The KUEHA project - A new solution for space cooling during summer

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This report presents a research project on space cooling in summer season with the objective to establish a theoretical preliminary analysis on how to cool through an existing hydronic heating system, not being floor/wall heating systems integrated in floor/wall contraction. The project is intended to prove that innovative, cost-effective and energy-efficient cooling solutions during the summer season can be implemented even in already existing buildings.

Motivation

Especially in urban areas, there are increasing thermal loads during the summer months. Various men-made factors (see **Figure 1**) cause specific local climatic conditions. These differ from those of the surrounding area mainly by significantly higher temperature stress and radiation loads, the latter leading to higher short and the long-wave temperature radiation appearance.

Against this background, the increasing thermal insulation of buildings can worsen the thermal situation in summer. The effect of the solar and internal heat loads in this case means that the surface temperatures of effective storage masses do not fluctuate at a constant, i.e. the level following the day/night change, but steadily increase, since the nocturnal cooling is greatly limited due to improved heat insulation or the absence of ventilation during the night.

During the planning and operation phases of non-residential buildings, the question of how to cool spaces during the summer heat is often not considered. This often leads to a considerable decrease of thermal comfort levels leading to difficult working conditions and expressed user complaints, which in turn are can lead to a decrease in work performance. In residential buildings, the decrease of thermal comfort can lead to significant health impairments, especially among the elderly. This stands in contrast to humans being able to benefit from increasingly sophisticated air-conditioning solutions - however, these are mainly used in vehicles or in the commercial leisure sector, which makes the difference to the thermal comfort enjoyed in buildings even more apparent.

Retrofitting spaces to meet thermal comfort during summer is often challenging: Frequently, so-called decentralized split air conditioning systems are used with problematic arrangements of the condenser (see **Figure 2**). Of particular concern is the inefficient fundamental and temporal use of electrical energy and the significant emission of waste heat into the surroundings. Although these divided systems are able to achieve the desired air temperatures, the thermal comfort is often not satisfying based on the often-considerable high air velocities in the form of drafts in combination with too low air temperatures.

In addition, unregulated relative humidity reaching a too low level could lead to health problems such as inflammations in the eye area and may result in increased risks of nasal infections due to the dehydrating

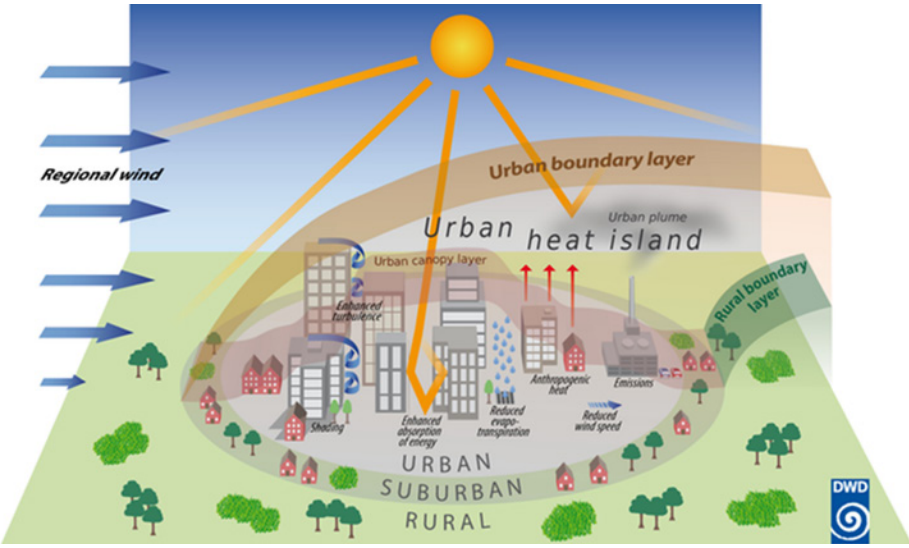

Figure 1. The urban climate and its influencing factors [5]

Figure 2. Space cooling during Summer - Typical sight in areas with high occurrence of split air conditioning systems.

of membranes. The inappropriate maintenance of the evaporator units can lead to filters and condensate pipes becoming breading grounds for microbes.

