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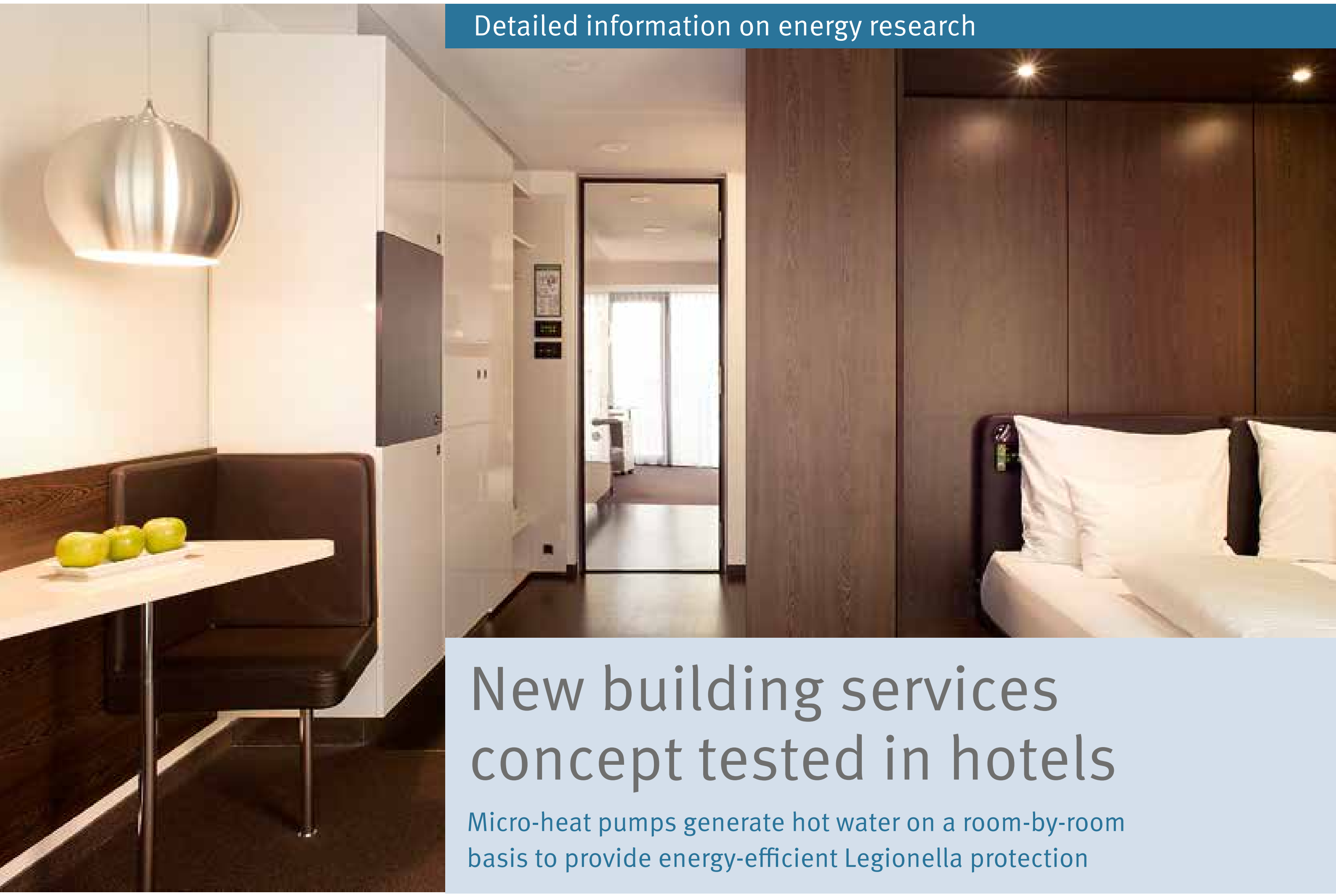
Detailed information on energy research



New building services concept tested in hotels

Micro-heat pumps generate hot water on a room-by-room basis to provide energy-efficient Legionella protection

BINE
Information Service

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The conversion of a residential building to a hotel in the centre of Munich focussed on comfort and energy efficiency. The building envelope almost achieves the passive house standard following the renovation. The system technology is adopting a different approach: decentralised heat pumps produce domestic hot water and space heating heat on a room-by-room basis. A twin-pipe chilled water network balances out the heat and cooling requirements between the individual rooms. Scientists at Rosenheim University of Applied Sciences investigated the efficiency of the concept for two and a half years and supported the operational optimisation.

