

# BSO 2016

BUILDING SIMULATION & OPTIMIZATION

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## BOOK OF PROCEEDINGS



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# BUILDING SIMULATION & OPTIMIZATION 2016

## BIOGRAPHIES



### Chair: Neveen Hamza

Neveen is a Senior Lecturer in Architecture and Programme Director: MSc in Sustainable Buildings and Environments in the School of Architecture, Planning and Landscape. She is the current Vice-Chair of IBPSA-England and has been elected for this position since 2010. She is on the Board of Directors for the journal of renewable energy among others and on the Board of Directors for a number of organizations working on net Zero energy building conservation. She has over 80 research publications and research grants in the field of building and urban energy performance evaluation in developed and developing countries.



### Chair of Scientific Committee: Chris Underwood

Chris Underwood is professor of Energy Modelling for the Built Environment at Northumbria University in Newcastle upon Tyne. He is an internationally-recognised expert in HVAC plant and controls and urban renewable energy systems. He has published over 100 research and scholarly outputs including 5 books and book chapter contributions. He is a former editorial board chairman of the CIBSE journal Building Services Engineering Research and Technology and holds CIBSE's Dufton and Napier-Shaw medals for contributions to research.

## KEYNOTE SPEAKERS



### Harsh Thapar

*CEnv. MEnvSc. MSc. BArch*  
*Performance Driven Design: Simulation, Experiments and more*

Harsh Thapar is an Associate at Foster and Partners. He works in the Specialist Modelling Group, which is an in house research and development team involved with complex geometry, environmental design research and innovation for projects.

He joined Foster+Partners in 2007 upon completing his MSc from Architectural Association School in London (AA), where he studied Sustainable Design. Harsh worked for leading architectural practises in India after his BArch degree at School of Planning and Architecture, New Delhi. He became a licensed architect in India and was involved in successful execution of Commercial and Hospital buildings for prominent Indian clients like Unitech. He was the project architect for India's first energy rated green hospital building in New Delhi for Fortis Healthcare.

His MSc research at the AA was focussed on design of 'Urban Form for Hot Climates'. For this he travelled extensively in UAE carrying out field measurements, surveys and technical simulation work. His research developed solutions for increasing outdoor comfort in hot humid climate and used advanced simulation software to test the hypothesis. He presented his research at the Passive and Low Energy Architecture Conference at Dublin on 2008 and was published.

At Foster+Partners, he has worked on low energy building design and sustainable Urban Form design on numerous projects like Hangzhou Financial District, China, Ireo Masterplan India etc. He has worked extensively on Masdar City, in Abu Dhabi, where he carried out field studies to understand outdoor comfort performance. These have been widely published. He was accepted as Member of Institute of Environmental Sciences, UK and became a Chartered Environmentalist in 2014.



## Ian Beausoleil-Morrison

*BPS: How did we get to where we are today and what are the key challenges for the future?*

Ian Bausoliel-Morison is a professor in the faculty of Engineering and Design in Carlton University, Ottawa, Canada. He holds the Canada research Chair in Innovative Energy Systems for residential buildings. He is co-founder and has been co-editor of the Journal for Building Performance Simulation since its establishment in 2008.

Ian held various roles in the IBPSA world organization, an IBPSA-World director since 2004, and a Vice president from 2006- 2010, then president from 2010-2015. He was awarded a IBPSA-fellow status in 2015 He has been a n operating agent for the international Energy Agency Energy conservation in Buildings Implementation Agreement, is past chair of ASHRAE's technical committee 4.7 on energy calculations. He has also been a theme leader for the Canadian research networks on solar buildings and is a member of the EPSRC peer review college.

Prior to joining Carlton in 2007, Ian worked for 16 years for Canmet ENERGY, where he led a team of researchers who developed models for innovative energy systems, such as micro-cogeneration and developed simulation tools for industry.

His research interests include solar housing, seasonal thermal storage, micro-generation and understanding occupants' behaviour. Currently is the lead investigator of the Urbandale Centre for Home Energy research, a research House situated on the Carlton University campus, that is dedicated to the study of solar-thermal and other innovative energy systems for radically reducing the dependence of housing on fossil fuels.



## Maria Nesdale

*ARB, RIBA, LEED® BD+C  
Education Practice Area Leader, Senior Associate*

As a Firmwide Leader of the Education Practice Area, in Gensler, London, Maria guides teams in designing enhanced educational environments that deliver a vastly enhanced learning experience for students of all levels. A Senior Associate and Registered Architect, Maria is highly regarded as a specialist in her field. She was invited to participate on the World Architecture News awards jury panel for education in 2012 and the World Architecture News Effectiveness Awards in 2013. She earned a B.A. (Hons) in Architecture at the University of Portsmouth and a Diploma in Architecture at the University of Westminster, where she also pursued Postgraduate Certificate Professional Practice in Architecture.

