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A REVIEW OF THE EVA – PROJECT: EVALUATION OF VISONARY ARCHITECTURAL CONCEPTS IN VIEW OF BUILDING PERFORMANCE

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ABSTRACT

This paper reports on the EVA-project, which was collaboratively conducted by the University of Applied Arts (Energy Design) and the TU Wien (Dept. of Building Physics and Building Ecology). This project focused on the assessment of a number of innovative architectural concepts in the field of energy-efficient architecture. Whereas a large number of building projects focuses on adding thermal insulation and rather rely on the performance of mass products like insulation panels, a by far smaller number of projects try to explore other ways of improving building performance, such as adaptive, moveable, or performance-shifting envelope element. Such architectural concepts often experience contra-arguments, such as the high risk of failure due to childhood diseases in the planning, the fear of increased cost and less-than-expected impact, or even invective as architect's fantasies. However, the track of innovation often has to cross rickety bridges to be accepted by the AEC (architecture-engineering-construction) domain. Toward this end, the EVA project provides two contributions: On the one hand, a structured evaluation database has been developed, in which "innovative architectural concepts" can be stored and queried regarding their key features. On the other hand, one innovative approach has been chosen, constructed and implemented in an existing building's envelope. The paper illustrates the idea, the principle construction, and the performance impact of this realization, which was pertaining to radiative heating and cooling achieved by adjustable distribution of thermal mass through indoor panels that were linked to outdoor façade elements.

INTRODUCTION

In the ongoing discourse on architecture and its role in view of energy consumption, GHG (Greenhouse Gases) emission, many stakeholders from the A-E-C domain suggest new ideas of how to reduce the portion of the built environment regarding harmful impact on the planet. Many of these concepts provide far-fetched ideas, which seem to be tempting approaches to the contemporary challenges and range from geo-engineering to small-scale interventions, such as autarky-systems for houses, household-intern circular economy approaches, and similar. However, the percentage of these concepts that are later translated into the built reality is a very small one. There could be a set of reasons for that: (i) There might be problems with upscaling; What works fine in a small scale model or on paper, might not necessarily being realized in an easy fashion in a scale 1:1 realization. Such realizations would often require a complex interaction between domains such as building engineering, architectural planning, mechatronics, Information technology, and others, which is both difficult and expensive; (ii) The real impact of realizations is often difficult to assess in a scaled model or simulation-based assessment. Thus, pioneer realizations often are observed critically and –

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in case of even slight failure – are considered as dysfunctional. The present contribution was written to document the outcomes of the EVA-project, which focused on the evaluation of innovative architecture concepts in general, and the realization of one of these concepts to proof its functionality. To achieve these goals, two efforts have been conducted: In the starting phase of the project, innovative architecture concepts that have been suggested for improvement of energy consumption or thermal comfort of buildings, or touch other environmental aspects have been collected, documented, and systematically evaluated. As a result, a database of innovative architecture concepts has been generated. Amongst many other projects from academia and professional context, works by the students of the University of Applied Arts in Vienna have been integrated into this database. Some of these concepts have been described in [1] and [2]. In a subsequent step, the concepts have been examined towards their feasibility in view of a realization. Thereby, a concept pertaining to variable thermal mass and indoor thermal comfort has been selected for a realization.

EVALUATION REPOSITORY OF INNOVATIVE ARCHITECTURE CONCEPTS

After starting collecting innovative architecture concepts from literature, academic resources and freelance professionals of the AEC- (architecture-engineering-construction) domain, it became clear that common databases do not allow for a specific evaluation of such concepts. Thus, a Grasshopper [3]-based database has been generated that is capable of helping with specific enquiries and visualization of the different concepts. Figure 1 illustrates the graphical algorithms behind that database. Figure 2 and 3 illustrate enquiries that can be done with this script, in detail percentages of touched keywords/domains by the projects, or how projects in detail work.

