First International Conference on Building Integrated Renewable Energy Systems

Conference organized in collaboration with COST Action TU 1205-BISTS

6th- 9th March 2017

Dublin Institute of Technology (DIT) Ireland

DIT Grangegorman

BIRES 2017 - PROCEEDINGS

Edited by: Soteris A. Kalogirou and David Kennedy

COST is supported by the EU Framework Program Horizon 2020

Conference organized in collaboration

with COST Action TU1205

COST BSTS

Conference Themes

Building Integration of:

- Solar thermal systems (STS)
- Photovoltaic / Thermal (PV/T)
- Thermal Storage (TS)
- Hybrid systems (HS)
- Renewable and Sustainable Energy Systems

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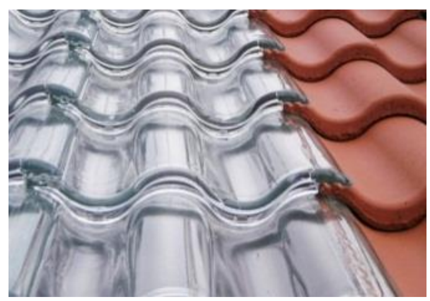
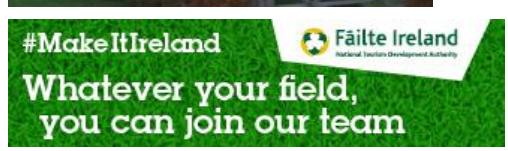


dublin energy lab.

MEET IN IRELAND



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Book Edited by: Soteris A. Kalogirou, David Kennedy

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Programme
St. Laurence, DIT Grangegorman

Monday 6th March: Registration and Welcome Reception 6pm to 8pm.

POSTER SESSION
ART EXHIBITION environmental matrix view
(Prof. Yiannis Tripanagnostopoulos)

Tuesday 7th March:

Registration 8.30am - 9am. St. Laurence, DIT Grangegorman
Tuesday 7th March 9am-9.20am.: Opening Address by:
Professor Brian Norton, President DIT and Conference Chair and
Professor Soteris Kalogirou, Chair of COST Action TU1205

Tuesday 7th March: 9.20am to 11am. Paper Presentations: Session 1.(5 papers)
Tuesday 7th March: 11.20am to 12.50pm. Paper Presentations: Session 2.(5 papers)
Tuesday 7th March: 2pm to 3.30pm. Paper Presentations: Session 3.(6 papers)
Tuesday 7th March: 3.45pm to 5.30pm. Paper Presentations: Session 4.(5 papers)
POSTER SESSION & ENERGY in ART EXHIBITION
(Prof. Yiannis Tripanagnostopoulos)

Wednesday 8th March:

Registration 8.30am - 9am. St. Laurence, DIT Grangegorman
Wednesday 8th March: 9.00am to 11.am. Paper Presentations: Session 5. (7 papers)
Wednesday 8th March: 11.20am to 12.50pm. Paper Presentations: Session 6. (5 papers)
Wednesday 8th March: 2.00pm to 3.30pm. Paper Presentations: Session 7. (6 papers)
Wednesday 8th March: 3.45pm to 5.30pm. Paper Presentations: Session 8. (5 papers)
POSTER SESSION & ENERGY in ART EXHIBITION
(Prof. Yiannis Tripanagnostopoulos)

Thursday 9th March:

Registration 8.30am - 9am. St. Laurence, DIT Grangegorman
Thursday 9th March: 9.00am to 11.am. Paper Presentations: Session 9. (7 papers)
Thursday 9th March: 11.20am to 12.50pm. Paper Presentations: Session 10. (5 papers)
Thursday 9th March: 2pm to3.30pm. H2020 Meeting
Thursday 9th March: 3.30pm. Close of Conference:
Prof. Brian Norton & Prof. Soteris Kalogirou

Note: **The Authors shown in the following list are the authors specified in the system on submission. The full list of the authors can be seen in the full papers.**

Tuesday 7th March Paper Session 1: St. Laurence's

Chairs: Prof. Soteris Kalogirou and Dr. Mervyn Smyth

Achievements of BFIRST EU funded project on BIPV technology (Paper 90)
1. Dr. Eduardo Roman - Tecnalia, Spain, Solar area, Energy and Environment division (TECNALIA)
2. Prof. Soteris Kalogirou - Cyprus University of Technology (CUT)
3. Dr. Maider Machado - Tecnalia Research and Innovation, Energy and Environment.

A Building Integrated Photovoltaic (BIPV) demonstration building in Belgium with new Fibre Reinforced Solar Technology PV modules: Analysis with Simulation and Monitoring data (Paper 92)
1. Dr. Rafaela Agathokleousa - Cyprus University of Technology, Limassol, Cyprus
2. Prof. Soteris Kalogiroua - Cyprus University of Technology, Limassol, Cyprus
3. Dr. Stephane Pierret - Optimal Computing, Mons, Belgium

Thermal testing of new photovoltaic (PV) modules for building integration, encapsulated with glass fibre reinforced composite materials and comparison with conventional Photovoltaic (Paper 91)
1. Prof. Soteris Kalogirou - Cyprus University of Technology, Limassol, Cyprus
2. Dr. Rafaela Agathokleousa - Cyprus University of Technology, Limassol, Cyprus

Evaluation of performance at experimental buildings and real demonstration sites in BFIRST project: Theoretical and practical aspects for BIPV monitoring system (Paper 25)
1. Dr. michele pellegrino - enea
2. Dr. Eduardo Roman - tecnalia
3. Dr. Stephane Pierret – optimal computing
4. Mr. Vangelis Mathas - Center for Renewable Energy Sources (CRES)
5. Prof. Soteris Kalogirou - Cyprus University of Technology (CUT)
6. Mr. Giovanni Flaminio - enea
7. Dr. Arturo Matano - enea
8. Dr. Martinez Asier - tecnalia
9. Dr. Anastasios Kyritsis - Center for Renewable Energy Sources (CRES)