Although energy costs in hotels account for five to ten per cent of the turnover, construction measures rarely focus on energy efficiency. However, this is not the case with the operator of the Derag Livinghotels. Together with building systems manufacturer COLT International, it developed an unusual concept for the building services technology for its hotel on Viktualienmarkt in Munich. It was aimed at providing users with high levels of comfort while keeping operating costs down due to its efficiency.

The six-storey former residential building, which was built in 1970 using reinforced concrete crosswall construction, was completely renovated in 2011 and converted into a four-star hotel. The building envelope with an average U-value of 0.5 W/m²K almost achieves the passive house standard. Striking are the large-sized windows made of solar protection glazing on the northeast and southwest elevations. There are 43 hotel rooms divided over 7 floors. Their inner bathrooms face the hallway. The decentralised system technology is housed in the dividing wall between the bathroom and bedroom, which usually also forms the head of the bed.

Focus on Legionella risks

The development of the new building services technology concept was triggered by the issue of Legionella protection. The hot water demand in hotel rooms is subject to considerable fluctuations. In the off-season, it is sometimes very sporadic, thereby promoting Legionella growth. This is usually countered with high supply temperatures or decentralised boilers. The innovative concept aims to solve this problem more energy-efficiently: the centrepiece is a small heat pump in each room, which generates the heat for the space and DHW heating, combined with a 160-litre buffer tank. The domestic hot water is always heated via a fresh water station. Heating and cooling energy are primarily transferred to the rooms by climate control ceilings and the central ventilation system.

In-house energy sources used

A twin-pipe system with a low temperature level (11 to 17 °C) traverses the entire hotel. This so-called neutral feed connects the rooms with one another and with a central buffer storage tank. The necessary flow rate is ensured by a twin pump that can automatically act as a single or double pump as required. When there is a need for cooling, the water from the neutral feed flows directly into the climate control ceilings and also serves as a heat source for the heat pumps. Each room can therefore use the surplus heating and cooling energy from other rooms. This coupling reduces the total energy consumption when heat and cooling requirements are present at the same time. If the heat fed into and withdrawn from the neutral feed is not balanced, surplus energy can be stored in heat or cold storage tanks and used if necessary. If the imbalance between the heating and cooling demand exceeds this storage capacity, additional energy is added. For the heating this is achieved using a solar thermal system, heat recovery from grey water as well as electric cartridge heaters; a chiller with free cooling provides cooling. The hotel only needs electricity for the energy supply. A minimal share of this can be provided by the in-house PV system.

Consumption in the spotlight

Because of the novel approach, considerable complexity of the system and the necessary control technology, the client decided to contact Rosenheim University of Applied Sciences to have the systems evaluated scientifically. The entire system level was measured and tested, and in addition 12 representative rooms were also measured individually.

The final energy consumption is generally low due to the well-insulated building envelope. For heating, it achieved an average of 17.4 kWh/m² p.a. for the two measuring years: 13.7 kWh/m² p.a. for hot water and 25.7 kWh/m² p.a. for cooling. The dual use of the neutral feed reduces the final energy demand for all thermal applications, whereby this is more evident with the domestic hot water due to its greater temporal overlap with the cooling demand than for space heating. Since LED lamps were consistently used, the lighting needed only 8.0 kWh/m² p.a. The ventilation system also works very efficiently. It consumed 4.2 kWh/m² p.a. during the first year of operation.

