PRESS RELEASE

Fraunhofer ISE Research Project Completed: Heat Pumps Provide Climate-Friendly Heating in Existing Buildings

Heat pumps provide efficient and climate-friendly heating also in existing buildings. This is the conclusion of a research project by the Fraunhofer Institute for Solar Energy Systems ISE. Over four years, researchers conducted detailed measurements on 77 heat pumps in single-family to three-family homes. The result: the heat pumps achieved seasonal performance factors ranging from 2.6 to 5.4. The CO_2 emissions of the heat pumps, calculated for the first time considering time-variable factors, were 64 percent lower in 2024 compared to those of natural gas heating systems. The research team also conducted long-term sound measurements and investigated how photovoltaic systems can be integrated into heat pump operation. In addition to Fraunhofer ISE, two energy suppliers and nine heat pump manufacturers participated in the project.

Heat pumps are becoming increasingly popular: In the first half of 2025, they ranked at the top of the sold heating systems for the first time in the history of the German heating market. This means they have displaced gas heating systems from the top spot. In new buildings, heat pumps have dominated for years, with nearly 70 percent of new constructions completed in 2024 using a heat pump for heating. However, homeowners of older existing buildings are still wondering whether these heat generators can also operate efficiently and climate-friendly in their homes.

Heat pumps work well, but there is also optimization potential

These doubts are unfounded. “The results clearly show that heat pumps can be operated efficiently even in older buildings and that they provide climate-friendly heating without the need for the buildings to be renovated to new construction standards,” says Danny Günther, team leader for 'Heat Pumps and Transformation of Existing Buildings' at Fraunhofer ISE. “However, we have also uncovered optimization potential.” Based on the detailed analysis of measurement data, it can be understood which planning or installation errors occur most frequently and where inefficient operational behavior is evident,” Günther adds.

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Efficiency: Seasonal performance factors ranging from 2.6 to 5.4

In the research project, Fraunhofer ISE monitored 77 heat pump heating systems under real conditions. The efficiency of the heat pumps has improved compared to the project "WPsmart in Existing Buildings", which was completed in 2019. Air/water heat pumps achieve an average seasonal performance factor (SPF) of 3.4, meaning they generate 3.4 units of heat from one unit of electricity. In the previous project, the average was 3.1. The air/water heat pump with the lowest efficiency had an APF of 2.6, while the highest reached 4.9. The more efficient ground-coupled systems exhibit an average APF of 4.3 (WPsmart in Existing Buildings: 4.1). The range for ground source heat pumps spans from 3.6 to 5.4. No correlation between the year of construction of the buildings and the efficiency of the heat pump was found.

The study also showed that adequately sized radiators can be operated at similarly low temperatures as underfloor heating. The energy consumption of the electric heating rods, which support the heat pump in particularly cold temperatures, plays a minor role in the measured systems, which is also linked to the comparatively mild weather conditions during the measurement period. They accounted for only 1.3 percent of the electrical work in air/water heat pumps, while the share was close to zero percent for ground source heat pumps.

Greenhouse gas emissions: 57 to 68 percent lower than with gas boilers

The efficient operation of heat pumps results in them being significantly more climate-friendly compared to natural gas heating systems. Considering the German electricity mix from the past year, the examined pool of heat pumps shows a calculated CO_2 reduction of 68 percent compared to gas heating systems. However, this annual accounting does not take into account the intra-year or intra-day variance in heat pump efficiency, as well as the contributions of individual power plant types to electricity production.

Therefore, the study has now also incorporated the quarterly calculated emission values from the German electricity mix for the first time. This allows for a more precise assessment of the climate-friendliness of heat pumps. With this dynamic accounting, the savings decrease, but only slightly. In 2024, the CO_2 emissions of the examined heat pumps were on average 64 percent lower than those of gas heating systems — four percentage points less than with the static method.

Sound measurements also conducted

In the project, the researchers also developed a method for conducting long-term sound field measurements of air/water heat pumps, with the objective to collect time-resolved data on sound immissions in different operating situations. This method was

successfully demonstrated on five randomly selected systems. In two buildings, the ambient noise was so dominant that the heat pumps had little acoustic impact on the neighboring building being studied. At three locations, the operation of the heat pumps was occasionally measurably above the ambient noise at night, for example, in a terraced house. In general, the sound power level of the heat pump used, its mode of operation, the installation location, and any sound insulation measures have a significant impact on the resulting emissions.

Combination of Heat Pumps and Photovoltaics

Additionally, the researchers at Fraunhofer ISE analyzed the combination of heat pumps with photovoltaic (PV) systems. A classic approach to increasing the self-consumption of locally generated PV electricity is to raise target temperatures when there is excess PV power. Operating the heat pump more frequently with solar power can be advantageous: solar electricity is cheaper than grid electricity, even at heat pump tariffs, heat pumps can be operated in a more climate-friendly manner, and it can relieve the distribution network at certain times.

The results of the investigation of six heat pump/PV combinations: without a battery, buildings with a PV system achieve 25 to 40 percent autonomy and 22 to 37 percent self-consumption. With a battery, these ranges shift significantly, with building autonomy values from 32 to 62 percent and building self-consumption values from 40 to 83 percent.