Energy investigation on households with BIPV modules under Net Metering Scheme (Paper 23)
1. Dr. Anastasios Kyritsis - Center for Renewable Energy Sources (CRES)
2. Dr. Efstathios Tselepis - Center for Renewable Energy Sources (CRES)
3. Mr. Vangelis Mathas - Center for Renewable Energy Sources (CRES)
4. Mr. John Nikoletatos - Center for Renewable Energy Sources (CRES)
5. Ms. Rafaela Agathokleous - Cyprus University of Technology (CUT)
6. Prof. Soteris Kalogirou - Cyprus University of Technology (CUT)

Tuesday 7th March Paper Session 2: St. Laurence's

Chairs: Professor Cristofari Christian and Dr. Deb Mondol Jayanta (UK)

Building façade integrated solar thermal collectors for water heating: simulation model and case studies (Paper 09)
1. Dr. Annamaria Buonomano - University of Naples Federico II
2. Mr. Cesare Forzano - University of Naples Federico II
3. Prof. Soteris Kalogirou - Cyprus University of Technology
4. Mr. Charalambos Kyriakou - Cyprus University of Technology
5. Prof. Adolfo Palombo - University of Naples Federico II

A building integrated solar air heating thermal collector prototype: modelling, validation and case studies (Paper 06)
1. Dr. Annamaria Buonomano - University of Naples Federico II
2. Mr. Claudio Esposito - University of Naples Federico II
3. Prof. Soteris Kalogirou - Cyprus University of Technology
4. Mr. Aggelos Mosphiliotis - Cyprus University of Technology
5. Prof. Adolfo Palombo - University of Naples Federico II
6. Mr. Zacharias Symeou - Cyprus University of Technology

Exergetic and energy-economic analysis of a Building Integrated PhotoVoltaic and Thermal system **(Paper 05)**
1. Dr. Annamaria Buonomano - University of Naples Federico II
2. Prof. Francesco Calise - University of Naples Federico II
3. Prof. Adolfo Palombo - University of Naples Federico II
4. Ms. Maria Vicidomini - University of Naples Federico II

Technical and economic analysis of a micro photovoltaic/thermal system working in Polish climatic conditions **(Paper 60)**
1. Mr. Jarosław Bigorajski - Warsaw University of Technology
2. Prof. Dorota Chwieduk - Warsaw University of Technology

A novel approach towards investigating the performance of different PVT configurations integrated on test cells: an experimental approach **(Paper 95)**
1. Mr. Vivek Tomar - Centre for Energy Studies, Indian Institute of Technology (IIT) Delhi, New Delhi, India.
2. Prof. Brian Norton - Dublin Institute of Technology
3. Prof. G.n. Tiwari - Centre for Energy Studies, Indian Institute of Technology

Tuesday 7th March Paper Session 3: St. Laurence's

Chairs: Dr. Annamaria Buonomano and Prof. Andreas Savvides

Aesthetic aspects for building integrated solar and wind energy systems **(Paper 89)**
1. Prof. Yiannis Tripanagnostopoulos - Dept of Physics, Univ. of Patras, Patra

Integration aspects of solar energy systems to renovated buildings **(Paper 88)**
1. Mr. Georgios Trypanagnostopoulos - Univ. of Patras, Patra 26500, Greece
2. Mrs. Eleni Karantagli - University of Patras, Patra 26500, Greece
3. Mr. Athanasios Koskinas - Univ. of Patras, Patra 26500, Greece
4. Prof. Yiannis Tripanagnostopoulos – Univ. of Patras, Greece

Single-Axis Mechanisms with Limited Stroke for Tracking Solar Thermal Collectors and Photovoltaic Modules Integrated in Building Façades **(Paper 87)**
1.Prof. Mircea Neagoe - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
2.Assoc Prof. Bogdan Burduhos - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
3.Assoc Prof. Mihai Comsit - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
4.Dr. Nadia Cretescu - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania

Trapeze solar-thermal collectors: implementation prerequisites and solutions **(Paper 86)**
1. Prof. Ion Visa - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
2. Dr. Mihai Comsit - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
3. Prof. Macedon MOLDOVAN - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania

Nearly Zero Energy Community – an affordable and feasible transition concept towards sustainable cities **(Paper 85)**
1. Prof. Ion Visa - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
2. Dr. Anca Duta - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania

Application Possibilities of Building Integrated Solar Tile Collectors (Paper 11)
1. Dr. Istvan Fekete - Faculty of Mechanical Engineering and Automation, PA University
2. Prof. Istvan Farkas - Szent Istvan University, Godollo

Tuesday 7th March Paper Session 4: St. Laurence's

Chairs: Prof. Brian Norton and Prof. Dorota Chwieduk

Outdoor performance of a trapeze solar-thermal collector for facades integration (Paper 84)
1. Dr. Anca Duta -Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
2. Prof. Ion Visa - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
3. Prof. Macedon Moldovan - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania

Experimental evaluation of the efficiency of Photovoltaic / Thermal (PV/T) modules integrated in the built environment (Paper 83)
1. Prof. Macedon MOLDOVAN - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
2. Prof. Ion Visa - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania
3. Dr. Anca Duta - Renewable Energy Systems and Recycling, Transilvania University of Brasov, Romania

The importance of the solar systems to achieve the nZEB level in the energy renovation of southern Europe's buildings ((Paper 82)
1. Dr. Chemisana Mateus - University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal.
2. Dr. Sandra Monteiro da Silva - University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal.
3. Dr. Manuela Almeida - University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal.

Optimization of a Building Integrated Solar Thermal System with Seasonal Storage (Paper 81)
1. Dr. Georgios Martinopoulos - International Hellenic University/School of Science
2. Mr. C Antoniadis - International Hellenic University/School of Science and Technology, Thessaloniki, Greece

Integration of PV Modules into the Building Envelope in Aim to Achieve Energy and Environmental Benefits (Paper 13)
1. Prof. Aleksandra Krstic-Furundzic - Faculty of Architecture, University of Belgrade,
2. Dr. Budimir Sudimac - Faculty of Architecture, University of Belgrade,
3. Mrs. Andjela Dubljevic - Faculty of Architecture, University of Belgrade,

POSTER SESSION & ART EXHIBITION (Prof. Yiannis Tripanagnostopoulos)

Wednesday 8th March Paper Session 5: St. Laurence's

Chairs: Dr. Laura Aeleni and Dr. Ricardo Mateus

Environmental Impact and Economic Analysis of a LED Lighting Products (Paper 80)
1. Prof. Christopher J. Koroneos - University of Western Macedonia, Bakola and Salviera, 50100, Kozani
2. Dr. Eva Nanaki - University of Western Macedonia, Bakola and Salviera