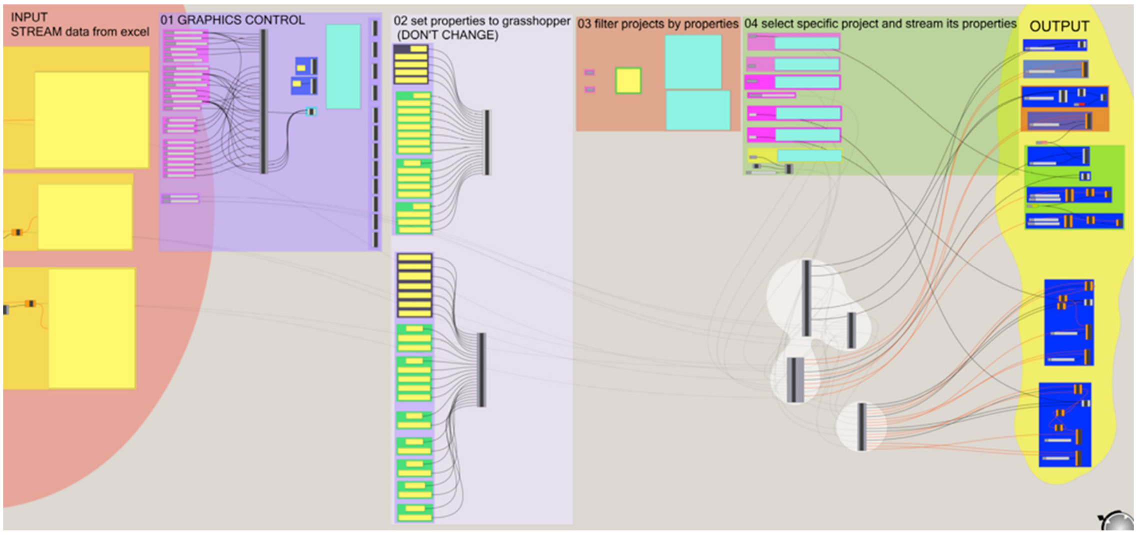

Figure 1. Graphical setup of the database in Grasshopper.

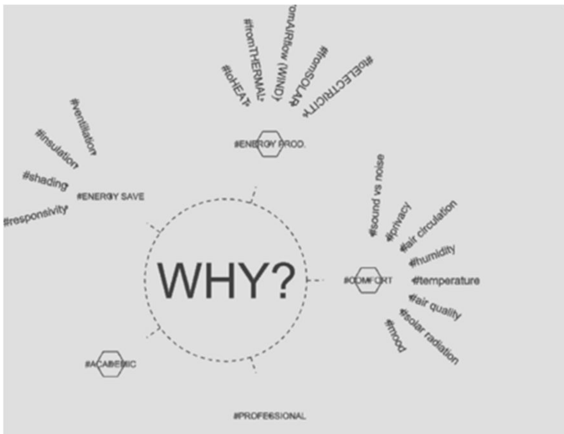

Fig 2. User Interface for enquiries of "Why" Questions in the database

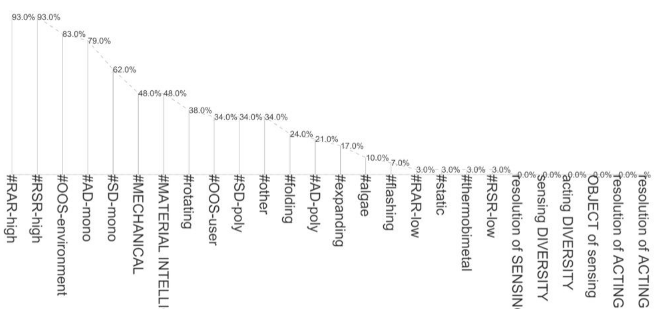

Fig. 3. Results of a "How"-Enquiry in the database.