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# TABLE OF CONTENTS

## Theme: Progress In Simulation Tools And Optimization Method

1031	<i>Numerical Modelling Of Thermal Comfort In Non-Uniform Environments Using Real-Time Coupled Simulation Models</i> <b>Francesco Babich, Malcolm Cook, Dennis Loveday and Paul Cropper</b>	4
1018	<i>Optimal Design Of Energy Conversion Units And Envelopes For Residential Buildings</i> <b>Thomas Schütz, Lutz Schiffer, Hassan Harb, Marcus Fuchs, and Dirk Müller</b>	12
1043	<i>The Importance Of Derivatives For Simultaneous Optimization Of Sizing And Operation Strategies: Application To Buildings And Hvac Systems</i> <b>Van-Binh Dinh, Benoit Delinchant, and Frederic Wurtz</b>	20
1035	<i>Integrating Architectural And Energy View Point For A Multi Objective Optimization During Early Design Stage</i> <b>Sudip Kumar Pal, Atsushi Takano, Kari Alanne, Kai Siren</b>	28
1089	<i>Bridging The Performance Gap: Information Delivery Manual Framework To Improve Life-Cycle Information Availability</i> <b>So Young Hyun, Ljiljana Marjanovic-Halburd, Rokia Raslan and Dimitrios Rovas</b>	36
1073	<i>Placing User Needs At The Centre Of Building Performance Simulation: Transferring Knowledge From Human Computer Interaction</i> <b>Simon Tucker, Clarice Bleil de Souza</b>	44
1074	<i>Exhaustive Search: Does It Have A Role In Exploratory Design?</i> <b>Jonathan Wright, Elli Nikolaidou, Christina J. Hopfe</b>	52
1086	<i>Influence Of Design Conditions On The Distribution Of Optimal Window-To-Wall Ratio For A Typical Office Building In Japan</i> <b>Liwei Wen, Kyosuke Hiyama</b>	60
1038	<i>Investigating The Impact Of Modelling Uncertainty On The Simulation Of Insulating Concrete Formwork For Buildings</i> <b>Eirini Mantesi, Christina J. Hopfe, Jacqueline Glass, Malcolm Cook</b>	68
1034	<i>Hybrid Discret-Continuous Multi-Criterion Optimization For Building Design</i> <b>Abbass RAAD, Van-Binh Dinh, Jean-Louis Coulomb, Benoit Delinchant and Frederic Wurtz</b>	76
1095	<i>New Profiles Of Occupancy Driven Loads For Residential Sector Energy Demand Modelling</i> <b>Dane George and Lukas Swan</b>	84
1101	<i>New Extension Of Morris Method For Sensitivity Analysis Of Building Energy Models</i> <b>Kathrin Menberg, Yeonsook Heo, Godfried Augenbroe and Ruchi Choudhary</b>	92
1115	<i>Data Driven Bottom-Up Approach For Modelling Internal Loads In Building Energy Simulation Using Functional Principal Components</i> <b>Rebecca Ward, Ruchi Choudhary, Yeonsook Heo and Serge Guillas</b>	100
1120	<i>Low-Rise Commercial Buildings Optimization – Energy Performance And Passive Cooling Potential In France</i> <b>Emmanuel Bozonnet, Remon Lapisa, Marc Abadie, Patrick Salagnac</b>	108
1152	<i>Measuring Light Through Trees For Daylight Simulations: A Photographic And Photometric Method</i> <b>Priji Balakrishnan &amp; J. Alstan Jakubiec</b>	115
1121	<i>Ecodesign Of A 'Plus-Energy' House Using Stochastic Occupancy Model, Life-Cycle Assessment And Multi-Objective Optimisation</i> <b>Thomas Recht, Patrick Schallbart, and Bruno Peuportier</b>	123

## Theme: Applications Of Environmental Sustainability (Case Studies)

1114	<i>Parametric Analysis Of Solar Shading Parameters In Intermediate Orientations Located In Desert Climates</i> <b>Ayman Wagdy, Sarah Mokhtar, Amira Abdel-Rahman</b>	131
1052	<i>Investigating The Potential Impact Of Stakeholder Preferences In Passivhaus Design</i> <b>Elaine Robinson, Christina J. Hopfe, Jonathan A. Wright</b>	139
1008	<i>The Impact Of Climate Change On The Energy-Efficient Refurbishment Of Social Housing Stock In Italy</i> <b>Leone Pierangioli, Gianfranco Cellai</b>	147
1077	<i>Assessment Of Indoor Visual Environments Using Dementia-Friendly Design Criteria In Day Care Centres</i> <b>María Carmen Carballeira Rodríguez and Neveen Hamza</b>	155
1078	<i>Cost-Effective Measures For Energy Improvement Of 1980'S Detached Houses In Cold Climate</i> <b>Tuomo Niemelä, Risto Kosonen, and Juha Jokisalo</b>	163
1013	<i>Assessment Of Daylight In Relation To The Agitation Levels Of People With Dementia</i> <b>Kenji Nagari, Neveen Hamza</b>	171
1024	<i>A Holistic Modelling Framework For Retrofitting Hard-To-Treat Homes In London: Energy, Comfort, Cost And Value Propositions</i> <b>Ram Joshi, Anna Mavrogianni</b>	179
1033	<i>Performance Of Personal Ventilation Systems In A Multi-Bed Maternity Ward</i> <b>Thomas A Corbett, Malcolm J Cook, and Dennis L Loveday</b>	187
1036	<i>Energetic Performance And Economic Feasibility Of Onsite Generation Technologies In A Nearly Zero Energy Building</i> <b>Benjamin Manrique Delgado, Sunliang Cao, Ala Hasan, Kai Sirén</b>	195
1070	<i>Study On District Energy Consumption Prediction Model Of Office Blocks In Cold Region, China With Simulation And Regression Analysis</i> <b>Sun Cheng, Zhang Ran</b>	203

## Theme: Advanced Simulation Of Building Systems

1003	<i>Pdec Tower Cooling Energy Performance Assessment Using Specific Enthalpy Calculation Methodology</i> <b>John P Brittle, Mahroo M Eftekhari &amp; Steven K Firth</b>	211
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1044	<i>Multi-Mode Model Of An Air Handling Unit For Thermal Demand Calculations In Modelica</i> <b>Philipp Mehrfeld, Moritz Lauster, Kristian Huchtemann, and Dirk Müller</b>	219
1049	<i>The Potential Of Predictive Control In Minimizing The Electricity Cost In A Heat-Pump Heated Residential House</i> <b>Behrang Alimohammadisagvand, Juha Jokisalo, Kai Sirén</b>	227
1100	<i>Implications Of A Decarbonised Grid Electric System For Building Emissions Calculation</i> <b>Paul French</b>	234
1146	<i>Dynamic Simulation Methods Of Heat Pump Systems As A Part Of Dynamic Energy Simulation Of Buildings</i> <b>Tuomo Niemelä, Mika Vuolle, Risto Kosonen, Juha Jokisalo, Walteri Salmi, Markus Nisula</b>	242
1167	<i>Application Of An Optimisation Approach For The Calibration Of High-Fidelity Building Energy Models To Support Model Predictive Control (MPC) Of Hvac Systems</i> <b>Gordon Aird, Daniel Coakley and Ruth Kerrigan</b>	250