System	*Components / Details*
Space heating and cooling	*Climate control ceilings in hotel room (supply temp. 37 °C or ≥ 16 °C)*
Domestic hot water heating	*Fresh water stations in hotel rooms; 45 °C at the tap*
Heat source: Space/domestic hot water heating	*Heat pump 1.5 kW_{el}; 5–7 kW_{th}, fed from neutral feed; feeds into buffer tank (160 l, 50 °C)*
Cooling source: Room cooling	*Connection to neutral feed (source temperature 11–17 °C, via return admixture ≥16 °C)*
Heating/cooling distribution	*Neutral feed (twin-pipe cold water distribution network, 11–17 °C, 35–50 m³/h flow rate) with central buffer tank (13 m³)*
Central storage system	*Heat storage tank 8 m³; cold storage tank 7 m³; use of thermal inertia*
Central heat generation	• *Cartridge heaters (36 $kW_{el/th}$)* • *Solar thermal system consisting of evacuated tube and flat-plate collectors (3 arrays covering 50 m²)* • *Heat recovery from grey water (from Δt at 3 K)*
Central cooling generation	*2 compression chillers with recooler on the roof, recooler can also be used as a free cooler (Compression cooling: 6.8 + 8.9 kW_{el}; 26.5 + 35.4 kW_{th} Free cooling: approx. 2.5 kW_{el}; 10 kW_{th})*
Electricity generation	*PV system: 4.9 kW_p; 35 m²; 7° inclination (north/east)*
Room ventilation	*Central ventilation system, cooling heat exchanger and dehumidification (6,000 m³/h_{max}; 2,000–2,500 m³/$h_{control}$; 30–100 m³/h per room)*

Fig. 1 *Summary: Installed building services technology*

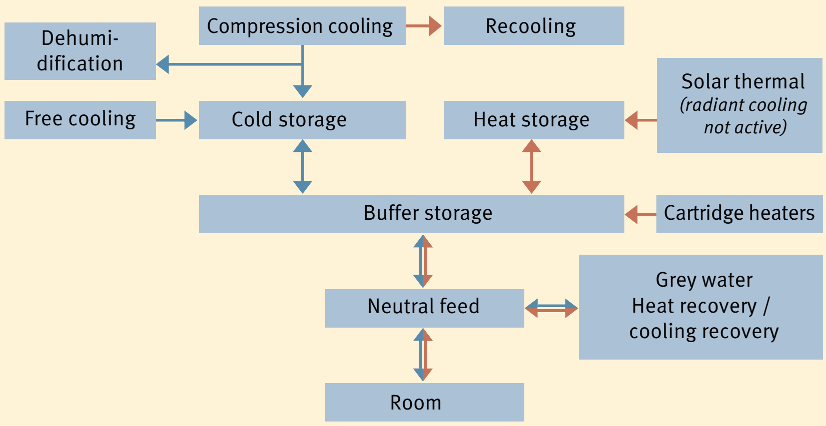

Fig. 2 *Schematic diagram showing the central heating and cooling generation*

The system requires a lot of auxiliary energy for distributing low-temperature heat – the circulating pump in the neutral feed network alone accounts for about 20 % of the power consumption of the building services systems. This power consumption is also noticeable as heat input. The building automation also consumes rather a lot of power with 7.5 %. Given its complexity, the regulation of the system has functioned relatively easily.

Since no external heat is needed in summer, the solar thermal system saves only a small amount of primary energy. The original idea of using the system for radiant cooling as well was not applied owing to the very low cooling output during operation. A PV system of the same size could probably save an additional 10,000 kWh p.a. of final energy.

Contractual commitment facilitates optimisation

Both the hotel operator and the systems manufacturer were motivated to optimise the new system. Both showed considerable interest in the monitoring data and were willing to make changes to system components or the control system during operation. A good prerequisite for this was the