Moreover, a catalogue of the innovative concepts has been generated. Thereby, a template has been used that allowed to extensively describe the specific aspects of each concept. Figure 4. Illustrates this template for the project KALEIDOSKIN (described in original in [1])

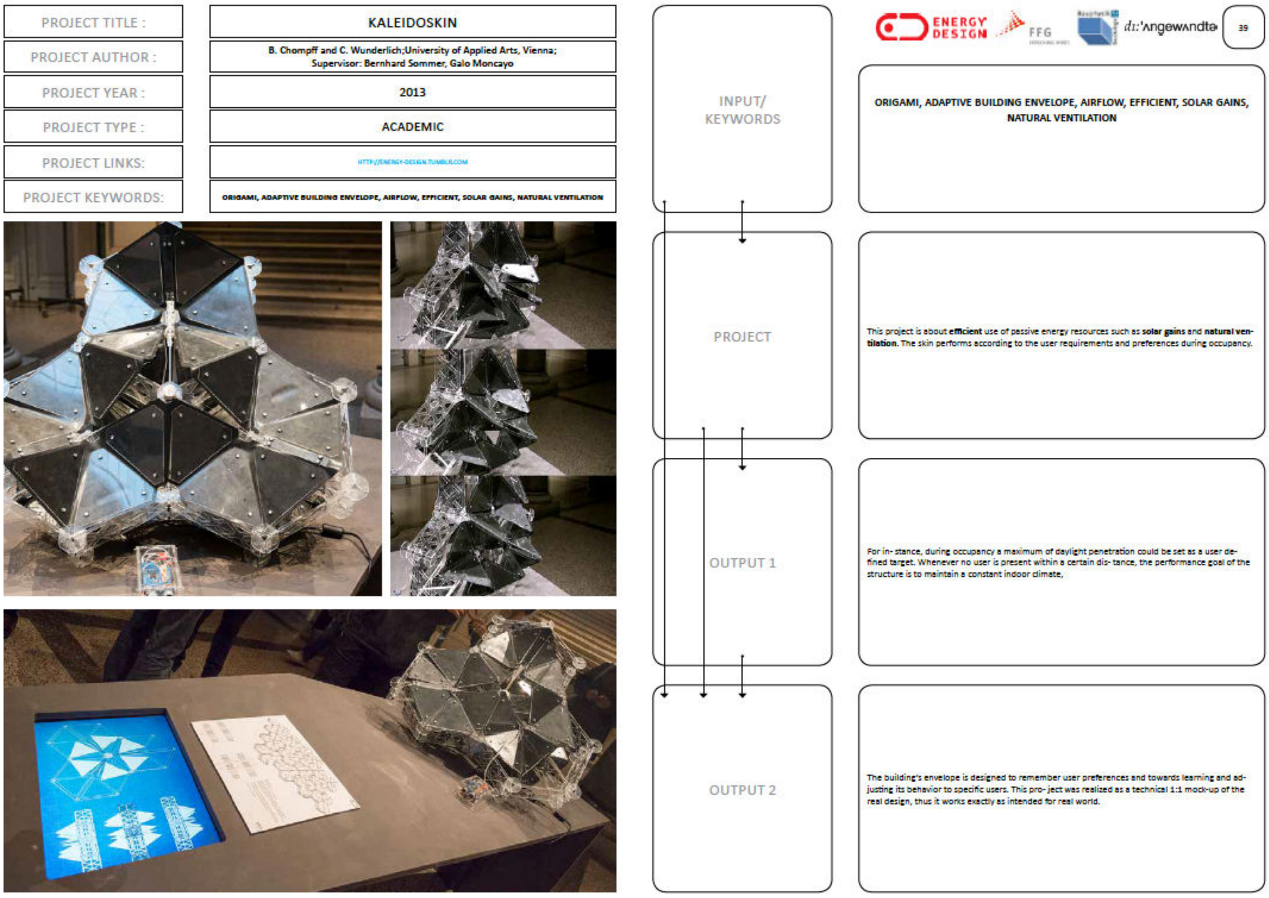

Figure 4. Project description template, filled with the information of the project KALEIDOSKIN.

