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Experimental investigation on fronTherm – a novel facade heating, cooling and ventilation system

Summary

In this work, fronTherm – a novel system that enables the simultaneous renovation of the building facades and the heating system without causing major work inside the building – is introduced and investigated experimentally. This heating, cooling and ventilation system consists of a small heat pump which is integrated into an insulation element and supplies heat for the interior by heat conduction over the wall and heated supply air. A prototype fronTherm module is tested in a dual climate chamber to perform tests under varying boundary conditions. At first, a functional test is performed to identify heating power rates and efficiency levels. Secondly, the complete system is investigated using a realistic wall setup and operating conditions inside the climate chamber. The results confirm the functionality of the novel heating and ventilation system in a laboratory environment.

Keywords: Serial renovation, heat pump, ventilation concept, building energy systems, solar heating

Field of application for the findings: Renovation of existing buildings, building heating and cooling

Addressed audience: Building planners, researchers and engineers in HVAC and heat pump systems

1. Introduction

The building sector has not been meeting its climate neutrality targets for several years (Loga, Tobias et. al 2015). A far-reaching renovation of the building stock – reduction of heat demand (measures on the building envelope) and decarbonization of heat generation – is needed. This requires renovation rates that seem inconceivable given the available skilled labor capacity today. Another major obstacle is that both investments usually have to be made together, and that work on the building envelope (e.g., insulation and window renewal) as well as in the technical and living or utility rooms (heat generators, heating and, where applicable, cooling surfaces) are required. In practice, this often leads to a delay in renovation measures or only the replacement of the heat generator, combined with undesirably high CO_2 emissions for decades to come. In the transformation of energy supply in existing buildings, in addition to renewable local and district heating, the use of heat pumps will play a decisive role (Walberg, Dietmar et. al. 2022).
Furthermore, air/brine heat pumps generally require an outdoor unit or a ground probe to extract the heat from the outside air or the ground. Both systems are often not applicable, especially in inner-city locations, particularly in apartment buildings, due to noise pollution and limited space (air source heat pumps) or the lack of spatial or geological conditions for geothermal probes.

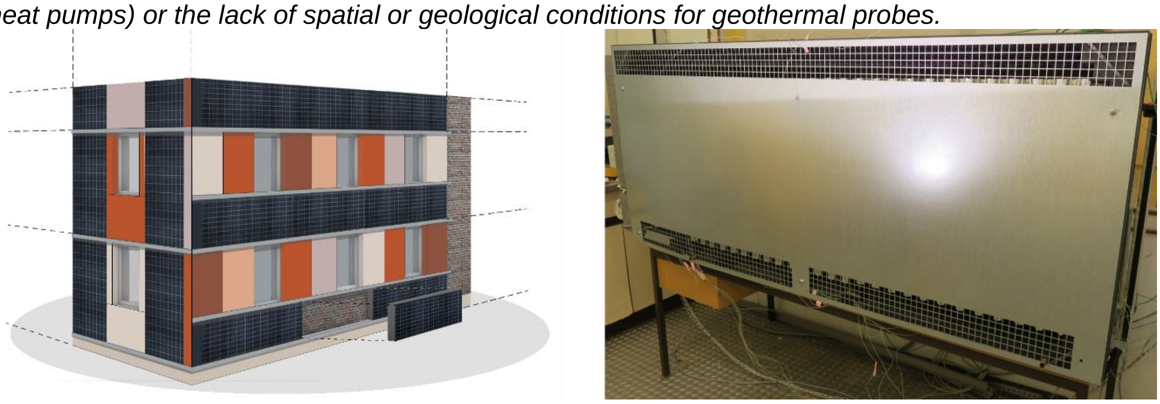

Figure 1: Renovation concept with innovative facade heating and cooling units with PV (left) and a functional prototype (right)