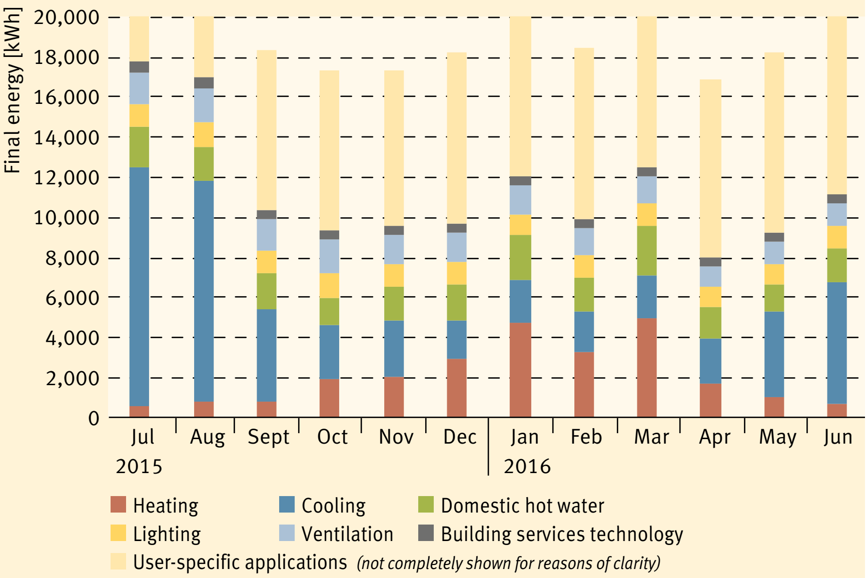

Fig. 3 *Final energy consumption balance in the second year of monitoring*

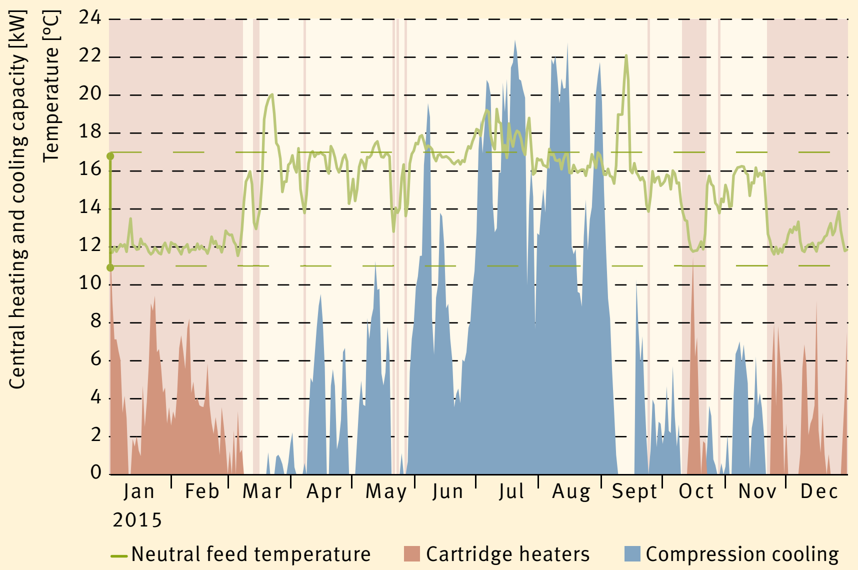

Fig. 4 *Temperature of the neutral feed and central heating and cooling capacity as daily mean values over one year*

contract design, which tied the systems manufacturer beyond the planning and commissioning. The fact that everyone was pulling together also made the work of the monitoring team at Rosenheim University of Applied Sciences easier and made it possible to significantly improve the efficiency of the operation.
The cooling of the hotel rooms initially proved problematic. There were several reasons for this: the cooling input from the heat pumps into the neutral feed when generating domestic hot water in summer was lower than the cooling demand in the building. As a result, the neutral feed was warmer than planned. The monitoring also revealed that the brand of climate control ceiling installed achieved less than one third of the manufacturer‘s declared cooling capacity. In combination, this occasionally led to interior temperatures of up to 29 °C. The system from a competitor, which was installed in a sample room, achieved the planned value. However, they have so far failed to reach an agreement with the manufacturer to get all the climate control ceilings replaced in the hotel rooms.
A doubling of the ventilation rate from April 2016 with originally not intended dehumidification of the supply air defused the problem, but quadrupled the power consumption of the ventilation system. In order to reduce the cooling loads, external solar shading was installed on the extensive glazing on the southwest elevation in 2016.
In the case of the neutral feed pump, the change from single to double pump operation often led to faults. In order to better adapt the pump operation to the actual flow rate requirement, another brand was installed and further optimised during operation. This not only reduced the frequency of the fault reports but also reduced the power consumed by the pump by almost 30 per cent.