Performance and stability of semitransparent OPVs for building integration: A benchmarking analysis (Paper 78)
1. Dr. Daniel Chemisana - 1Applied Physics Section of the Environmental Science, University of Lleida

A Review of New Materials Used for Building Integrated Systems (Paper 77)
1. Dr. Jasna Radulovic - Faculty of Engineering, University at Kragujevac, Serbia
2. Dr. Danijela Nikolic - Faculty of Engineering, University at Kragujevac, Serbia

3. Dr. Mirko Blagojevic - Faculty of Engineering, University of Kragujevac, Serbia
4. Dr. Ivan Miletic - Faculty of Engineering, University at Kragujevac, Serbia
5. Dr. Mina Vasković - Faculty of Engineering, University at Kragujevac, Serbia

Experimental and numerical analysis of overheating in test houses with PCM in Latvian climate conditions (Paper 76)

1. Mr. Janis Ratnieks - University of Latvia, Riga Technical university
2. Dr. Andris Jakovičs - University of Latvia, Riga Technical university
3. Dr. Staņislavs Gendelis - University of Latvia
4. Prof. Diāna Bajāre - Riga Technical University

A new approach on corrosion tests for building materials with PCM (Paper 74)

1. Prof. Halime Paksoy - Çukurova University, Chemistry Department, 01330, Adana, Turkey
2. Prof. Gulfeza Kardas - Chemistry Department, Cukurova University, Turkey
3. Dr. Kemal Cellat - Chemistry Department, Cukurova University, Turkey
4. Dr. fatih tezcan - Chemistry Department, Cukurova University, Turkey

Benchmarking of energy demand of domestic and small business buildings (Paper 73)

1. Prof. Luisa F. Cabeza - Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida
2. Dr. Julia Coma - Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida
3. Mr. Jose Miguel Maldonado - Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida, Spain
4. Dr. Alvaro De Gracia - Universitat Rovira i Virgili, Av. Paisos Catalans 26, 43007 Tarragona, Spain.
5. Mr. Toni Gimbernat - SINAGRO ENGINYERIA S.L.P, Av. Estudi General 7, Altell 5, 25001, Lleida, Spain
6. Mrs. Teresa Botargues - USERFEEDBACK PROGRAM SL, Sant Jaume Apòstol

Building-integrated photovoltaic/thermal (BIPVT) prototype: Environmental assessment focusing on material manufacturing (Paper 07)

1. Dr. Chrysovalantou Lamnatou - University of Lleida
2. Dr. Mervyn Smyth - Ulster University
3. Dr. Daniel Chemisana - University of Lleida

Wednesday 8th March Paper Session 6: St. Laurence's

Chairs: Prof. Soteris Kalogirou and Prof. Luis Braganca

Two active integrated storage systems: Double skin facade and active slab with PCM (Paper 72)

1. Prof. Luisa F. Cabeza - Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida
2. Dr. Lidia Navarro - Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida
3. Dr. Alvaro De Gracia - Universitat Rovira i Virgili, Av. Paisos Catalans 26, 43007

Innovative Pathways to Thermal Energy Storage (INPATH- TES) project (Paper 71)

1. Prof. Luisa F. Cabeza - University of Lleida
2. Dr. Gabriel Zsembinszki - Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida
3. Ms. Gundula Weber - Austria Institute of Technology

Financial return of Solar Thermal Heating with Seasonal Thermal Energy Storage - a Swedish case study (Paper 70)

1. Dr. Shane Colclough - University of Ulster
2. Dr. Philip Griffiths - University of Ulster
3. Prof. Neil Hewitt - University of Ulster, Newtownabbey, Co Antrim, Ireland

Power Quality Analysis using Harmonic Heating factor by Multiple Energy Efficient Appliances in Smart Building (Paper 68)

1. Mr. Chittesh Veni Chandran - Dublin Institute of Technology
2. Dr. Malabika Basu - Dublin Institute of Technology

3. Dr. Keith Sunderland - Dublin Institute of Technology

Investigation of Joule heating effect on Performance of PV modules based on equivalent Thermal-Electrical Model **(Paper 67)**
1. Ms. Houda Morchid - Dublin Institute of Technology
2. Prof. Michael Conlon - Dublin Institute of Technology

Wednesday 8th March Paper Session 7: St. Laurence's

Chairs: Prof. Rosita Norvaisiene and Prof. Gilles Notton

Performance Evaluation of the Senergy Polycarbonate and Asphalt Carbon Nano-Tube Solar Water Heating Collectors for Building Integration **(Paper 65)**
1. Mr. Adrian Pugsley - Ulster University
2. Dr. Aggelos Zacharopoulos - Ulster University
3. Dr. Mervyn Smyth - Ulster University
4. Dr. Jayanta Mondol - Ulster University

Investigation of the thermal performance of a Concentrating PV/Thermal Glazing Façade Technology **(Paper 64)**
1. Dr. Aggelos Zacharopoulos - Ulster University
2. Dr. Jayanta Mondol – Ulster University
3. Dr. Mervyn Smyth - Ulster University
4. Dr. Trevor Hyde - Ulster University
5. Mr. Adrian Pugsley - Ulster University

Reactive power control for smarter (urban) distribution network management with increasing integration of renewable prosumers **(Paper 59)**
1. Mr. Arsalan H Zaidi - Dublin Institute of Technology
2. Dr. Keith Sunderland - Dublin Institute of Technology
3. Dr. Massimiliano Coppo - University of Padova
4. Prof. Michael Conlon - Dublin Institute of Technology
5. Dr. Roberto Turri - University of Padova

Double skin façades integrating photovoltaics and active shadings: a case study for different climates **(Paper 10)**
1. Prof. Andreas Athienitis - Concordia University
2. Dr. Annamaria Buonomano – Concordia University, University of Naples Federico II
3. Mr. Zissis Ioannidis - Concordia University
4. Dr. Konstantinos Kapsis - Concordia University
5. Prof. Ted Stathopoulos - Concordia University

