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DECARBONISATION THROUGH INNOVATION

Low-temperature heating and efficient cooling with maximum use of the hydronic resources

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Abstract

As demand for energy-efficient building retrofits increases, integrating heat pump technologies into existing heating systems presents both opportunities and challenges. This paper explores a mixed technology approach combining different heat pump types - air-to-water, water-to-water, and water-to-air micro heat pump systems - aiming to maintain as much as possible existing infrastructure while transitioning to low-temperature systems. The paper focuses on the strategic use of water-to-air heat pumps, which can directly replace conventional radiators. This approach allows to overcome retrofit challenges, reusing existing piping, addressing heat losses and high temperature differentials (ΔT) in systems where traditional fan coils or low-temperature emitters are less effective. This enables a significant reduction in supply temperature to as low as 15 °C. Thus, the primary heat pump, typically a water-to-water or air-to-water unit can cover, 75–80% of the buildings total heating load, with the remaining demand is met locally by water-to-air units. This configuration reduces both the design capacity and installation complexity of the primary system, leading to significant cost savings, particularly for ground-source heat pumps, where borehole drilling or direct heat exchange with probes can be minimized. Additionally, integration with solar systems and/or dry coolers is feasible, enhancing energy savings during cooling mode. With waterloop solutions, LT heating and cooling are simultaneously possible, delivering same possibilities as 4-pipes systems with 2-pipes system only. Heat extracted from indoor air can be repurposed for domestic hot water production, achieving temperatures up to 55 °C. Heat recovery can be done without the need for a condensation drain system due to a specially designed injection kit designed for certain countries. This combined technology approach offers a practical and scalable pathway to decarbonize existing building stock, including hotels, hospitals, and multi- family buildings, facilitating energy efficiency improvements without extensive modifications and supporting the transition to low-energy, renewable-based building services.

Keywords: heat pump; waterloop; renovation; low temperature emitters

1. Introduction

As the urgency to decarbonize the built environment intensifies, retrofitting existing buildings with energy-efficient heating solutions has become a critical priority in Europe. Heat pump technologies offer a promising pathway, yet their integration into legacy systems presents technical and economic challenges. This paper investigates a mixed-technology approach that leverages air-to-water, water-to-water, and water-to-air micro heat pump systems to optimize retrofit strategies. By strategically deploying water-to-air units capable of replacing conventional radiators, the proposed solution enables significant reductions in supply temperatures, minimizes infrastructure modifications, and enhances system efficiency. The study and case histories demonstrates how this configuration can reduce primary system capacity, simplify installation, and facilitate integration with renewable energy sources, offering a scalable model for low-temperature heating and cooling

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in complex building typologies such as hotels, historical buildings, hospitals, solo and multi-family residences. This paper will present the theoretical systems, as well as the applied deployment of the technologies into the renovation of a hotel in Auer, South Tyrol, Northern Italy. With the objective of ensuring such solutions can be scalable in future to enable building renovations at European level.

2. Presentation of the technology renovation solutions

2.1. The Water Loop Heat Pump (WLHP)

Water Loop Heat Pump (WLHP) is the solution developed by INNOVA to renovate existing heating systems, also allowing summer air conditioning of living spaces, and to increase their energy efficiency without substantial interventions on the distribution networks and without the need for invasive construction work on the building envelope or interior spaces. WLHP is based on local heating and cooling units designed to replace the existing radiators in rooms. These are water-to-air heat pumps that use low-temperature water (20÷30 °C) circulating in the distribution network previously used to supply the radiators for heat exchange.

WLHP units are equipped with a Panasonic DC inverter rotary compressor and tangential fan, both with inverters to ensure maximum continuous modulation, and a refrigeration circuit filled with R290 (propane) with a very low environmental impact (GWP 3 AR4, GWP 0,02 AR6).

The dimensions are compact, ideal for replacing existing radiators. For example, the horizontal versions (1.04÷3.1 kWt ; 1.12÷2.59 kWf) are 144 mm deep, 641 mm high and 775 to 1225 mm wide, and a vertical version is also available. Noise emissions are kept within acceptable levels for domestic applications (33÷35 dB(A) at nominal power, 28÷31 dB(A) at minimum speed). In addition, the WLHP units can be controlled from a wall-mounted panel, installed in a standard 503 box, and feature Wi-Fi, so the system does not require electrical cables between units and thermostats.