Focus on hotel guests

In 123 evaluated questionnaires, the hotel guests rated the overall comfort as good. Often, however, they considered the room temperature to be too high. In this context, they also felt that the control of the indoor temperature was not effective. The low capacity of the climate control ceilings, which caused the ceilings to work frequently at their performance limits, certainly played a role here. The noise emitted by the heat pumps was also criticised.
As part of the monitoring the question was therefore raised whether radiant heating and cooling systems – which are fundamentally beneficial in terms of the energy performance but sluggish – are suitable for hotels. The hotel guests evidently expect a quick response to their readjustments. The researchers believe that it may therefore be expedient to include the subjective expectations when planning hotel buildings. In the further development of the system, the systems manufacturer is now planning to connect a recirculating air cooling system to the neutral feed.

Parameters identified for greater efficiency

The unusual energy concept with its many decentralised heat pumps and combined use of heating and cooling via the neutral feed has proven itself in daily use. This is confirmed by the high thermal performance factors between the system level and useful energy. However, the consumption of auxiliary energy still needs to be significantly decreased in order to make the overall concept competitive. Since the cooling input via the heat pumps does not compensate for the cooling demand in the rooms in summer, the system requires a greater cooling supply than was originally assumed. However, the efficiency of the cooling generation still falls short of the potential offered by the prototype: the structural conditions have meant that it has not been subsequently possible to optimally integrate the recooling hydraulically by means of free cooling or the use of a chiller. For this reason, in primary energy terms the prototype has been initially worse than a conventional system comprising a gas condensing boiler, chiller and 6-line distribution system. An initial approach would be to replace the cartridge heaters with an air heat pump.
The monitoring has also recorded the user-specific energy consumption. In the hotel rooms this included consumption by the kitchenettes, television sets and loads connected to the electrical sockets. At the building level, the reception area, kitchen, breakfast room, server room, laundry and changing rooms as well as the lift were included. Overall, these accounted with 61.6 kWh/m² p.a. for about half of the total consumption in this hotel – a starting point for future efficiency concepts.

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In 2016 there were 447 million overnight stays in hotel accommodation in Germany. According to an extensive survey of the members of the German Hotel and Restaurant Association (DEHOGA), one night's sleep costs about 70 kWh on average. The growing comfort demands made by hotel guests are continuously increasing consumption. At the same time, some hoteliers are discovering sustainability and energy efficiency as unique selling points.

For several years DEHOGA has been helping its members to implement energy-saving measures with information, advice and certification as part of its "Hospitality Industry" energy campaign. Since 2015, the German Energy Agency (dena) has been investigating energy consumption in hotels and possible savings potential in the "Check-in Energy Efficiency" pilot project funded by the German Federal Ministry for Economic Affairs and Energy. Using actual buildings it is intended to show which investments can achieve concepts for hotels that are viable in both economic and energy performance terms. KfW Bankengruppe is providing funding for the renovation projects. The University of Wuppertal is in charge of the monitoring and across-the-board evaluation of the participating hotels.

A newly launched research network led by Regionalmanagement Nordhessen is working to develop a dynamic, efficient energy management system for controlling all areas in hotels. The research will involve both operators and users. The considerable complexity of energy loads in hotels opens up a variety of options for demand-driven control – whereby the energy requirements of the rooms only make up part of this. As a prerequisite for the development work, an initial analysis is therefore being conducted to investigate the distribution of the energy demand across the different functional areas in the hotel industry and the different forms of energy. The developed control strategies should not impair the comfort of the hotel guests but engage them in the energy saving measures.

Project participants

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- **Concept, planning, execution of building services technology:** COLT International GmbH, Soltau, Thorsten Hesse | www.colt-info.de

Links and literature (in German)

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