Experimental performance comparison of a Hybrid Photovoltaic/Solar Thermal (HyPV/T) Façade Module with a flat ICSSWH module **(Paper 56)**
1. Dr. Mervyn Smyth - Ulster University
2. Mr. Adrian Pugsley - Ulster University
3. Mr. George Hanna - Ulster University
4. Dr. Aggelos Zacharopoulos - Ulster University
5. Dr. Jayanta Mondol - Ulster University
6. Dr. Ahmad Besheer - Ulster University

Numerical study of PCM integration impact on overall performances of a highly building integrated solar collector **(Paper 04)**
1. Dr. Fabrice Motte - University of Corsica
2. Dr. Gilles Notton - University of Corsica
3. Dr. Chrysovalantou Lamnatou - University of Lleida

4. Prof. Christian Cristofari - University of Corsica
5. Prof. Daniel Chemisana – University of Catalonia

Wednesday 8th March Paper Session 8: St. Laurence's

Chairs: Prof. Adolfo Palombo and Dr. Jasna Radulovic

The Potential of Concrete Solar Thermal Collectors for Energy Savings (Paper 55)
1. Mr. Richard O'Hegarty - Trinity College Dublin
2. Dr. Oliver Kinnane - University College Dublin
3. Dr. Sarah McCormack - Trinity College Dublin

Optimization assessment of the energy performance of a BIPV/T-PCM system using Genetic Algorithms (Paper 54)
1. Mr. Ricardo Pereira - LNEG
2. Dr. Laura Aelenei - LNEG

Investigating the potential for flexible demand in an office building with a BIPV façade and a PV roof system (Paper 53)
1. Prof. Daniel Aelenei - Nova University of Lisbon-Faculty of Cience and Technology
2. Mr. Miguel Santos - Nova University of Lisbon-Faculty of Cience and Technology
3. Dr. Laura Aelenei - LNEG

Building Integrated Photovoltaics in the overall building energy balance: Lithuanian Case (Paper 49)
1. Mr. Rokas Tamasauskas - Institute of Architecture and Construction of Kaunas University of Technology, Lithuania
2. Dr. Rosita Norvaisiene - Kaunas University of Applied Engineering Sciences, Tvirtoves al., Kaunas, Lithuania
3. Dr. Vytautas Sucila - Faculty of Electrical and Electronics Engineering of Kaunas, Lithuania

Modular Building Intergraded Solar-Thermal Flat Plate Hot Air Collectors (Paper 43)
1. Prof. Soteris Kalogirou - Faculty of Engineering and Technology, Cyprus University of Technology
2. Dr. Georgios Florides - Faculty of Engineering and Technology, Cyprus University

POSTER SESSION & ART EXHIBITION (Prof. Yiannis Tripanagnostopoulos)

Thursday 9th March: Paper: Session 9. St. Laurence's

Chairs: Prof. Aleksandra Krstic Furundzic and Dr. Chrysovalanto Lamnatou

Modular Building Intergraded Solar-Thermal Flat Plate Hot Water Collectors (Paper 42)
1. Prof. Soteris Kalogirou - Faculty of Engineering and Technology, Cyprus University of Technology
2. Dr. Georgios Florides - Faculty of Engineering and Technology, Cyprus University

Passive Solar Floor Heating in Buildings utilizing the Heat from an Integrated Solar Flat Plate Collector (Paper 41)
1. Dr. Georgios Florides - Faculty of Engineering and Technology, Cyprus University of Technology
2. Prof. Paul Christodoulides - Faculty of Engineering and Technology, Cyprus University of Technology
3. Prof. Soteris Kalogirou - Faculty of Engineering and Technology, Cyprus University

Adaptive solar building envelope with thermal energy storage (Paper 39)
1. Ms. Shauli Chakraborti - Ulster University
2. Dr. Jayanta Mondol - Ulster University

3. Dr. Mervyn Smyth - Ulster University
4. Dr. Aggelos Zacharopoulos - Ulster University
5. Mr. Adrian Pugsley - Ulster University

Geometrical Optimization of the Urban Fabric in order to ensure the Viability of Building Integration of Active Solar Systems (Paper 31)

1. Dr. Andreas Savvides - University of Cyprus
2. Mr. Constantinos Vassiliades - University of Cyprus
3. Dr. Aimilios Michael - University of Cyprus

A Review of Possible Pathways for Avoiding Snow and Ice Formation on Building Integrated Photovoltaics (Paper 29)

1. Mr. Per-Olof Andersson - Norwegian University of Science and Technology (NTNU)
2. Prof. Bjørn Petter Jelle - Norwegian University of Science and Technology (NTNU) and SINTEF Building and Infrastructure
3. Dr. Tao Gao - Norwegian University of Science and Technology (NTNU)
4. Dr. Serina Ng - SINTEF Building and Infrastructure
5. Dr. Josefine Selj - Institute for Energy Technology (IFE)
6. Dr. Sean Erik Foss - Institute for Energy Technology (IFE)
7. Prof. Erik Stensrud Marstein - Institute for Energy Technology (IFE) and University of Oslo (UiO)
8. Dr. Tore Kolås - SINTEF Materials and Chemistry

Economics of building-integrated solar thermal systems (Paper 26)

1. Dr. Christoph Maurer - Fraunhofer Institute of Solar Energy Systems ISE
2. Dr. Mervyn Smyth - Ulster University

Design of an inverted absorber compound parabolic concentrator for solar air heating (Paper 58)

1. Mr. Fernando Guerreiro - Dublin Institute of Technology
2. Prof. David Kennedy - Dublin Institute of Technology
3. Prof. Michael Mc Keever - Dublin Institute of Technology
4. Prof. Brian Norton - Dublin Institute of Technology

Thursday 9th March: Paper: Session 10. St. Laurence's

Chairs: Prof. Yiannis Tripanagnostopoulos and Prof. Ion Visa

A Review of Materials Science Research Pathways for Building Integrated Photovoltaics (Paper 21)