## TUESDAY

### Theme: Progress In Simulation Tools And Optimization Method

1124	<i>Automated Optimum Geometry Generation Of A Building For The Minimization Of Heating And Cooling Energy Demands</i> <b>Ala Hasan, Teemu Vesanen, Nusrat Jung, Riikka Holopainen</b>	258
1118	<i>Real World Complexity In Reflectance Value Measurement For Climate-Based Daylight Modelling</i> <b>Eleonora Brembilla, Nafsika Drosou, and John Mardaljevic</b>	266
1061	<i>A Simulation Based Optimization Approach For Determining The Optimum Energy Saving Solutions For Buildings</i> <b>Aslihan Senel Solmaz, Fahriye Hilal Halicioglu, and Suat Gunhan</b>	274
1113	<i>Multivariable Optimization For Zero Over-Lit Shading Devices In Hot Climate</i> <b>Mohamed Amer, Ayman Wagdy</b>	282
1093	<i>Performance Comparison Between Knn And NGSA-II Algorithms As Calibration Approaches For Building Simulation Models</i> <b>Shadi Basurra and Ljubomir Jankovic</b>	289

### Theme: Urban Performance Simulation

1138	<i>Second-Level Space Boundary Topology Generation From CityGML Inputs</i> <b>G.N. Lilis, D.V. Rovas, I. Prieto</b>	297
1129	<i>A Parametric Study Of The Impacts Of Pitched Roofs On Flow And Pollution Dispersion In Street Canyons</i> <b>Hui Wen and Liora Malki-Epshtein</b>	305
1134	<i>Modelling And Monitoring Tools To Evaluate The Urban Heat Island's Contribution To The Risk Of Indoor Overheating</i> <b>Rochelle Schneider dos Santos, Jonathon Taylor, Mike Davies, Anna Mavrogianni and Phil Symonds</b>	313
1112	<i>Optimising The Urban Environment Through Holistic Microclimate Modelling – The Case Of Beirut's Pericenter</i> <b>Hiba Mohsena, Rokia Raslanb, Ibtihal El- Bastawissi</b>	321
1047	<i>CityGML Import And Export For Dynamic Building Performance Simulation In Modelica</i> <b>Peter Remmen, Moritz Lauster, Michael Mans, Tanja Osterhage and Dirk Müller</b>	329
1022	<i>Three-Dimensional High-Resolution Urban Thermal &amp; Mechanical Large Eddy Simulation Interactive Physics Between Buildings, Land Cover And Trees</i> <b>Mohammed Bakkali, Atsushi Inagaki, Yasunobu Ashie, Manabu kanda, Mike Davies, Philip Steadman, and Siegfried Raasch</b>	337

### Theme: Progress In Simulation Tools And Optimization Method

1072	<i>Modelling And Calibration Of A Domestic Building Using High-Resolution Monitoring Data</i> <b>Dashamir Marini, Candy He, Richard Buswell, Christina Hopfe, and Dru Crawley</b>	345
1172	<i>Using Parametric Design To Optimize Building's Façade Skin To Improve Indoor Daylighting Performance</i> <b>Aya Elghandour, Ahmed Saleh, Osama Aboeineen and Ashraf Elmokadem</b>	353
1012	<i>Evaluation And Comparison Of Building Performance In Use Through On-Site Monitoring And Simulation Modelling</i> <b>Elena Cuerda, Olivia Guerra-Santin, Fco. Javier Neila and Natalia Romero</b>	362
1083	<i>Development And Analysis Of A Predictive Control Algorithm For Embedding In A Microprocessor Controller</i> <b>Ljubomir Jankovic</b>	370
1030	<i>Hybrid Approach For Building Envelope Optimisation Using Genetic Algorithms And Simulated Annealing</i> <b>Piyush Varma and Bishwajit Bhattacharjee</b>	378
1011	<i>Iea Annex 60 Activity 2.3: Model Use During Operation, Approach And Case Studies</i> <b>Raymond Sterling, Thorsten Mueller, Ando Andriamamonjy, Alberto Giretti, Marco Bonvini, Zheng O'Neill, Michael Wetter, Mats Vande Cavey, Andrea Costa, Gesa Boehme, Wangda Zuo, Ralf Klein, Bing Dong, Marcus M. Keane</b>	385

### Theme: Advances In Building Performance Simulation Tools

1010	<i>Automatic Calculation Of A New China Glare Index</i> <b>Yi Chun Huang and Tsung-Hsien Wang</b>	393
1053	<i>An Advanced Tool To Visualize Results Of Parametric Analyses</i> <b>Mattia Donato, Roberto Caria, Toby Clark, Gianluca Rapone, Giovanni Zemella</b>	401
1055	<i>Placing User Needs At The Center Of Building Performance Simulation (Bps) Tool Development: Using 'Designer Personas' To Assess Existing Bps Tools</i> <b>Clarice Bleil de Souza, Simon Tucker</b>	409
1065	<i>Investigation Of The Effective Parameters In Square Unit Based Shading Systems; A Scope Of Achieving Balance Between Daylight And Thermal Performance</i> <b>Mohamed Saad, Mostafa Atwa</b>	417
1068	<i>Optimal Planning Tool For Nearly Zero Energy District</i> <b>Genku Kayo, Ala Hasan, Ivo Martinac, Risto Lahdelma</b>	425

### Theme: Applications Of Environmental Sustainability (Case Studies)

1128	<i>Evaluation Of Energy And Indoor Environmental Performance Of A Uk Passive House Dwelling</i> <b>Xinxin Liang, Mohammad Royapoor, Yaodong Wang, Tony Roskilly</b>	<b>433</b>
1132	<i>Comparison Of Dynamic Thermal Simulation Results With Experimental Results: Trombe Wall Case Study For A Cyprus Test Building</i> <b>M. Ozdenefe, M. Rezaei and U. Atikol</b>	<b>438</b>
1145	<i>Data Reasoning In The Evaluation Of Domestic Thermal Energy Use</i> <b>Chris Fishlock, Keerthi Rajendran, Mohammad Royapoor and Anthony P. Roskilly</b>	<b>446</b>
1106	<i>Thermal Analysis Of A Multifunctional Floor Element</i> <b>G.P. Lydon; J. Hofer; Z. Nagy; A. Schlueter</b>	<b>452</b>
1111	<i>Optimum Atria Type In Terms Of Thermal Comfort For High Rise Office Buildings In The Semi-Arid Climate Of Middle East</i> <b>Marveh Jaberansari, Hisham Elkadi</b>	<b>460</b>
1116	<i>Optimization Of Office Building Façade To Enhance Daylighting, Thermal Comfort And Energy Use Intensity</i> <b>Mahmoud Gadelhak, Werner Lang</b>	<b>467</b>
1102	<i>A Generative Performance-Based Design For Low-Cost Brickwork Screens</i> <b>Sahar Abdelwahab, Yomna Elghazi</b>	<b>475</b>
1041	<i>Influence Of High Performance Façade On Heating/Cooling Load In Office Buildings In London And Hongkong</i> <b>Wei Wang and Chanakya Arya</b>	<b>483</b>
1163	<i>Correlation Between Retrofitting Building Envelope And Thermal Improvement On Social Housing In Hot-Arid Climate</i> <b>Ali Sedki, Neveen Hamza and Theo Zaffagnini</b>	<b>491</b>
1059	<i>Using Interpolation To Generate Hourly Annual Solar Potential Profiles For Complex Geometries</i> <b>Christoph Waibel, Ralph Evins and Jan Carmeliet</b>	<b>499</b>
1147	<i>Building Performance Simulation Of Advanced Energy Technologies To Achieve Net Zero Energy Dwellings In UK</i> <b>Rajat Gupta, and Matt Gregg</b>	<b>507</b>
1029	<i>Teaching Building Performance Simulation: Ever Done An Autopsy?</i> <b>Ian Beausoleil-Morrison and Christina J Hopfe</b>	<b>515</b>