REALIZATION OF AN INNOVATIVE ARCHITECTURE CONCEPT FOR EVALUATION PURPOSES

The architecture concept that was selected for realization addressed the issue of summer overheating in indoor spaces (lack of thermal comfort in indoor spaces). Inspired by a project by Carlo Ratti of the *MIT senseable city lab*, which has been exhibited at the Architecture Biennale in Venice some years ago [4], variable thermal mass panels have been designed and built for an interior space. The test site thereby encompassed two office room cells, which were widely identical in their size, materials, windows orientation and size, and usage. Figure 5 illustrates the rooms (Raum A, and Raum B).

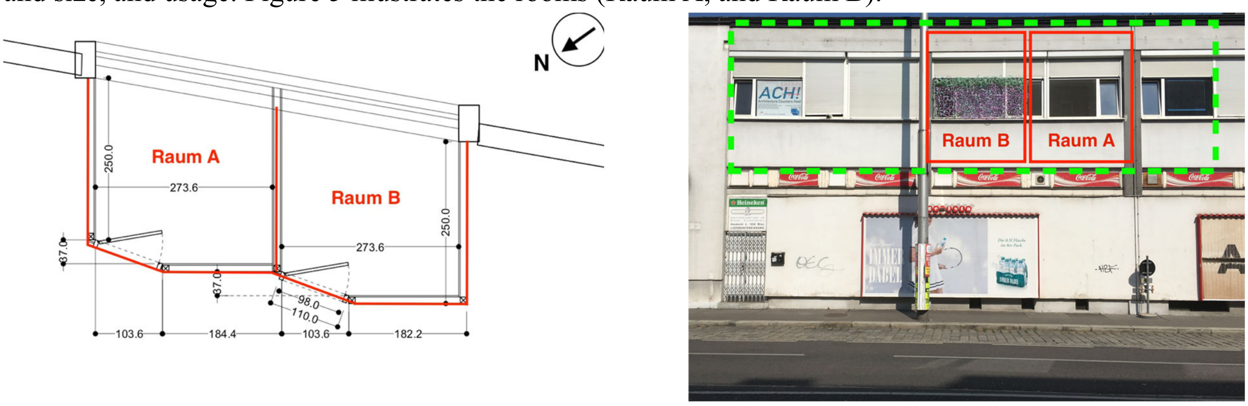

Figure 5. Test site rooms (left: Plan, right: View from Street)

The background of the selected project is, that while still many buildings possess a sufficient thermal mass, this thermal mass can seldom be utilized for a short-term thermal comfort improvement in case of summer overheating. Moreover, typical retrofit incentives feature thermal insulation from outside or inside, so that sometimes reactive thermal mass is hindered to be heated up or chilled down. Ratti's idea was that it is not really necessary to be surrounded by areas of high thermal mass, but rather that occupants find a healthy relation of air- and mean radiant temperature in spaces. This concept in principle is also supported by the late Ole Fanger thermal comfort theory (which still is matter of many discussions, for instance in [5]). As such, the pursuit of an occupant by panels that react on that person's presence could offer microclimatic aid against overheating or undercooling in spaces, which negatively influence the thermal comfort.
This principle of personalization of thermal comfort via reactive panels was now translated to a technical system that was implemented in room B. Figure 6 illustrates the principle of the realization: A set of panels that are mounted on the inner enclosures of the space are equipped with hoses, through which water can be pumped (1). On the outer wall surface of the room collector/chiller panels are mounted, similarly equipped with hoses than the inner panels (2). These two types of panels are connected via a buffer storage, in the realization case a portable insulated camping box (3). Persons and their position in the room are detected via occupancy sensors (4). Via a set of microcontrollers (5), the indoor panels are provided with warm / cold water from the buffer or directly from the collector panel. Needless to say, the pumps and routines of filling the buffer tank with chilled water requires the utilization of the outdoor panel during day and night (nighttime chilldown). Figure 7 shows a photo and a thermography of an indoor panel, while Figure 8 illustrates the hose system forming the outdoor collector panel (green hoses were part of a sun protection system, while purple hoses formed the chilling hoses for cooling water during night). Figure 9 shows an overview perspective of the overall system, including the hose system and the controllers (Arduino-Boards, Computers executing grasshopper algorithms, etc.)