Therefore, the research project fronTherm develops a novel heating system that enables the simultaneous renovation of the building envelope and heating system without causing major work inside the building. It is intended to enable the efficient use of solar and heat pump technology and can also be used error-free by trained personnel. It could thus enable a significant increase in renovation rates in a disruptive way, thereby making a significant contribution to the energy transition in the building sector. The solution concept is based on facade heating and cooling units (known as fronTherm modules), which can be mass-produced and are installed on the outside of the facade, see Figure 1. Each module contains a micro heat pump with a condenser surface for heat dissipation on the inside facing the building wall, and an evaporator surface on the outside facing the ambient air and sun (heating mode). This surface can also be equipped with PV modules on suitably exposed facades. In the case of cooling, the condenser becomes the evaporator surface and vice versa. The facade heating and cooling units serve as the only source of heat and cooling for the building.

In this way, a single renovation measure can simultaneously take four steps toward climate neutrality:
• Reduction of heating and cooling load through insulation of the facade
• Installation of PV to generate the electrical energy required to operate the heat pumps in the annual balance and thus cover the heating requirements in the balance sheet
• Replacement of old heating systems with efficient heat pump technology
• Cooling in summer. The facade heating and cooling units are connected to the heat pump system

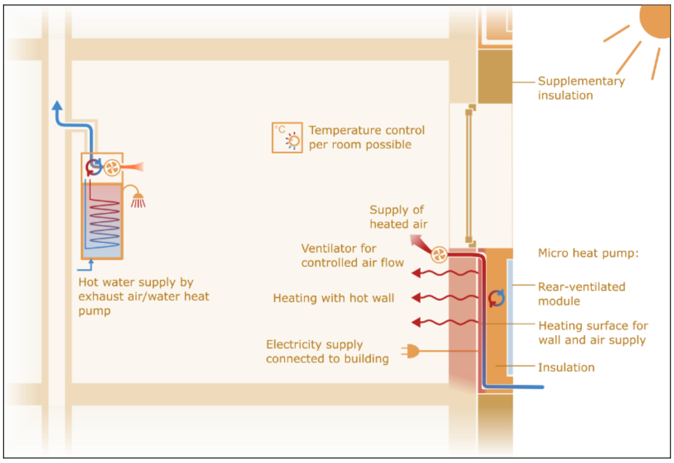

Figure 2: Operating principle for heating and cooling

Figure 2 shows a schematic representation of the operating principle for the heating mode. Since ventilation heat losses account for an increasing proportion of the heating load in energy-efficient buildings, the concept includes a solution for mechanical residential ventilation that can also be implemented in existing buildings at relatively low cost. This is based on a classic exhaust air system. The central component for this is the exhaust air/water heat pump for heating drinking water, which centrally in each residential unit – typically in the bathroom – draws in the exhaust air, cools it and discharges it to the environment via a wall outlet. At the same time, outside air flows into the living spaces through the facade units, where an additional ventilator is placed in the supply pipes to ensure a sufficient air flow. The supply air can be preheated in winter to temperatures of up to around 50 °C using the integrated heat pump. The preheated supply air also helps to heat the exterior walls equipped with facade units.

2. Experimental setup and procedure

The experimental investigation is done in two steps and is focused on the heating operation. At first, a functional test of the fronTherm module regarding achievable heating power, heating efficiency in terms of COP and sound power level is performed at different values for compressor speed, supply air ventilator speed as well as temperature levels for condenser and evaporator. For this purpose, the module is tested in an insulated dual climate chamber with one side representing the building interior at room temperature (20 °C) and the other side the ambient at different temperatures, which can is controlled in the range of -10 °C to 10 °C, see Figure 3. The module is installed on a plasterboard within a multi-layer area placed in a window, which connects the warm and cold side as shown in Figure 3. Behind the plasterboard is an absorber plate that dissipates the heat conducted from the module and allows for a precise measurement of that heat flux using an electromagnetic flowmeter and Pt100 temperature sensors. Further, the inlet water temperature and the mass flow