Process Matrix for Optimization

Despite good measured efficiency values, the research project also highlighted optimization potentials. For example, many heat pumps were oversized in relation to consumption, and the switching frequencies were very high for some systems. In some systems with combined storage, a reliable separation of temperature levels for space heating and domestic hot water heating was not achieved, leading to unnecessary heat provision at the hot water temperature level.

Based on the analysis of the measurement data and feedback from stakeholders, the research team at Fraunhofer ISE created a process matrix in the final report. This documents possible quality deficiencies for the individual phases of planning, installation, and commissioning. It also shows how to address these issues. The results and recommendations from the project provide valuable insights for planners, installers, and operators of heat pump systems.

61 Buildings with Air/Water Heat Pumps, 16 with Ground Source Heat Pumps

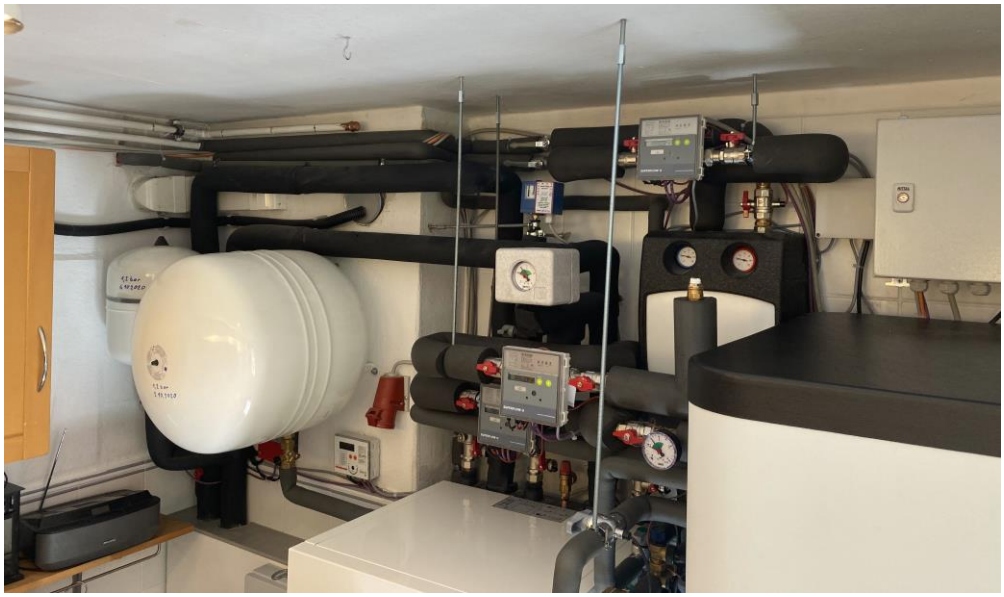
The examined pool of systems included 61 units with the heat source being outside air. These air/water heat pumps are the most commonly used type of heat pump in Germany. 16 systems utilize a brine/water heat pump, drawing heat from the ground. 34 of the examined heat pumps come from the project "WPsmart in Existing Buildings", completed in 2019, where the research partners continued monitoring, partly with more recent heat pump models. 43 measurement objects were newly added.

For the efficiency evaluation, heat pumps in buildings constructed between 1826 and 2001 were considered. The heated area ranges from 90 to 370 square meters, with an average of 170 square meters. Residential buildings built before 1977 (the first thermal insulation regulation) have been renovated more extensively than the national average. For example, half of the buildings, 51 percent, had their façades retrofitted with insulation—nationwide, only 30 percent were insulated based on 2016 data. Buildings constructed from 1977 onwards are, with one exception, entirely unrenovated.

Partners of Fraunhofer ISE included heat pump manufacturers Bosch Thermotechnik, Glen Dimplex Deutschland, Max Weishaupt, NIBE Systemtechnik, Panasonic Heating & Ventilation Air-Conditioning Europe, DAIKIN Airconditioning Germany, Stiebel Eltron, Viessmann, and Vaillant, as well as energy suppliers Lechwerke and Stuttgart municipal utilities. The Federal Ministry for Economic Affairs and Energy (BMWi) financially supported the project under the funding code FKZ: 03EN2029A.

The detailed results of the research project 'Quality Assurance of Heat Pumps in Existing Buildings,' abbreviated as 'WP-QS in Existing Buildings,' can be found on the project page:
https://www.ise.fraunhofer.de/en/research-projects/wp-qs-im-bestand.html

Transparency notice: An earlier version of this press release referred to the reference values according to TA Lärm (Technical Instruction for Protection against Noise) in the paragraph on sound measurements. We have corrected this, as the evaluation of the field sound measurements in the project was not in compliance with this guideline. The goal was rather to collect time-resolved information on sound emissions under different operating conditions using the developed method. The measurement results in this form cannot indicate whether the TA Lärm was adhered to.



Heat pump system and storage with heat meters in the hydraulics. © Fraunhofer ISE