To remedy these problems, this project proposes to achieve the cooling of spaces through the (existing) heating system, preferably combined with an effective cooling arrangement. Such arrangement could be achieved through a co- or tri-generation, e.g. in the form of a gas engine CHP or a fuel cell. The exhaust waste heat which could be used in the summer by adsorption or adsorption refrigeration machine. District heating systems are also suitable to be used as cooling systems. For this case, brine-water heat pumps with surface or subsoil water as a heat sink offer particularly favorable possibility to cool. When only the brine circuit is used for the recooling of the brine but not a compressor, these systems are very cost effective over long periods of time.

Particularly interesting in this regard is the use of near-surface subsoil water, deeper inland water layers or the use of running water.

In specific circumstances, a further reduction of the electricity demand for soil-coupled heat pumps can be expected as the soil can regenerate better during the summer heat input for the winter.

It should also be considered that in residential buildings the heating of domestic hot water often occurs in parallel to the cooling of rooms in summer. For these scenarios, the heat extracted from the building can nearly completely contribute to an increase in efficiency.

Current state of knowledge

Due to the limited cooling capacities of radiators and the problem of condensing water, in Germany cooling with radiators is met with skepticism. Yet in Japan, this method has been present for several decades (see **Figure 3**). In the Japan case, where the dew point is passed constantly, the resulting condensate is collected and removed. This pragmatic approach allows very low surface temperatures of radiator surfaces and results in an improved heat transfer. The possibility of air drying is an additional system advantage in regions with a particularly humid ambient climate.

In Europe, drying air in a room by cooling the air over free heating surfaces/radiators is currently not feasible. From a scientific view, this is a rather interesting area for research due to its high potential for future application. Avoidance of the dew point below leads to lower benefits of the free heating surfaces/radiators but allows for the use of cooling at a relatively high temperature levels. Realization is, therefore, a return-side cold extraction from existing plants, the use of natural sources or the use of adsorption refrigeration machine with a low temperature level on the drive side and a cold supply at a relatively high temperature level.

Practical studies on cooling with free heating surfaces/radiators have so far been carried out only to a very limited extent in Germany and more under laboratory-like conditions (see [7]).

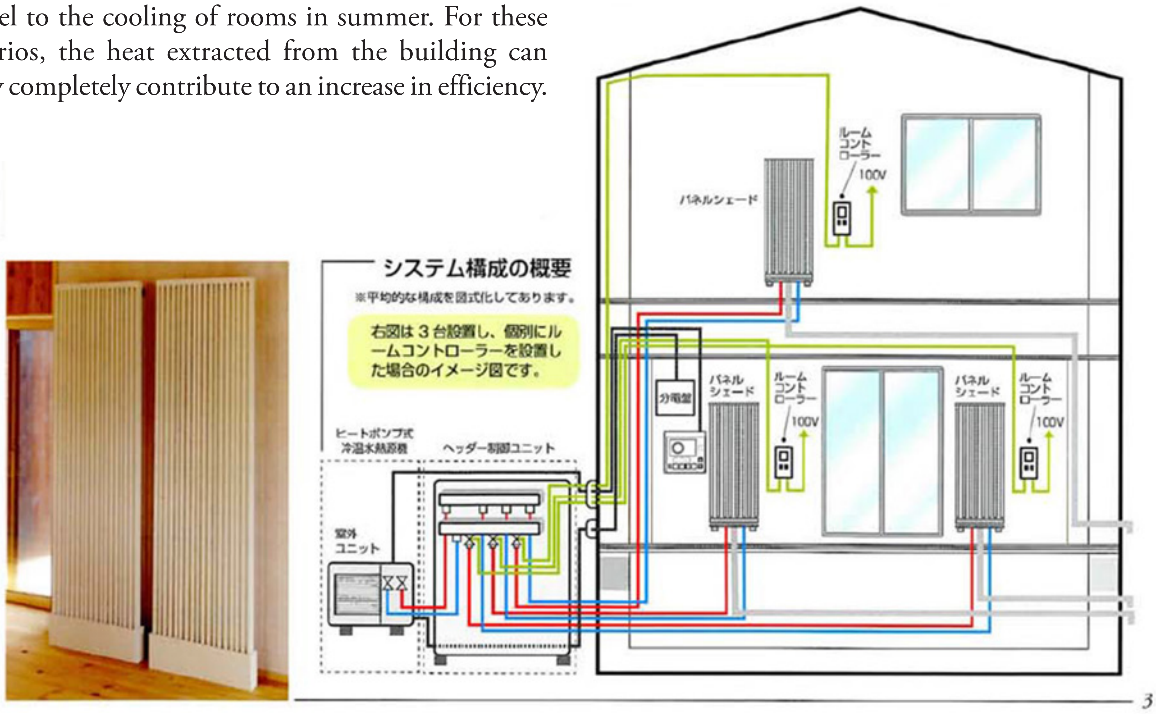

Figure 3. Heating and cooling by heating surfaces/radiators offered by a Japanese private enterprise. [8]