1. Prof. Bjørn Petter Jelle - Norwegian University of Science and Technology (NTNU) and SINTEF Building and Infrastructure
2. Mr. Per-Olof Andersson - Norwegian University of Science and Technology (NTNU)
3. Ms. Anna Fedorova - Norwegian University of Science and Technology (NTNU)
4. Dr. Tao Gao - Norwegian University of Science and Technology (NTNU)
5. Dr. Serina Ng - SINTEF Building and Infrastructure
6. Dr. Josefine Selj - Institute for Energy Technology (IFE)
7. Dr. Sean Erik Foss - Institute for Energy Technology (IFE)
8. Prof. Erik Stensrud Marstein - Institute for Energy Technology (IFE), and, University of Oslo (UiO)
9. Dr. Tore Kolås - SINTEF Materials and Chemistry (NTNU)

Building Integration of Solar Thermal Systems - Exemple of a Refubirshment of a Church Rectory (Paper 19)

1. Prof. Christian Cristofari - University of Corsica
2. Dr. Mihail-Bogdan Carutasiu - University Politehnica of Bucharest
3. Dr. Jean-louis Canaletti - University of Corsica -IUT
4. Dr. Rosita Norvaisiene - Kaunas University of Applied Engineering Sciences
5. Dr. Fabrice Motte - University of Corsica
6. Dr. Gilles Notton - University of Corsica

The Pilot Photovoltaic/Thermal Plant at the University of Catania: description and preliminary characterization **(Paper 17)**
1. Prof. Giuseppe Tina - University of Catania
2. Prof. Antonio Gagliano - University of Catania
3. Prof. Francesco Nocera - University of Catania
4. Prof. Alfio Dario Grasso - University of Catania

Thermal mass performance of concrete panels incorporated with phase change materials **(Paper 16)**
1. Ms. Dervilla Niall - Dublin Institute of Technology
2. Dr. Oliver Kinnane - University College Dublin
3. Dr. Roger West - Trinity College Dublin
4. Dr. Sarah McCormack - Trinity College Dublin

Multicriterial Optimization of Procedures for the Selection the Best Measures for Energy Performances Improvement of the Multifamily Housing in Belgrade **(Paper 14)**
1. Prof. Aleksandra Krstic-Furundzic - University of Belgrade, Faculty of Architecture
2. Dr. Tatjana Kosic - University of Belgrade, Faculty of Architecture

Large-Scale Laboratory Investigation of Building Integrated Photovoltaics –A Review of Methods and Opportunities **(Paper 30)**
1. Ms. Anna Fedorova - Norwegian University of Science and Technology (NTNU)
2. Prof. Bjørn Petter Jelle - Norwegian University of Science and Technology (NTNU), and, SINTEF Building and Infrastructure
3. Mr. Erlend Andenæs - Norwegian University of Science and Technology (NTNU)
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5. Mr. Ole Aunrønning - Norwegian University of Science and Technology (NTNU)
6. Dr. Christian Schlemminger - SINTEF Building and Infrastructure
7. Prof. Stig Geving - Norwegian University of Science and Technology (NTNU)

Thursday 9th March: Paper: 2pm to 3.30pm H2020 MEETING. St. Laurence's

Presented by Philip Cheasty, Irish National Contact Point, H2020 (Energy), Enterprise Ireland and Mrs. Katherine Eve., Renewable Energy Journal.

Thursday 9th March: 3.30pm. Close of Conference: Prof. Brian Norton & Prof. Soteris Kalogirou

POSTER PAPERS

Solar Photovoltaic System Inverter Configuration Performance Analysis for a Building Integrated System Experiencing Shade (Paper 97)
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A review of new materials used for building integrated systems

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Abstract: Solar energy has a significant impact on the environment, so the development of new technologies in this field is very important for many reasons and is subject of many researches nowadays. Incorporation of phase change materials (PCMs) into building structures has been found as useful for reduction of temperature fluctuations, while maintaining the thermal comfort. Numerous methods were developed by previous researchers using this type of materials. This paper reviews some latest publications on the use of new materials in buildings, covering PCMs, nanomaterials and nanofluids, current building applications and their thermal performance analyses. These materials have predictable applications in buildings for effective use of solar energy. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. Also, nanofluid technology has been developed in the past decade. Nanofluids have a great potential for solar thermal applications, especially because of their specific heat and thermal conductivity increasing. Uses of hybrid nanofluids for solar thermal collectors are expected to give excellent performance improvement. This paper also investigates the feasibility of using PCMs for thermal management of Building Integrated Solar Thermal Systems (BISTS).

Keywords: Phase change materials, Nanomaterials, Nanofluids, Building Integrated Systems

1. Introduction

The fast paced technology development during the last decades of XX century led to the appearance of several new materials suitable for use in BISTS, such as phase change materials (PCMs), nanomaterials and nanofluids which revealed many interesting properties reported in the past decades. The unique set of features of these materials offers unprecedented potential for various applications, including Building Integrated Solar Thermal Systems.

Over the last decade PCMs are very attractive for research as they represent an innovative solution that can contribute to the improvement of the energy performance of buildings. A trend towards integrating PCMs into transparent envelope components is observed recently (Fokaides et al., 2015). Thus integration of these materials into buildings is their significant application, and it enables more dynamic use of energy. A large number of PCMs are available in any required temperature range. PCMs utilize the latent heat of phase change to control temperatures within a specific range. Sharma et al. (2009) review summarizes the investigation and analysis of the available thermal energy storage systems incorporating PCM for use in different applications.

New opportunities for the development of nanoelectronic devices for solar cell applications were brought by nanotechnology as new technology in processing PV solar sell. Characteristics

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Characteristics of bulk materials are substantially different than semiconductor particles with dimensions in nanometer range. Due to quantum confinement effects in nanocrystalline semiconductors an effective increase in bandgap is achieved. As energy band-gap can be controlled by nanoscale components, nanotechnology referred as "third generation PV" is used to help increasing conversion efficiency of solar cell (Tyagi et al., 2013).

Nanofluids can be tailored to provide superior optical and thermo-physical properties and thus have increasingly attracted attention for use in solar thermal applications. Up to a 10% increase in the efficiency has been reported through the use of nanofluids compared to conventional collectors (Mesgari S. et al, 2016). As a colloidal mixture made of a base fluid and a nanoparticle, nanofluid is a new generation of heat transfer fluids becoming a high potential fluid in heat transfer applications due to enhanced thermal conductivity (Devendiran, 2016).

2. Phase Change Materials

Three general categories of PCMs are organic, inorganic and eutectics, and they can be further classified according to various components of the PCMs, (Sharma et al., 2009; Kalnæs and Jelle, 2015).