### Theme: Advances In Building Performance Simulation Tools

1094	<i>An Open IFC To Modelica Workflow For Energy Performance Analysis Using The Integrated District Energy Assessment By Simulation (Ideas) Library</i> <b>Ando Andriamamonjy, Ralf Klein, Dirk Saelens</b>	<b>523</b>
1108	<i>Integrated Refurbishment Of Collective Housing And Optimization Process With Real Products Databases</i> <b>Boris Brangeon, Emmanuel Bozonnet, Christian Inard</b>	<b>531</b>
1135	<i>BIM Based Clash Detection Applications: Potentials And Obstacles</i> <b>Mohamed Magdy Nour</b>	<b>539</b>
1126	<i>BIM Enabled Building Energy Modelling: Development And Verification Of A GBXML To IDF Conversion Method</i> <b>Vanda Dimitriou, Steven K. Firth, Tarek M. Hassan and Farid Fouchal</b>	<b>547</b>
1133	<i>Performance Implications Of Fully Participating Furniture And Fittings In Simulation Models</i> <b>Jon Hand</b>	<b>555</b>
1021	<i>Validation Of Atmospheric Boundary Layer CFD Simulation Of A Generic Isolated Cube: Basic Settings For Urban Flows.</i> <b>Rawand Khasraw Bani</b>	<b>563</b>

### PAPERS IN PROCEEDINGS ONLY

1175	<i>Energy Performances Of Future Dynamic Building Envelopes</i> <b>Julian (Jialiang) Wang and Liliana Beltran</b>	<b>570</b>
1154	<i>Performance Evaluation Of Mixed-Mode Ventilation Incorporating An Optimal Control</i> <b>Xuyang Zhong and Hector Altamirano-Medina</b>	<b>576</b>
1002	<i>Daylighting In Renovated School Building</i> <b>Hasim Altan, Jitka Mohelnikova and Petr Hofman</b>	<b>584</b>
1054	<i>Simulation-Based Optimization On Window Properties Based On Existing Products</i> <b>Julian (Jialiang) Wang, Luisa Caldas, Lei Huo, and Yehao Song</b>	<b>590</b>
1080	<i>Multi Objective Optimisation For The Minimisation Of Life Cycle Carbon Footprint And Life Cycle Cost Using Nsga Ii: A Refurbished High-Rise Residential Building Case Study</i> <b>Simona Vasinton, Rokia Raslan</b>	<b>597</b>
1007	<i>Toward A Tool To Optimize The Daylighting Into The Process Of Architectural Design –Reverse Approach–</i> <b>Ahmed Motie Daiche, Said Mazouz, Safa Daich and Mohamed Yacine Saadi</b>	<b>605</b>

# CORRELATION BETWEEN RETROFITTING BUILDING ENVELOPE AND THERMAL IMPROVEMENT ON SOCIAL HOUSING IN HOT-ARID CLIMATE

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## ABSTRACT

This study examines the effectiveness of a combined strategy of retrofitting building envelope using an agricultural residue (maize) as an external insulation material and natural ventilation behaviours to improve indoor thermal comfort in a residential building. A prototype for a social housing multi-storey building is selected in the hot arid climate of Cairo, Egypt. Building performance simulation using IES<VE> (the produced version of 2013) is used to predict the effectiveness of adding an external organic insulation material on the building envelope. Behaviours of natural ventilation are then included to predict a naturalistic approach for indoor thermal management. The simulation was conducted in a typical floor apartment that facing the warmest south orientation. Results revealed that -comparing to the base case - an improvement of 5.5% happened in winter period when applying external insulation only, while this percentage reduced to be 4.4% when applying the combined strategy. Further, this combined strategy was effective in summer period as it has improved indoor comfort by 58.3% while an improvement of 10.2% occurred when applying external insulation only. In addition, during spring-autumn period, the strategy was not effective as it made an improvement in indoor comfort by 6.0% from the base case and by 1.9% when applying external insulation only.

## INTRODUCTION

As practices of building with high thermal mass mud walls disappeared by time in favour of contemporary construction materials that offer less time lag properties, it is essential to consider a combination of fabric insulation with a strategy for natural ventilation to improve indoor thermal conditions in hot arid climates (Roaf, 2001)

It is acknowledged that using external insulation, thermal mass (El-Hefnawi, 2000) with light colours external surfaces, shading devices (Gado, 2000 and Attia, 2010) minimizing window to wall ratio (Hamza et al, 2001) and using nocturnal ventilation (Givoni, 1998) will yield positive results in terms of thermal comfort and energy efficiency in various climatic zones in Egypt.

Technical interventions in this study focus on the building's envelope as the moderator between the indoor and outdoor environments. Accordingly, minimizing heat gain in a hot arid climate, through the building envelope is essential for reducing cooling energy demand. In a climate with large diurnal (day-night) temperature swings, this study looks at the impact of improving building fabric thermal insulation combined with natural ventilation behaviours to passively reduce cooling energy demand.