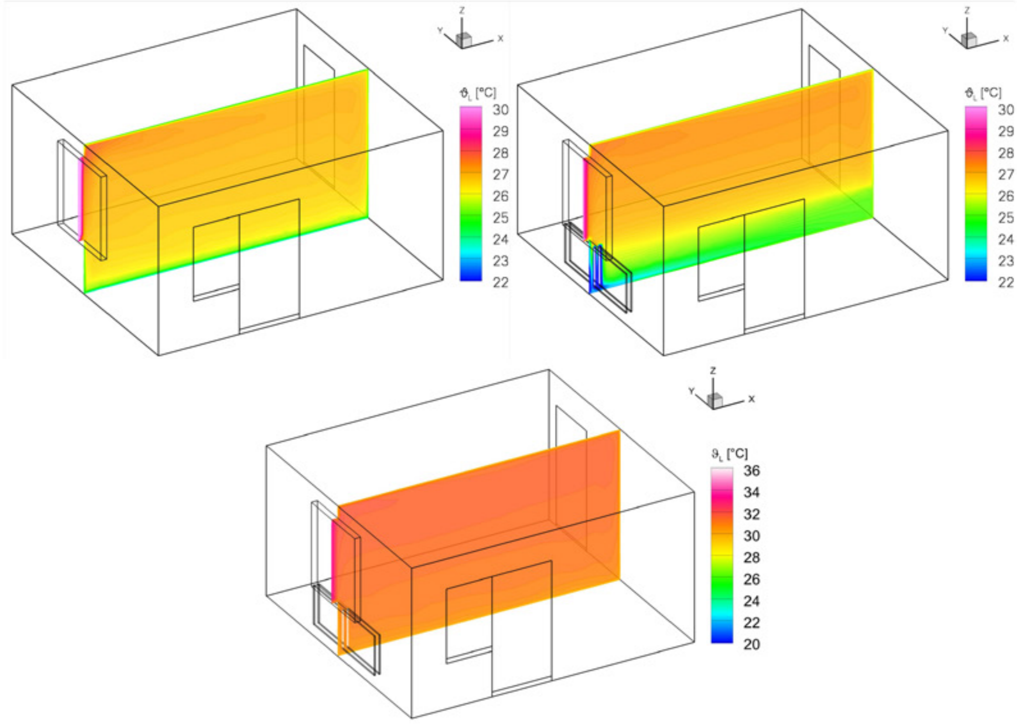

Figure 4. Cooling through free heating surfaces/radiators (right) compared to floor cooling (left) and the non-cooled comparative example. [9]

A detailed theoretical study of the possibilities and challenges of cooling using free heating surfaces/radiators was given in [9] and [6]. These include studies on the effect of buoyancy forces on the inside water flow of free heating surfaces/radiators and their influence on the room air flow and the thermal comfort. **Figure 4** shows the basic effects of cooled heating surfaces. Compared to the uncooled comparison case, despite the limited heating power, a significantly lower room temperature is reached. Particularly interesting is the applying the cold-air lake principle, as is normally achieved by using cold water in floor-heating systems. This can directly cool the heat sources, while their heat loads being dissipated by the self-adjusting buoyancy current of the occupied area towards the ceiling. The described local cooling effect eludes previous general balances and is therefore a particularly interesting subject of further investigations. An important point on the way to practical implementation is the consideration of the heating surface flow. Regardless of the manifold design possibilities of the radiator connections, the inner tube guide ensures that the flow medium flows in the upper distributor and exits form the lower collector. This ensures a uniform temperature profile on the surface of the radiator. In the case of cooling, an upper inflow may cause the water introduced to drop as soon as it flows into the radiator because of gravity. As a result, a short-circuit flow sets in on the connection side. The radiator surface is not cooled uniformly (see **Figure 5**). A short-circuit flow can be avoided by reversing the flow or increasing the mass flow.