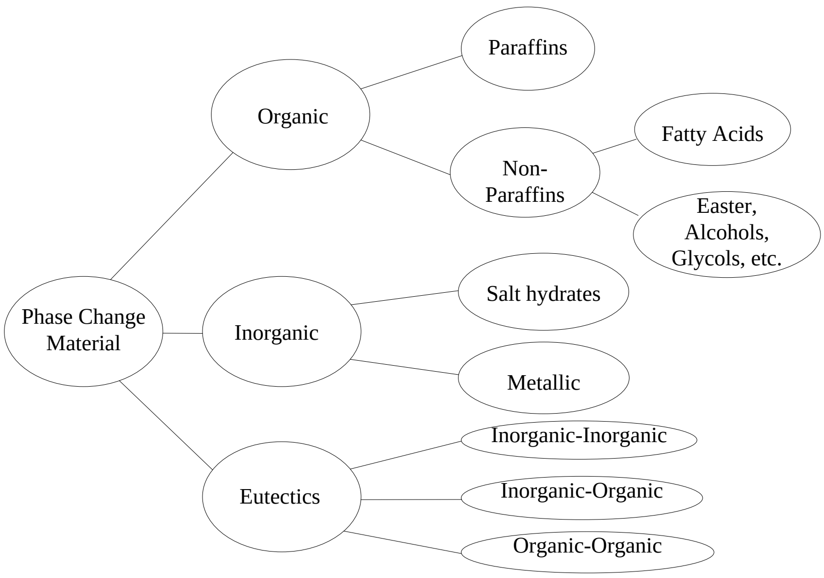

Fig. 1. General categorization of PCMs

PCMs can be found in a wide variety of temperature ranges. The PCMs in number of studies have been limited to PCMs with phase change temperatures in the appropriate range to be efficient in buildings. Cabeza et al. (2011) have listed several tables of PCM properties where the potential areas of use have been divided by the PCMs' phase change temperature. For use in buildings, three temperature ranges were suggested: (1) up to 21 ^{o} C for cooling applications, (2) 22–28 ^{o} C for human comfort applications, and (3) 29–60 ^{o} C for hot water applications

Only a few of many substances studied as potential PCMs are commercialised as so. Detailed review of the different substances (organic, inorganic and eutectic) that have been studied by different researchers for their potential use as PCMs is given by Zalba et al. (2003).

Fokaides et al. (2015) summarized the employed testing facilities, equipment and measurements for the investigation of the thermal performance of PCMs for transparent building elements from literature. Also, this study presented the main solutions proposed in the literature for applications in the past few years for PCMs integrated into transparent buildings elements. Kalnæs and Jelle (2015) have compared and summarized the advantages and drawbacks of organic, inorganic and eutectic PCMs, Table 1.

Table 1. Overview of advantages and drawbacks for PCMs.

Organic		Inorganic		Eutectics	
Advantages	Drawbacks	Advantages	Drawbacks	Advantages	Drawbacks
- No supercooling - No phase segregation - Low vapour pressure - Large temperature range - Self-nucleating - Compatible with conventional construction materials - Chemically stable - Recyclable - High heat of fusion	- Flammable - Low thermal conductivity - Low volumetric latent heat storage capacity	- High volumetric latent heat storage capacity - Higher thermal conductivity than organic PCMs - Low cost - Non-flammable - Sharp phase change	- Corrosive to metals - Supercooling - Phase segregation - Congruent melting - High volume change	- Sharp melting points - Properties can be tailored to match specific requirements	- Limited data on thermophysical properties for many combinations - High cost

Organic PCMs are divided into paraffin and non-paraffin (Tyagi and Buddhi, 2007; Sharma et al., 2009).Paraffins are available in a large temperature range, which make them suitable for use in various other areas besides building related applications. Non-paraffins used as PCMs include fatty acids and their fatty acid esters and alcohols, glycols, etc. Fatty acids have received the most attention for use as PCMs in buildings and the most interesting ones include lauric acid, myristic acid, palmiticacid and stearic acid. Organic PCMs have many qualities which make them suited for building applications, but the fact that many organic PCMs are considered flammable is a crucial drawback for which impacts the safety aspect of organic PCMs considerably when aimed at building applications (Kalnæs and Jelle, 2015).

Inorganic materials are further classified as salt hydrate and metallic. These phase change materials do not supercool appreciably and their heats of fusion do not degrade with cycling (Sharma et al., 2009). Inorganic compounds have a high latent heat per unit mass and volumes. In comparison to organic compounds, they are low cost and are non-flammable. Inorganic metallic materials are not within the desired temperature range and in addition they have severe weight penalties, which make them unsuited for building applications. Hydrated salts consist of an alloy of inorganic salts and water and enable a cost-effective PCM due to their easy availability and low cost. The phase change transformation contains of hydration or dehydration of the salts. These processes are typical melting and freezing. The salt hydrate may either melt to a salt hydrate containing less water or to an anhydrous form where salt and water are completely separated (Sharma et al., 2009).

A eutectic is a minimum-melting composition of two or more components, each of which melts and freeze congruently, forming a mixture of the component crystals during crystallization (Tyagi and Buddhi, 2007). Combinations of organic–organic, inorganic–inorganic or organic– inorganic components make eutectics appropriate for specific applications. Organic eutectic mixtures consisting of fatty acids are mostly investigated. Karaipekli and Sari (2008) have explored organic eutectic which consist of capric acid and myristic acid, Sari et al. (2004) have studied some organic eutectics: lauric acid and stearic acid, myristic acid and palmitic acid and palmitic acid and stearic acid and Shilei et al. (2006) have analysed organic eutectic consist of capric acid and lauric acid. The most common inorganic eutectics that have been investigated consist of different salt hydrates. One of advantages of eutectic mixtures is their capability to obtain more desired properties such as a specific melting point or a higher heat storage capacity per unit volume. The thermo-physical properties are to be tested and proved in the future, which makes them adequate for further investigations (Kalnæs and Jelle, 2015).

3. Nanomaterials

Nanomaterials have predictable applications in buildings for effective use of solar energy, especially for PV applications. There are three devices used in nanotechnology for PV cell production: carbon nanotubes (CNT), quantum dots (QDs) and "hot carrier" (HC).