## INSULATING MATERIALS CHARACTERISTIC PROPERTIES

Characteristics that influence insulant's performance are thermal conductivity, thermal resistance, transmittance, specific heat capacity and density. However, these criteria are extended in this study to include:

- The ecological aspect of this material (materials derived from organic or recycled sources and which do not use high levels of energy during production);
- Availability of raw materials for local production;
- Possibility of economic material production and;
- Natural organic material (from animals or plants).

This study focuses on the application of natural organic materials to improve thermal comfort and energy efficiency in the case study buildings for the following reasons:

1. Natural insulation materials do not underperform when compared to manmade synthetic insulation. Further, they are renewable and sustainable materials.
2. The CO<sub>2</sub> footprint of natural organic insulation is considerably less than other forms of synthetic insulation materials.
3. The specific heat capacity, for a large number of natural fibre insulation materials, exceeds 2000 J/Kg.K, while, for mineral wool is only 800 J/Kg.K and for plastic insulations is 1400 J/Kg.K. when taking into account the high density of the majority of natural insulation

materials, then, the thermal mass of natural insulants such as wood fiber, cellulose and hemp is higher than other forms of insulants with the same R- value.

- There is a future possibility to produce natural insulants in Egypt as it has a large amount of agricultural waste (El-Shimi, 2005). Through Public-Private Partnership (PPP) and tax reliefs, the government can incentivise private construction firms to use agricultural residues to manufacture natural-based insulation materials.

previous studies show that maize stalks are considered the second highest agricultural residues in Egypt (El-Shimi, 2005; El-Mashad, 2003). In addition, the world production from corn stalks and cobs is 600 million tons in 2003 that exceeded rice and wheat, and it is being produced widely as compressed insulation boards (Panyakaew S.; Fotios S., 2008). Maize was selected as an insulation material for the case study. Table (1) below shows that the by-product of wheat constitutes the largest proportion of total wastes of agricultural products in Egypt, its application to this study was overlooked for the above reasons, furthermore, there is no evidence - to the best of the researcher's knowledge - that it is produced as an insulation materials for buildings yet.

Table 1  
Agricultural residues in Egypt (Hamdy, 1998)

CROPE	TOTAL WASTES (1000 TON)
Wheat	5998
Maize	3814
Sugar Cane	3634
Rice, Paddy	2724
Tomatoes	1441
Seed Cotton	835
Broad Beans, Dry	467
Sugar Beets	440
Potatoes	380
Wheat	5998

### CASE STUDY TECHNICAL DETAILS BEFORE AND AFTER INTERVENTION

The case study is a six storey prototypical residential buildings for housing medium income families in Egypt. This section explains in details the building envelope in terms of thermal behaviour before and after adding the insulation. Each floor includes six apartments. Each apartment consists of a living room, two bedrooms, one kitchen and one bathroom. Figures 1 & 2 show the typical floor plan and the cross sections with the critical thermal points of the building envelope that will be presented before and after the interventions.

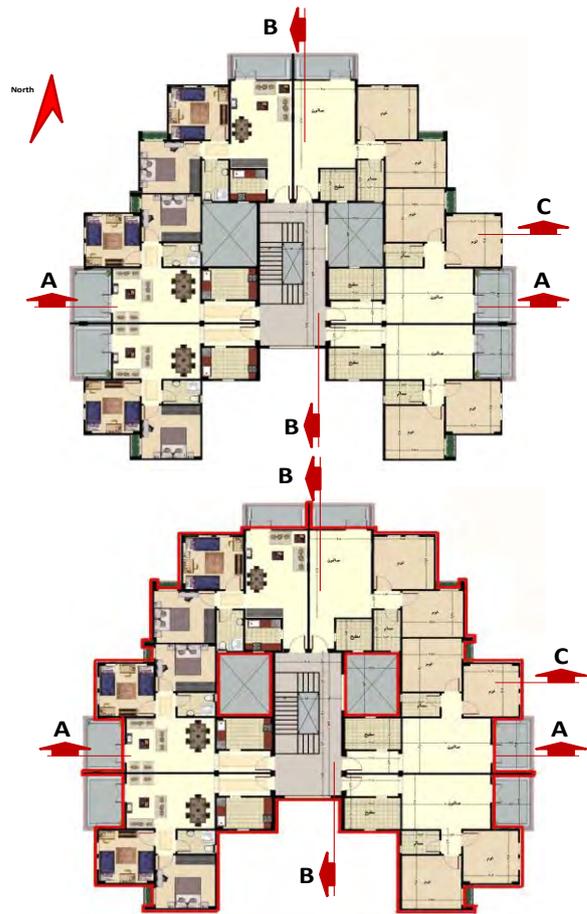


Figure 1 Case study floor plan before (above) and after adding insulation around external walls (below)

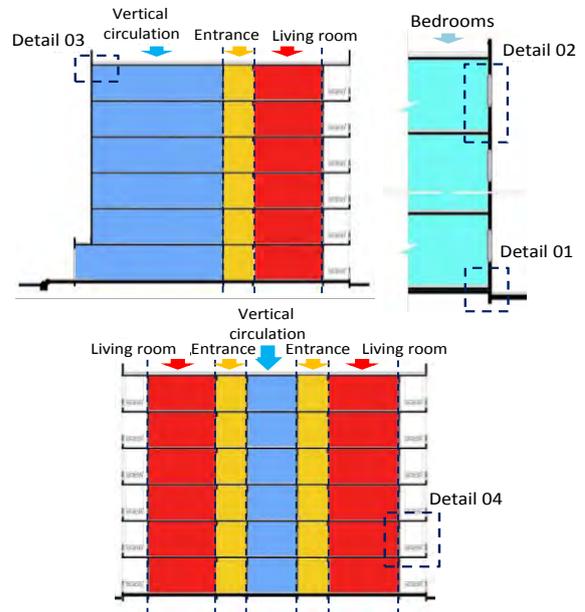


Figure 2 Case study sections showing the critical thermal points that are zoomed in table 2

#### Before intervention (Status-quo)

The following details (table 2) show the critical points in the building envelope before adding external insulation material (status-quo).