The KUEHA project [11][1]

Future work: The previous theoretical findings on cooling using free heating surfaces/radiators are to be put to practical use in the context of the project. This requires proof of the fundamental effects and evaluation of their effects under practical conditions of use. Furthermore, it is to be examined to what extent the impact of these effects can be optimized by control engineering or planning measures. Regarding the installed radiator types, there should initially be no application

[1] The sponsor of the research initiative is the Federal Ministry for Economic Affairs and Energy (BMWi) [1]. The short name KUEHA is derived from the German short title "Cooling with the existing heating system".

Partners of the project are the State Enterprise Saxon Real Estate and Construction Management (SIB) [4], the Kermi GmbH [2] and the Ohra Energie GmbH [3]. The project is supported by partners with excellent expertise in the practice of planning and management of buildings, in the development of radiators/heatsinks with the associated control systems and refrigerators, as well as in the field of energy supply.

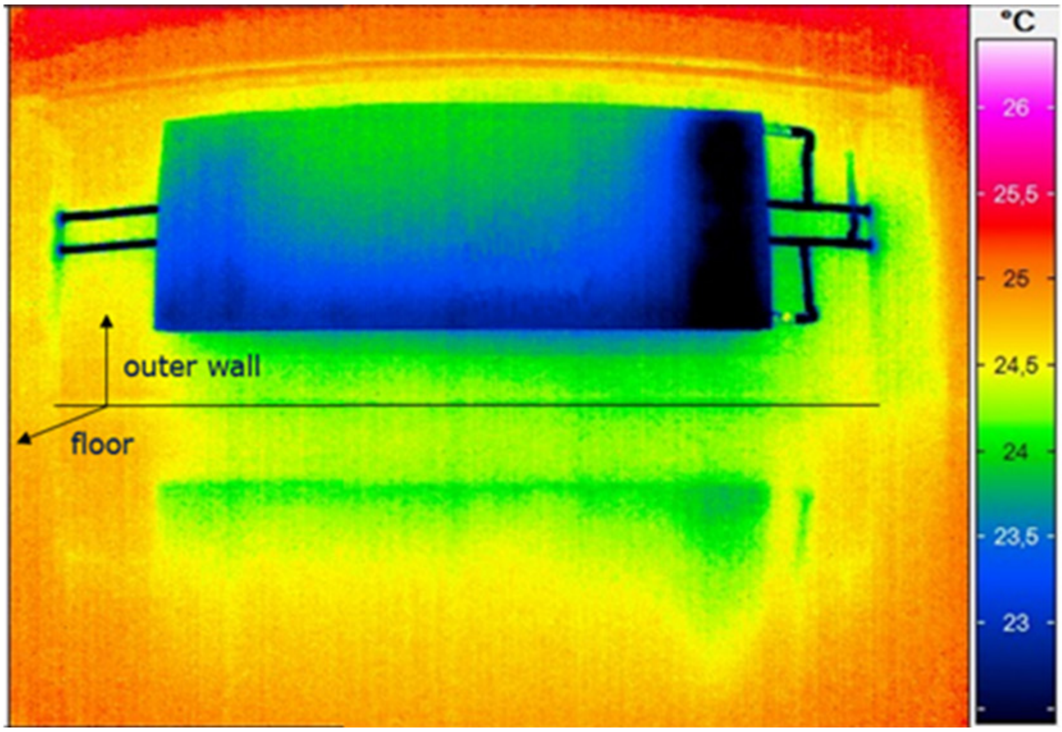

Figure 5. Thermography image of a short-circuit flow.

Figure 6. KUEHA - field objects. [11]

restrictions. However, as part of the project, design recommendations for improving the cooling effect are being developed.

The focus of the methodological approach is the monitoring of executed facilities. For this purpose, several field testing facilities will be determined within the scope of the project (see **Figure 6**). The objects were selected or rebuild with the objective that not only examining different space cooling systems but also to evaluate different types of cooling. The field studies are supplemented by investigations in a climatic room

[10]. The transferability of the measurement results to changed boundary conditions is examined with the help of the coupled plant and building simulation. Simulation tools are available for the detailed evaluation of the thermal conditions in the room, simulating the room air flow with high resolution. The field measurements will start in the summer of 2018. In [11] the authors will inform about the current status of the investigations. ■

Acknowledgment

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