Carbon nanotubes (CNT) are constructed of a hexagonal lattice carbon with excellent mechanical and electronic properties (El Chaar et al., 2011). With *n* lines and *m* columns the nanotube structure is a vector which defines how the graphene (an individual graphite layer) sheet is rolled up. Nanotubes can be metallic or semiconducting. CNTs provide the highest spectral absorptivity (particularly on a per unit mass basis) over the entire solar range and they are present in different forms: single-walled carbon nanotubes (SWCNTs), double-walled carbon nanotubes (DWCNTs) and multi-walled carbon nanotubes (MWCNTs) (Chaar et al., 2011). SWCNTs are formed by wrapping a one-atom-thick layer of graphene into a seamless cylinder while DWCNTs and MWCNT are formed by concentrically wrapping two and multiple layers of graphite, respectively (Mesgari S. et al., 2016).

Naphthalocyanine (NaPc) dye-sensitized nanotubes have been developed. These resulted in higher short circuit current, while the open circuit voltage is reduced. The efficiencies are still in the 3–4% range but much research is being conducted in this field.

Nanometer-sized crystallite semiconductors produced by number of methods are quantum dots (QDs) (Razykov et al., 2011). Their ability to tune the absorption threshold simply by choosing the dot diameter is the main advantage. QDs can be described as a material that is built with many forms of material thus makes it a special semiconductor system with an ability to control band-gap of energy. According to opportunity to control the energy of carrier states by adjusting the confinements in all three spatial dimensions QDs are known as "artificial atoms". Aroutiounian et al. (2005) developed a mathematical model to calculate photo current for the solar cell that is QD based. Efficiency of solar cells based on QD are easily influenced by the defects on them (Gorji, 2012).

The Hot Carriers solar cells technique utilizes selective energy contacts to extract light generated by "hot carriers" (HC) (electrons and holes) from semiconductor regions without transforming their extra energies to heat. That is why it is the most challenging method compared to CNT and QD (El Chaar et al., 2011). HCs have to be collected from the absorber over a very small energy range, with selective energy contacts, which is the most novel approach for PV cell production and it allows the use of one absorber material that yields to high efficiency under concentration.

Efficiency of HC reaches 66% which is three times higher than existing cell made from silicon (Ross, 1982), but this technology will never fully develop until a solutions to the main material challenges are found. The schematic of HC solar cell is presented in Fig. 2, adapted from Tyagi et al. (2013).

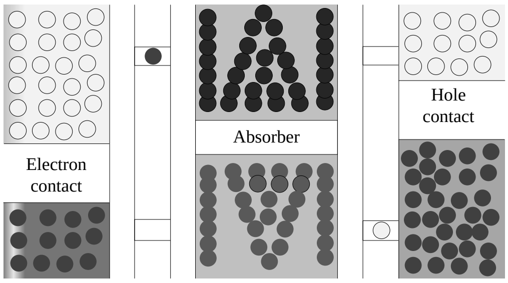

Fig. 2. HC schematic

4. Nanofluids

Nanofluids can be normally classified into two categories: metallic and non-metallic nanofluids. The third category is hybrid nanofluids (Nagarajan et al., 2014). Metallic nanofluids refer to those containing metallic nanoparticles (Cu, Al, Zn, Ni, Si, Fe, Ti, Au and Ag), while nanofluids containing non-metallic nanoparticles such as aluminium oxide (Al2O3), copper oxide (CuO) and silicon carbide (SiC, ZnO,TiO2) are considered as non-metallic nanofluids, semiconductors (TiO2), Carbon Nanotubes and composites materials such as nanoparticles core polymer shell composites. A single material does not possess all the favourable characteristics required for a particular purpose. It may have either good thermal properties or good rheological properties. In many practical applications it is required to trade-off between several properties, and that is where hybrid nanofluids come, exhibiting remarkable physicochemical properties that do not exist in the individual components.

Mainly two techniques are used to produce nanofluids. One-step technique combines the production of nanoparticles and dispersion of nanoparticles in the base fluid into a single step, and this technique have some variations. The two-step method is extensively used in the synthesis of nanofluids considering the available commercial nanopowders supplied by several companies. In this method, nanoparticles are first produced and then dispersed in the base fluids.

Based upon the preparation methods, there are different types of nanofluids: alumina nanofluids, aluminum nitride nanofluids, zinc oxide nanofluids, titanium dioxide nanofluids, silicon dioxide nanofluids, iron oxide nanofluids, copper nanofluids, carbon nanofluids, gold and silver nanofluids, graphene nanofluids, and hybrid nanofluids.

The properties of nanofluids mainly based on five parameters: thermo fluids, heat transfer, particles, colloid and lubrication. The physical properties of nanofluids are quite different from the base fluid.

5. PCM, nanomaterial and nanofluid applications in BISTS

PCM can be used in thermal energy storage applications. The ideal PCM to be used for any thermal storage system must meet following requirements: high sensitive heat capacity and heat of fusion; stable composition; high density and heat conductivity; chemical inert; nontoxic and non-inflammable; reasonable and inexpensive. The salt hydrates, paraffin and paraffin waxes, fatty acids and some other compounds in the nature have high latent heat of fusion in the temperature range from 30ºC to 80ºC that is interesting for solar applications.

The integrated PCM solar collector storage concept is economically promising in low temperature SWH systems for domestic, agricultural and industrial applications. A system of this type combines collection and storage of thermal energy into a single unit. Integrated PCM solar collector for a low-temperature SDHW system using salt hydrate eutectic mixture where the PCM is held inside the collector and thermally discharged to cold water flowing through a heat exchanger is developed by Rabin et al. (1996). Integrated system is shown in Fig. 3.

