DSC
Gerard Ferrer¹, Camila Barreneche^{1,2}, Aran Solé¹, Luisa F. Cabeza¹
¹University of Lleida, Pere de Cabrera s/n 25001, Lleida, Spain. E-mail: lcabeza@diei.udl.cat
²Department of Materials Science & Metallurgical Engineering, Universitat de Barcelona, Martí i Franqués 1-11, 08028-Barcelona, Spain. E-mail: cbarreneche@diei.udl.cat
- Paper 029 Corrosion of AISI316 stainless steel by molten carbonate mixtures
Mercè Segarra¹, Juan Gallardo¹, Camila Barreneche², Ana Inés Fernández¹, Ming Liu³, N.H. Steven Tay³, Frank Bruno³
¹DIOPMA, Dept. Materials Science and Metallurgical Engineering, Universitat de Barcelona, Martí i Franques, 1, 08028 Barcelona, Spain. E-mail: m.segarra@ub.edu
²GREIA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida, Spain.
³Barbara Hardy Institute, School of Engineering, University of South Australia, Mawson Lakes Boulevard, Mawson Lakes, SA5095 Australia.

- Paper 031 Crossed analysis by T-history and Turbiscan for the characterization of PCM with Glauber salt
Maria Gabriela De Paola¹, Marilena De Simone¹, Natale Arcuri¹, Vincenza Calabrò²
¹University of Calabria, Dept. of Mechanical, Energy and Management Engineering (DIMEG), P. Bucci 46/C, 87036 - Rende, Italy. E-mail: marilena.desimone@unical.it
²University of Calabria, Dept. of Informatics, Modelling, Electronics and System Engineering (DIMES), P. Bucci 41/C, 87036 - Rende, Italy.
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- Paper 054 Double salts coming from wastes of the non-metallic industry for thermal energy storage (TES)
Andrea Gutierrez¹, Camila Barreneche^{2,3}, Mario Grageda^{1,4}, Luisa F. Cabeza³, Svetlana Ushak^{1,4}
¹Department of Chemical Engineering and Mineral Processing and Center for Advanced Study of Lithium and Industrial Minerals (CELiMIN), Universidad de Antofagasta, Campus Coloso, Av. Universidad de Antofagasta 02800, Antofagasta, Chile. E-mail: svetlana.ushak@uantof.cl
²Department of Materials Science and Metallurgical Engineering, Universitat de Barcelona, Martí i Franqués 1, 08028 Barcelona, Spain
³GREA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida, Spain
⁴Solar Energy Research Center (SERC-Chile), Av Tupper 2007, Piso 4, Santiago, Chile
- Paper 053 Design of mixtures with bischofite as low temperature thermal energy storage materials
Yana Galazutdinova¹, Svetlana Ushak^{1,2}, Luisa F. Cabeza³, Mario Grágeda^{1,2}
¹Center for Advanced Research in Lithium and Industrial Minerals, Department of Chemical Engineering and Mineral Processing, University of Antofagasta, Avenue Universidad de Antofagasta 02800, Antofagasta, Chile. E-mail: svetlana.ushak@uantof.cl
²Solar Energy Research Center (SERC-Chile), University of Chile, Av. Tupper 2007, Santiago, Chile
³GREA Innovació Concurrent, Universitat de Lleida, edifici CREA, Pere de Cabrera s/n, 25001 Lleida Spain. E-mail: lcabeza@diei.udl.cat
- Paper 039 Mathematical modeling of solidification with subcooling
Avihai Uzan, Yoram Kozak, Yosef Korin, Gennady Ziskind
Heat Transfer Laboratory, Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105 Israel. E-mail: gziskind@bgu.ac.il
- Paper 020 (Proceedings only) The development of three different carbon based networks for the enhancement of thermal properties of energy storage materials: heterogeneously suspended graphite nanofibers, aligned graphene fibers, and aerogels
Rebecca Weigand, Yue Xu, Di Zhang, Gang Feng, Amy Fleischer
Department of Mechanical Engineering, Villanova University, Villanova, PA USA. E-mail: amy.fleischer@villanova.edu

20:00-23:00

Conference Dinner – “Arabica” Restaurant, Beer-Sheva

Day 3: Thursday, February 18

09:00-10:00

Session 8: Storage Costs and Societal Aspects

Chairpersons: Michel de Paepe (Belgium) and Andre Thess (Germany)

- Paper 011 Acceptable and realised storage capacity costs of thermal energy storages
Christoph Rathgeber, Stefan Hiebler, Eberhard Lävemann, Andreas Hauer
Bavarian Center for Applied Energy Research (ZAE Bayern), Walther-Meißner-Str. 6, 85748 Garching, Germany. E-mail: christoph.rathgeber@zae-bayern.de
- Paper 013 Embodied energy and cost of high temperature thermal energy storage systems for use in concentrated solar power plants
Rhys Jacob¹, Martin Belusko¹, A.I. Fernández², L.F. Cabeza³, Wasim Saman¹, Frank Bruno¹
¹Barbara Hardy Institute, University of South Australia, Mawson Lakes, SA 5095, Australia. E-mail: rhys.jacob@mymail.unisa.edu.au
²Department of Materials Science and Metallurgical Engineering, Universitat de Barcelona, Martí i Franqués 1, 08028 Barcelona, Spain
³GREA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001 Lleida, Spain
- Paper 027 Reflections on the social approach of renewable energy studies using TES as case study. A responsible and participatory overview for researchers
Ruth Carbajo, Luisa F. Cabeza
GREA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001 Lleida, Spain. E-mail: ruth.carbajo@diei.udl.cat

10:00-10:30

Coffee break

10:30-11:50

Session 9: Building Applications

Chairpersons: Diana Bajare (Latvia) and Yoram Kozak (Israel)

- Paper 021 Comparative study of sustainable and Mediterranean conventional constructive systems thermal behavior
Susana Serrano¹, Belén González², Antonia Navarro², Luisa F. Cabeza¹
¹University of Lleida, Pere de Cabrera s/n, Lleida, Spain. E-mail: lcabeza@diei.udl.cat
²GICITED Departament Construccions arquitectòniques II (EPSEB - UPC), Dr. Marañón 44-50, Barcelona, Spain. E-mail: antonia.navarro@upc.edu
- Paper 044 The inherent thermal storage capacity of buildings – potential for load shifting with electricity powered heating systems
Henryk Wolisz, Tobias Blacha, Pooyan Jahangiri, Mark Wesseling, Dirk Müller
RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, 52074 Aachen, Germany. E-mail: hwolisz@eonerc.rwth-aachen.de
- Paper 046 Impact of different building materials on summer comfort in Latvian climate
Andris Jakovics¹, Stanislavs Gendelis¹, Diana Bajare², Ansis Ozolins¹
¹University of Latvia, Zellu 25, Riga, Latvia. E-mail: Andris.Jakovics@lu.lv
²Riga Technical University, Kalku 1, Riga, Latvia. E-mail: Diana.Bajare@rtu.lv

Paper 056 Advanced solar energy store for residential buildings using phase change materials

Ming Jun Huang, Philip Griffiths, Neil James Hewitt

Centre for Sustainable Technologies, Ulster University, Northern Ireland, UK

E-mail: m.huang@ulster.ac.uk

12:00-12:30

Closing Session

12:30-13:30

Lunch (optional)