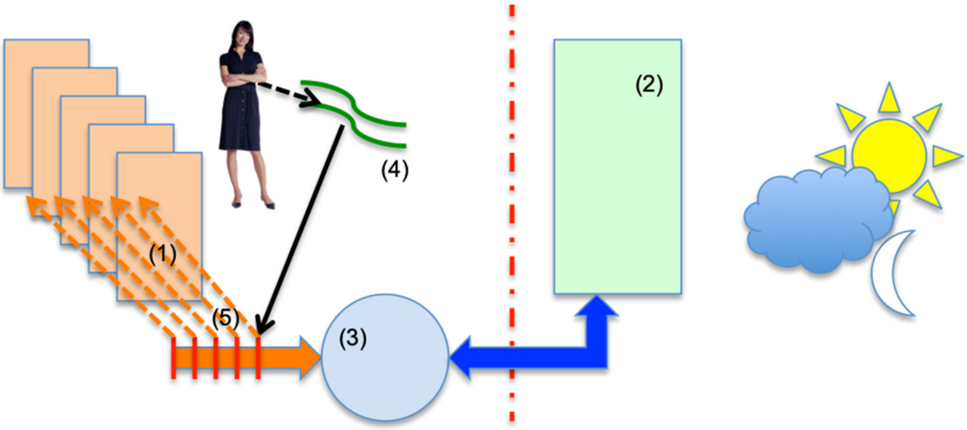

Figure 6. System components: (1) Indoor panels equipped with hoses for changing the temperature / thermal mass of the panels; (2) exterior chilling/collector panels; (3) buffer storage tank; (4)occupancy/location sensors; (5) microcontrollers steering the overall system.

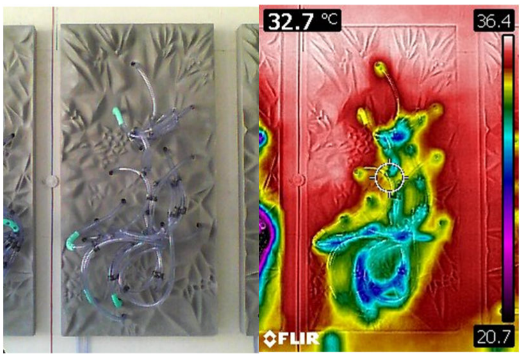

Figure 7 (left): Photo and thermography of an indoor panel;#
Figure 8 (right): Outdoor collector/chiller hoses (purple hoses)