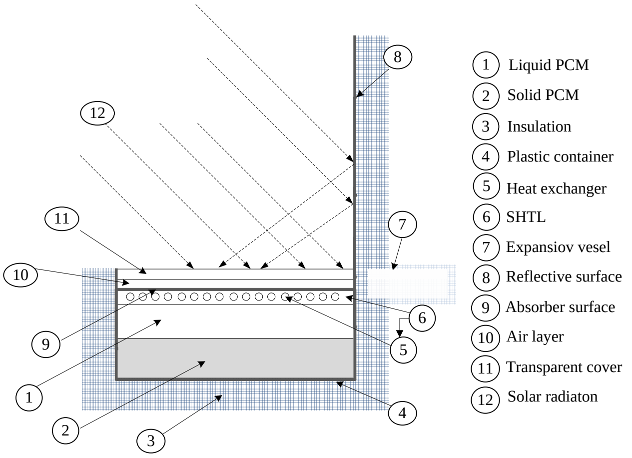

Fig. 3. Integrated PCM solar collector storage system designed

A type of water-PCM solar collector consisting of two adjoining sections is developed by Kürklü et al, (2002). One section is filled with water and the other with paraffin wax, where melting temperature is in range 45–50 ^{o}C, as it is shown Fig. 4. The experimental results indicated that the water temperature could exceed 55 ^{o}C during a typical day of high solar radiation and remain over 30 ^{o}C during the whole night.

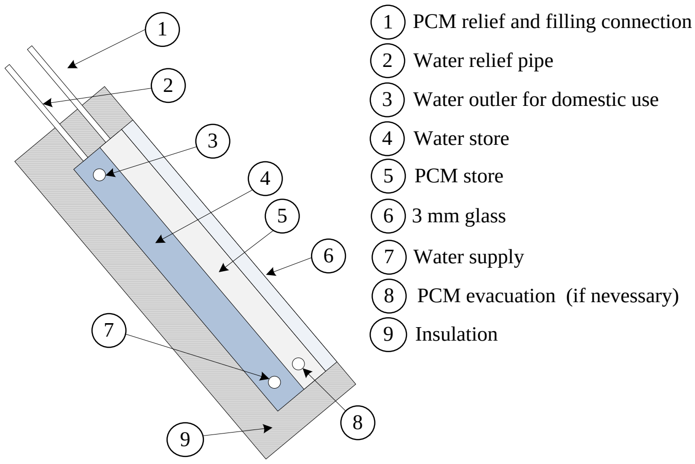

Fig. 4. Schematic view of solar collector construction with PCM

The key component in the solar domestic hot water system using phase change materials is the latent heat storage unit. Many researchers focused on improving the heat transfer inside it, in order to improve the energy storage and thermal performance of solar hot water systems. Recently, the incorporation of PCM in different applications has grown interest to the researcher. A large number of solid–liquid PCMs have been investigated for heating and cooling applications (Sharma et al., 2009).

Nanotubes can potentially replace indium tin-oxide in solar cells as a transparent conductive film in solar cells to allow light to pass to the active layers and generate photocurrent (Kaushik and Majumder, 2015). CNTs in organic solar cells help reduce energy loss and increase resistance to photooxidation. Germanium CNT diode can be fabricated and it exploits the photovoltaic effect. PV technologies may incorporate CNT-Silicon hetero junctions to leverage efficient multiple-exaction generation at p-n junctions formed within individual CNTs.

The inclusion of nanoscale components in PV cells (BIPV or PV/T) is a way to reduce some limitations. First, the ability to control the energy bandgap provides flexibility and inter-changeability. Second, nanostructured materials enhance the effective optical path and significantly decrease the probability of charge recombination.

The use of nanocrystal QDs, which are nanoparticles usually made of direct bandgap semiconductors, lead to thin film solar cells based on a silicon or conductive transparent oxide (CTO), like indium-tin-oxide (ITO), substrate with a coating of nanocrystals (Razykov et al., 2011).

Initially, the nanofluid applications in solar collectors and water heaters are investigated from the efficiency, economic and environmental points of view. The experimental analysis of thermal conductivity done by some authors, and optical properties of nanofluids are also reviewed. The reason is that these parameters show the capability of the nanofluid to work as an enhanced HTF under high temperature. Sani et al. (Reddy et al, 2016) reported the optical characterization of single-wall carbon nanohorn (SWCNH) nanoparticles for solar energy application. The result shows that carbon nanohorn-based nanofluids can be useful for increasing the efficiency and compactness of thermal solar devices.

Some authors carried out the investigation of nanofluids in the flat-plate collector for low-temperature applications and they found that a nanofluid-based solar collector is more efficient than a conventional solar collector (Reddy et al, 2016).

6. Conclusion

Incorporation of phase change materials (PCMs) into building structures has been found as useful for reduction of temperature fluctuations, while maintaining the thermal comfort. The applications in which PCMs can be applied are vast, and mainly includes heat and coolness storage in buildings. The nano-technology has brought new opportunities for the development of nanoelectronic devices for solar cell applications. Nanofluids have been utilized to improve the efficiency of several solar thermal applications. But the most important challenge in front of the scientist is the cost of nanoparticles, their synthesis, and instability and agglomeration problem. These problems need to be resolved in the coming future with improvement in nanotechnology. All these materials (PCMs, nanomaterials and nanofluids) have predictable applications in buildings for effective use of solar energy, but many more applications are yet to be discovered.

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COST Action TU1205:
Building Integration of Solar Thermal Systems (BISTS)

Overview of the Action:

Energy use in buildings represents 40% of the total primary energy used in the EU and therefore developing effective energy alternatives is imperative. Solar thermal systems (STS) will have a main role to play as they contribute directly to the heating and cooling of buildings and the provision of domestic hot water. STS are typically mounted on building roofs with no attempt to incorporate them into the building envelope, creating aesthetic challenges and space availability problems. The Action will foster and accelerate long-term development in STS through critical review, experimentation, simulation and demonstration of viable systems for full incorporation and integration into the traditional building envelope. Viable solutions will also consider economic constraints, resulting in cost effective Building Integrated STS. Additionally, factors like structural integrity, weather impact protection, fire and noise protection will be considered. The most important benefit of this Action is the increased adoption of RES in buildings. Three generic European regions are considered; Southern Mediterranean, Central Continental and Northern Maritime Europe, to fully explore the Pan-European nature of STS integration. The Action consortium presents a critical mass of European knowledge, expertise, resources, skills and R&D in the area of STS, supporting innovation and conceptual thinking.

Action web page: http://www.tu1205-bists.eu/

Domain: Transport and Urban Development (TUD).

http://www.cost.eu/COST_Actions/tud/Actions/TU1205

Countries participating: Austria, Belgium, Bulgaria, Cyprus, Denmark, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Serbia, Spain, Turkey, United Kingdom.

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