Table 2

Case study details before intervention (status-quo)

DETAIL	DRAWINGS
Detail 1 wall ground floor connection Detail	
Detail 2 window wall typical floor connection Detail (from outdoors)	
Detail 4 roof wall connection	
Detail 5 balcony wall connection Detail	

Tables 3 and 4 shows the thermal properties for the external wall and roof layers. Figures 3 and 4 show the predicted thermal behaviour of the wall and roof

during the lowest recorded outdoor temperature in winter and highest recorded outdoor temperature in summer. According to IES<VE> data base for Cairo weather profile (the hourly average temperatures during 28 years), the lowest recorded average temperature was 7 °C, average external relative humidity was 87% and the highest average recorded temperature was 41.3 °C, average external relative humidity was 14%. Noticeably, the graphs show the poor thermal performance of the building envelope.

Table 3

Thermal properties of external wall layers

NO.	THICKNESSES	MATERIALS (IN TO OUT)	$\lambda$ (W/MK)	R (M <sup>2</sup> K/W)	U-VALUE (W/M <sup>2</sup> K)
		Thermal contact resistance		0.130	7.7
1	2	Plaster paint	0.25	0.008	125
2	20	cement render	1.40	0.014	71.4
3	120	Clay brick	0.60	0.182	5.5
4	20	cement render	1.40	0.014	71.4
5	2	Plaster paint	0.25	0.008	125
		Thermal contact resistance		0.040	25
	164	Whole component		0.396	2.53

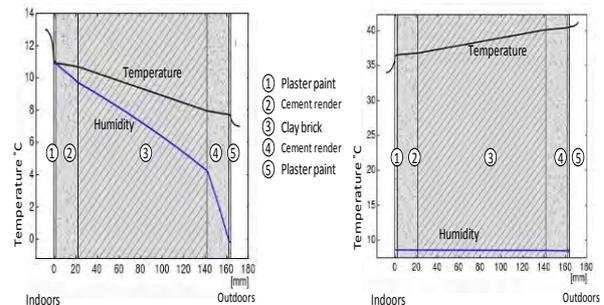


Figure 3 Thermal behaviour of the external wall during the lowest recorded temperature (on the left) and the highest recorded temperature (on the right)

Table 4

Thermal properties for roof layers

NO.	THICKNESS	MATERIALS (IN TO OUT)	$\lambda$ (W/MK)	R (M <sup>2</sup> K/W)	U-VALUE (W/M <sup>2</sup> K)
		Thermal contact resistance		0.130	7.7
1	2	Plaster paint	0.25	0.008	125

2	20	cement mortar	1.40	0.014	71.4
3	100	Reinforced concrete	2.50	0.040	25
4	70	Sloped concrete	1.30	0.054	18.5
5	2	Water proof			
6		Insulation panels of maize fiber	0.036	1.7	0.58
7	60	sand	2.00	0.030	33.3

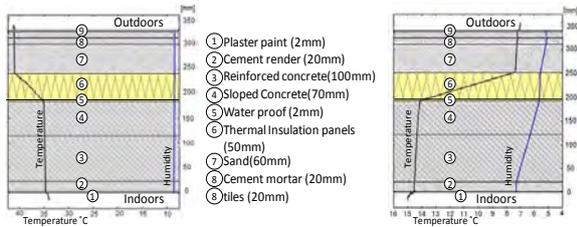


Figure 4 Thermal behaviour of the roof during the lowest recorded temperature (on the left) and the highest recorded temperature (on the right)

#### After intervention

The following details in table 5 shows the critical points in the building envelop after adding the insulation material. Table 6 and figure 5 show the predicted thermal performance of the wall after adding external insulation. Different thicknesses of insulation were applied and simulated in the case study but there was no difference in thermal performance of the building envelop, accordingly, it was decided to apply the standard thickness of 6 cm of maize fiber panels.

Table 5

Case study details after intervention

DETAIL	DRAWINGS
Detail 1 wall ground floor connection Detail	
Detail 3 window wall typical floor connection Detail (from outdoors)	

Detail 4 roof wall connection (external view)	
Detail 5 balcony wall connection Detail	

Table 6

External wall layer properties after adding insulation of maize fiber

N O.	THI CK NE SS	MATERIALS (IN TO OUT)	$\lambda$ (W/ MK)	R (M <sup>2</sup> K /W)	U-VA LUE (W/ M <sup>2</sup> K )
		Thermal contact resistance		0.130	7.7
1	2	Plaster paint	0.25	0.008	125
2	20	cement render	1.40	0.014	71.4
3	120	Clay brick	0.60	0.182	5.5
4	20	cement render	1.40	0.014	71.4

5	2	Plaster paint	0.25	0.008	125
6		Insulation panels of maize fiber	0.036	1.7	0.58
7	20	cement render	1.40	0.014	71.4
8	2	Plaster paint	0.25	0.008	125
		Thermal contact resistance		0.040	25
Total	164	Whole component		2.12	0.47

the morning and afternoon when they come back from their work. This approximated to one hour for simulation reasons.

In summer the night purge ventilation was applied From 7:00 pm to 7:00 am. In consequence, the comparison made between the four scenarios shown in table (7).

Table 7  
Case study simulation scenarios

SCENARIO NUMBER	DESCRIPTION
1	the base case (status-quo of the building with all windows are closed 24 hours)
2	the base case after adding external insulation of maize fiber and closing windows 24 hours
3	windows were opened from 8:00 to 9:00 and from 17:00 to 18:00 in winter and from 18:00 to 7:00 in summer without applying external insulation
4	the combination of scenarios (2) and (3)

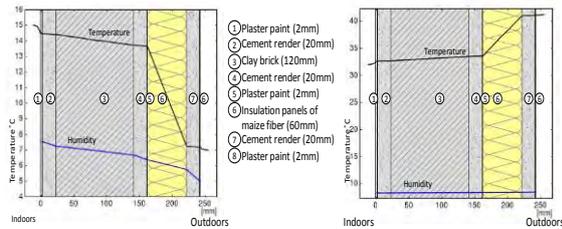


Figure 5 Thermal behaviour of the insulated external wall during the lowest recorded temperature (on the left) and the highest recorded temperature (on the right)

### COMBINING INSULATION WITH NATURAL VENTILATION BEHAVIOURS

To examine the effectiveness of insulation retrofitting techniques with natural ventilation, natural ventilation behaviours were applied. These behaviours were based on observational studies (Sedki, 2014). In winter, it was observed that occupants open the windows for short durations in

### Winter period

Homes in Cairo do not have central heating systems. Small electric heaters are used for heating spaces. This study looks at the possibility of passively increasing comfort in the winter period. The comparison was made among scenarios (1), (2), (3), and (4) shown in table 7.