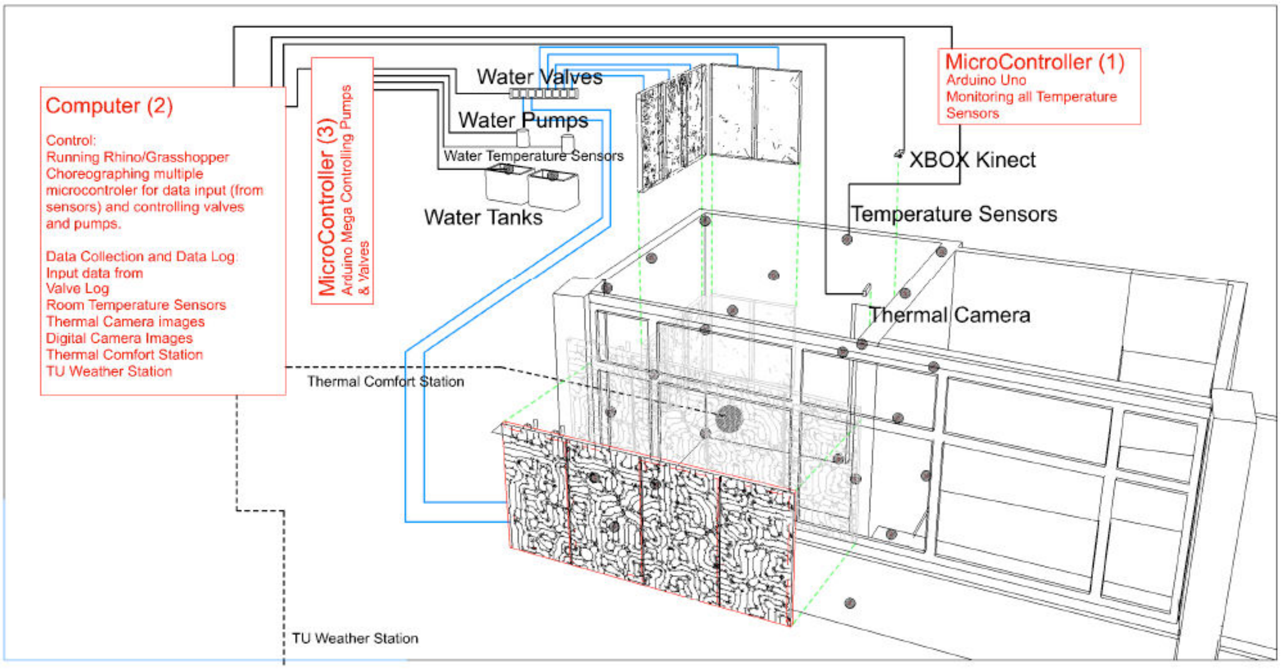

Figure 9. Overview perspective of the overall system.

PERFORMANCE OF THE REALIZATION

In a test series that has been conducted in August 2018, the performance of the system was assessed, and some calibration of the valve and pump settings have been conducted. Figure 10 illustrates the flowpatterns of the indoor panels and outdoor panels.

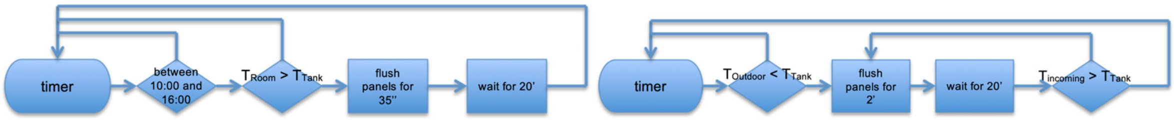

Figure 10. Flow patterns in indoor panels (left) and outdoor panels (right)

The air temperature and globe temperature (radiative temperature measured with a globe thermometer) have been measured during the test series. Figure 11 illustrates the effect of the system during the test phase (after some days of inswing-phase): Room B, the one equipped with the system, was able constantly maintain both a lower air and radiant temperature than room A (the “control room”). While the temperature differences dropped between 0 and 1 K during night, during day at least 2 K temperature differences could be observed, including some peaks that showed temperature differences up to 10 K. Thus, it can be said that in principle the system worked fine.

CONCLUSION AND FUTURE RESARCH

The presented evaluation of innovative architecture concepts resulted in two major outcomes: One the one hand, an innovative database of environmentally-relevant innovative architecture concepts was generated with a state-of-the-art tool. This database will be furtherly developed and extended, and being put to a website. On the other hand, we translated an innovative concept to a 1:1 realization and could proof that the idea in principle works. Needless to say, the realization was far from an industrial building product that could be integrated in hundreds or thousands of buildings, and of course there are still some issues, e.g. a calibration of the flow-patterns and algorithms, or the aspect that we supply heat energy to the outside and eventually increase Urban Heat Island effects. However, the concept could offer mitigation for summer overheating in office spaces with little required energy (the electricity necessary for computer and pump/valve operation could be supplemented by Photovoltaics mounted on the same façade).