through the absorber circuit can be adjusted for a control of the condensation temperature. A layer of insulation is placed between the absorber plate and the warm side of the climate chamber to minimize the undesired heat flux towards the warm side, which can be determined via installed surface temperature sensors. A second plasterboard for mechanical stability completes the setup on the room side. Compared to a regular wall, the applied structure allows faster measurement cycles at varying boundary conditions due to significantly lower thermal capacity and a reduced response time. The heat supplied to the room via the supply air flow can be determined by a measurement of the air flow with a hot-wire anemometer and the temperature change between inlet and outlet. Further, the refrigerant pressure at the outlets of condenser and evaporator as well as the temperatures at various positions of the refrigerant circuit and on the surfaces of condenser and evaporator are measured.
The determination of the wall- and air-sided heat extraction as well as the electric power consumption allows the calculation of the heat pump efficiency (COP) at different boundary conditions, which provides the basis for an overall system performance evaluation. Further measured quantities are used to gain more insight into the thermal behavior of the module as well as the states in the refrigerant loop, in order to evaluate and further optimize the prototype design with respect to thermal performance.
In the second step of the experimental investigation, a complete system test is conducted, including a realistic wall setup, an exhaust air/water heat pump which is installed for hot water production in each apartment and the central fronTherm system controller. In the climate chamber measurement setup, the multi-layer construction is therefore replaced by a regular wall where the module is mounted on to be able to perform dynamic tests under realistic conditions.

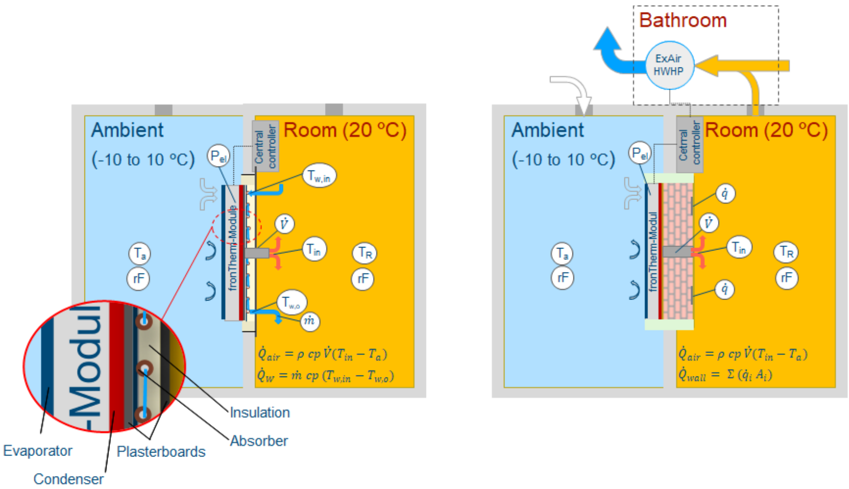

Figure 3: Test setup of the functional test (left) and the system test (right)

3. Results

The experimental *setup is completed and the commissioning phase confirmed the functionality of the fronTherm module regarding expected temperature and pressure levels under the tested conditions. While the functional test of the module will be carried out over the next weeks, the system test is planned to start in one month and will last for another four to six weeks.*

This work introduces the operating principle as well as the prototype setup and presents measurement results, which characterize the performance of the system under varying conditions and prove the functionality of the fronTherm system as heating and ventilation system.

References

[1]: Loga, Tobias et al.: Deutsche Wohngebäudetypologie – Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden. 2., erw. Auflage, IWU, 2015.

[2]: Walberg, Dietmar et al.: Wohnungsbau: Die Zukunft des Bestandes – Studie zur aktuellen Bewertung des Wohngebäudebestands in Deutschland und seiner Potenziale, Modernisierungs- und Anpassungsfähigkeit. Bauforschungsbericht Nr. 82 der Arbeitsgemeinschaft für zeitgemäßes Bauen e.V., 2022.