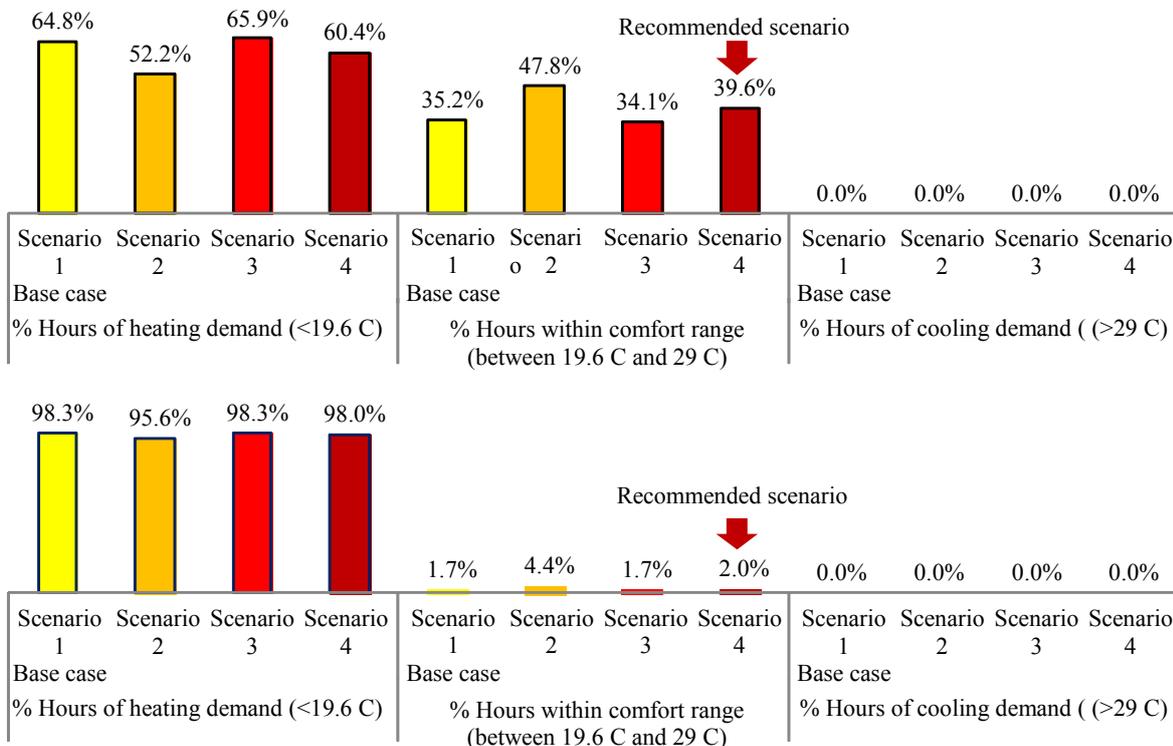


Figure 6 simulation results for the peak month of January (above) and conclusion of simulation results for the whole winter period (below)

In January, the peak heating dominated month in Cairo. Scenarios (1), (2), (3), and (4) achieved 1.7%, 4.4%, 1.7% and 2.0% respectively from total hours are within comfort range and 98.3%, 95.6%, 98.3% and 98.0% from total hours are of heating demand. Based on this comparison, there is no significant difference among all scenarios. Accordingly, none of them is effective during the month of January for the reference case under the climate condition of Cairo. Furthermore, scenario (2) achieved the highest range of comfort, however, it is not preferable because of indoor air quality reasons.

February, March, November, and December have got almost similar results of the month of January (Sedki, 2014).

From the above investigations for the whole period of winter months (the period of zero cooling demand in January, February, March, November and December) (Figure 6), among all presented scenarios, scenario (2) is the recommended one for indoor air quality reasons, however, it achieved the second highest range of comfort and it makes improvement by only 4.4% from the base case during all the total period of winter season. Consequently, this strategy is not much effective in winter season.

### Summer period

Homes in Cairo do not have central cooling systems. Rich people put air conditioning units for cooling spaces. The study seeks to passively increasing comfort for the low income class people who live in the case study buildings in summer period. the comparison was made among scenarios (1), (2), (3), and (4) shown in table 7.

In July (figure 7), this is one of the peak months of cooling demand in Cairo. Scenarios (1), (2), (3), and (4) achieved 8.7%, 0.0%, 61.4% and 71.5% from total hours are within comfort range and 91.3%, 100.0%, 38.6% and 28.5% from total hours are of cooling demand. Based on this comparison, thermal comfort was significantly improved comparing to the base case when combining the external insulation with an appropriate occupant behaviour of night purge ventilation in this month.

June, August, and September, have got almost parallel results of the month of July (Sedki, 2014).

From the above investigations for the whole period of summer months (the period of zero heating demand in June, July, August, and September) (Figure 7), the application of external insulation combined with an appropriate occupant behaviour of night purge ventilation on the case study (scenario 4) made an improvement in indoor thermal comfort by 58.3% from the base case during all the total period of summer season. Further, by comparing scenario 3 and 4, it shows that applying external insulation only made a slight improvement in indoor thermal comfort during the whole summer period, this illuminates the importance to combine it with occupant behavioural natural ventilation strategy.

Noticeably, in scenario 2 when apply external insulation on the case study with closed windows 24 hours, it gave negative effect in comfort level probably because it decreases heat loss by trapping the internal heat gains inside the spaces and stop the heat exchange process through building envelop.