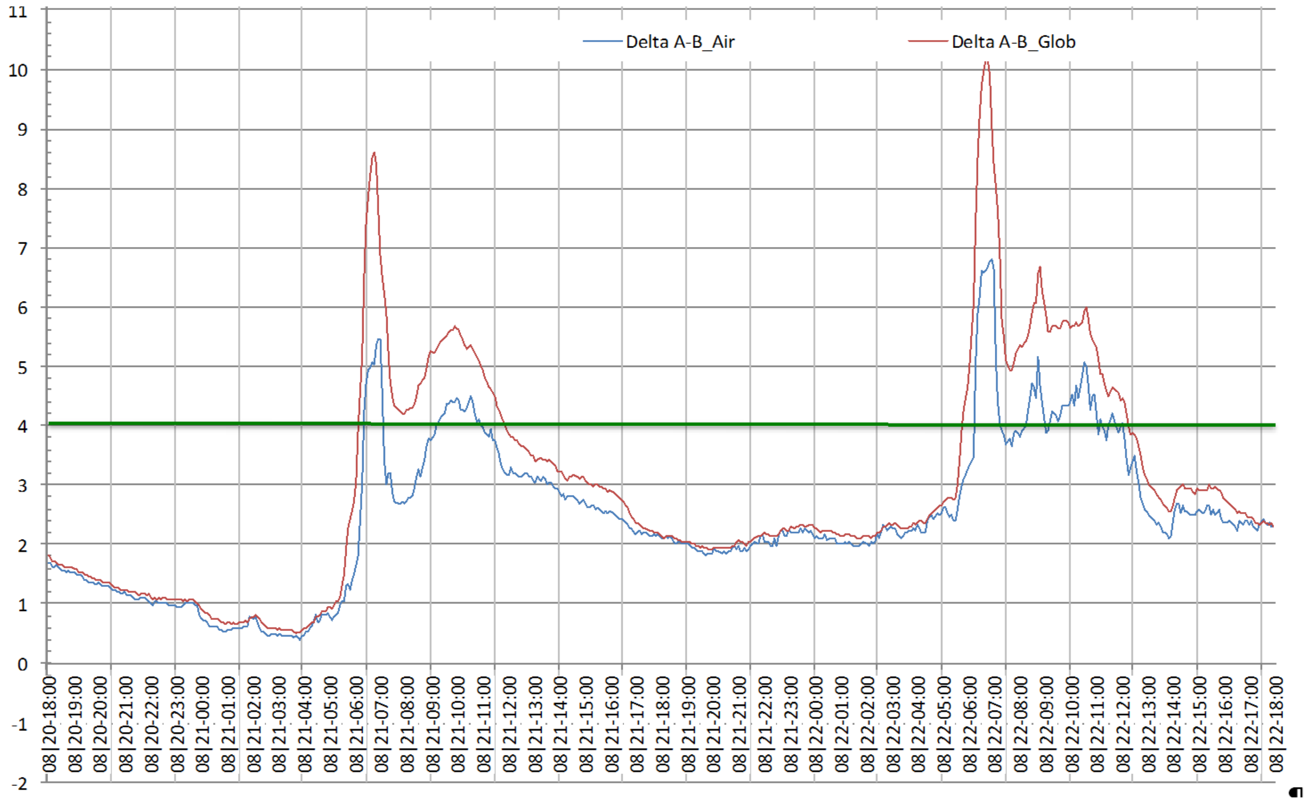

Figure 11. Temperature difference between rooms A and B in air temperature and mean radiant temperature (via globe thermometer) during test days in August 2018.

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