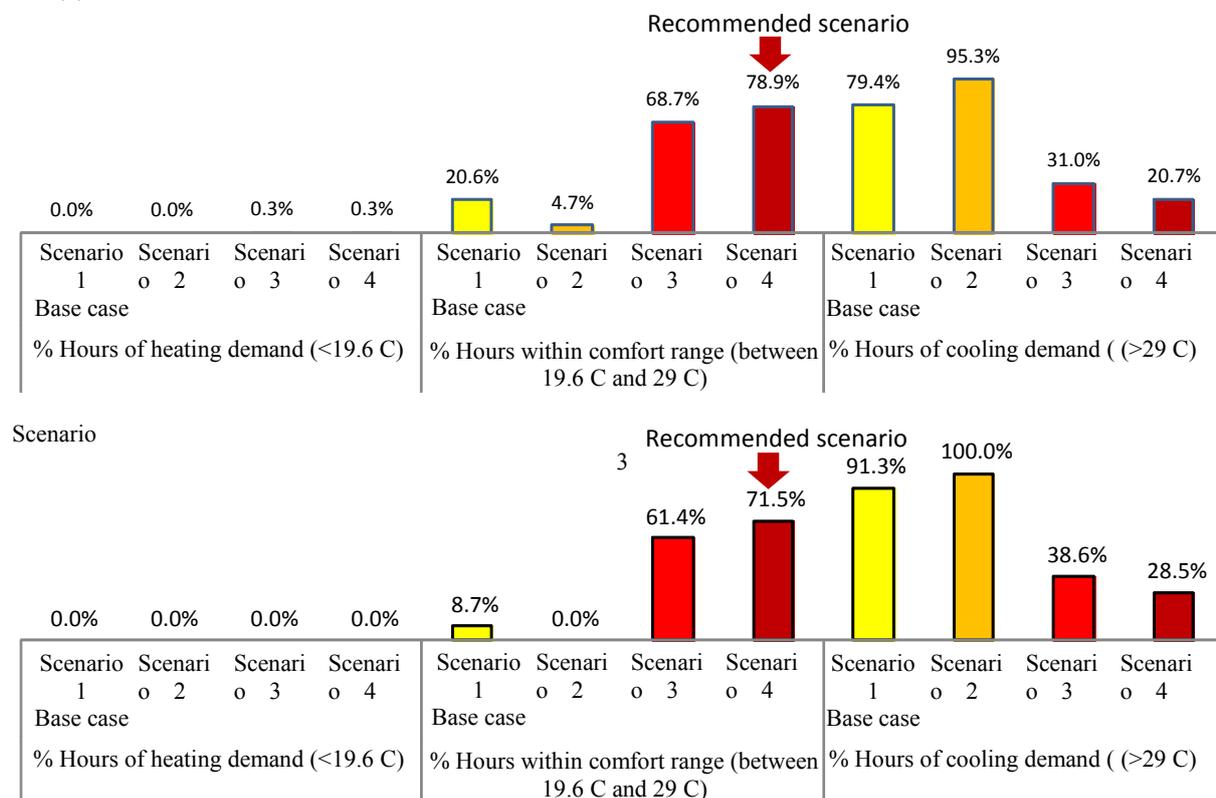


Figure 7 simulation results for the peak month of July (above) and conclusion of simulation results for the whole summer period (below)

### Spring-Autumn period

This period was represented by the months of April, May and October. It is actually considered the most comfortable month in Cairo that need neither heating nor cooling. However, simulation results show that little percentages of heating or cooling demand are required to reach the hundred percent of comfort. This happens because of some fluctuations in weather during these months in Cairo.

In figure 8 Scenarios (1), (2), (3), and (4) achieved 76.9%, 66.9%, 81.0% and 82.9% respectively from total hours are within comfort range, 3.1%, 0.0%,

quality (in terms of cooking odors and so on). However, with minor improvements by only 0.3% from the base case during the winter season.

For the summer months, the application of external insulation combined with night purge ventilation on the case study made an improvement in indoor thermal comfort by 58.3% from the base case. Further, external insulation only made a minor improvement, thus, the combined strategy is highly recommended in summer season. However, Same strategy achieved inconsequential improvement by 6% from the base case in spring-autumn period.

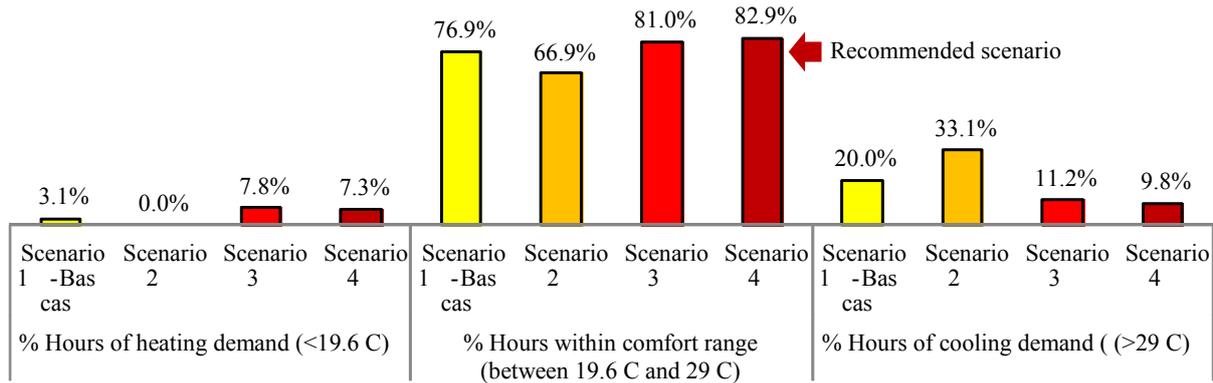


Figure 8 the conclusion of simulation results for the whole Spring-Autumn period

7.8%, and 7.3% respectively from total hours are of heating demand and 20.0%, 33.1%, 11.2% and 9.8% from total hours respectively are of cooling demand.

Based on this comparison, thermal comfort was slightly improved comparing to the base case when combining the external insulation with an appropriate occupant behaviour of night purge ventilation (scenario 4) in these months. Negative impact on comfort happened when applying external insulation only, that confirms the importance of natural ventilation to exchange heat between indoors and outdoors.

### CONCLUSIONS

This study examined the effectiveness of combining external insulation retrofitting technique made of a local organic insulation material with natural ventilation strategies on indoor thermal comfort. Natural ventilation scenario was applied according to occupants behaviour in winter as they opening windows in the morning and afternoon. In summer and spring-autumn period the night purge ventilation was applied.

In winter, Building performance simulation results indicate that applying insulation on the base case scenario (windows closed 24 hours) achieved the highest improvement in comfort by 2.7% comparing to the base case, however, it is not preferable as it leads to poor indoor air quality.

The combined strategy of external insulation and ventilation achieved the second highest range of comfort hours passively and is better for indoor air

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