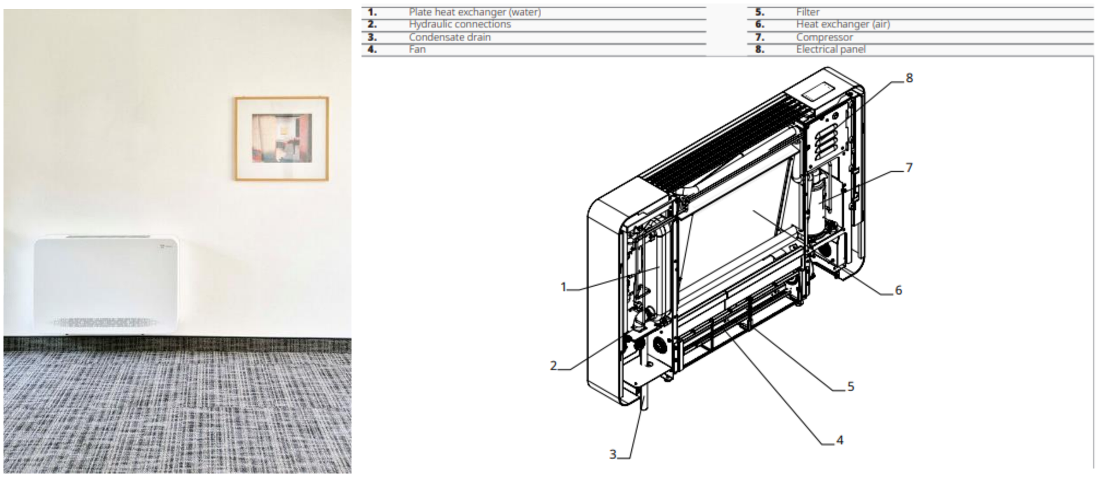


Figure 1 & 2. Picture of the Water Loop Heat Pump and its internal components

2.2. The Water Loop Heat Pump into the heating and cooling system applied in a hotel renovation

The Hotel Heide Park, a family-run 3-star hotel located in Ora (Auer, about 20 km south of Bolzano), which offers 49 rooms equipped for travelers and tourists, as well as spaces and services for dining, socialising and relaxation, was looking to upgrade its energy systems, while minimizing the renovation works on the heating and cooling distribution networks. Completely renovated about ten years ago, the hotel has recently been improved in terms of thermo-hygrometric comfort, offering guests perfectly air-conditioned rooms even in hot weather, while reducing energy consumption and climate-changing emissions.

The new installation was completed in May 2025, without any changes to the existing generator or significant work on the heat transfer fluid distribution network, thus avoiding the need for work inside the rooms and other spaces open to the public.

The hotel's heating system was originally based on a 197 kW methane-fired condensing boiler, operating at 80/60 °C, and also supplying domestic hot water. Heat distribution was managed through a 2-pipe network with eight riser lines, each equipped with its own electric circulation pump. Radiators with thermostatic valves served as the terminal units, allowing room-level temperature control.

The conversion of the hotel's heating system to a Water Loop Heat Pump (WLHP) configuration was carried out over a two-month period and involved a comprehensive upgrade of both generation and distribution components. Central to the new system heat pumps, each capable of delivering up to 30-31 kW of heating at A7/W35°C and 20–23 kW of cooling at A35/W7°C (much more at A35/W25, our reference for WLHP). These units consist of Panasonic DC inverter outdoor modules, installed on the rooftop terrace, and indoor modules located in the technical room. The heat pumps were selected and sized primarily to meet the building's summer cooling requirements, while also fulfilling the thermal load for bedrooms and breakfast room and contributing to generale heating demand during colder months. The networks have a dual power supply that maintains the water loop at 32-33 °C (winter) and 25 °C (summer), regardless of the outside air temperature and under all operating conditions.

To support system stability and optimize performance, two inertial thermal storage tanks of 800 liters each were installed in series downstream of the indoor units. These tanks help buffer thermal loads and ensure consistent operation of the heat pumps. A new hydronic manifold was added in parallel to the existing one, allowing the circuits to be flexibly supplied by either the heat pumps or the gas boiler, depending on operational needs.

Approximately 70 new WLHP terminal units were installed throughout the building, replacing the original radiators in public areas, circulation zones, and guest rooms. In certain guest room bathrooms, new radiators were installed to replace the existing ones, maintaining adequate heating comfort in these areas.

Following the system conversion, a detailed comparison of flow rates was conducted for each individual circuit. Based on the results, several electric circulation pumps were replaced with models capable of delivering the required flow rates to compensate for the reduced operating temperatures introduced by the WLHP system.

The current distribution system has very small pipes indeed; this was the reason why the circulation pumps replacement was required.

The proper hydronic balance and reliability of the distribution network is guaranteed by a special function, available on each unit, which permits to set a certain flow rate in order to get the proper water flow, allowing the right water flow adduction to the units supplied with longer and/or smaller pipes.

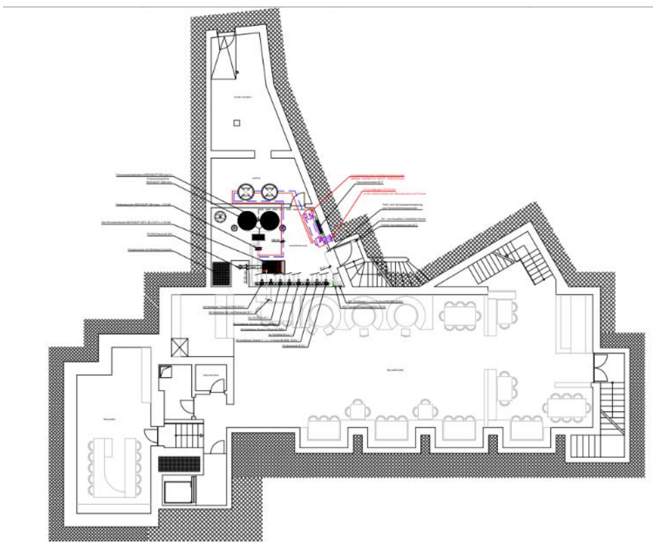


Figure 3 & 4. The hotel outdoor units installation, plans and picture

Figure 5 & 6. The WLHP on the floor plan and installed in the hotel room

3. Energy efficiency and performance gains, while saving energy and costs

The Water Loop Heat Pump (WLHP) system installed in the hotel has been operational since May 2025, and its performance has been under continuous observation to assess real-world efficiency and validate design assumptions. Although the monitoring campaign is still ongoing, the initial data collected between May 20 and July 10, 2025 (51-day period) provides valuable insights into the system's behavior under actual operating conditions.

During this period, the total thermal demand on the water loop was measured at 6,831 kWh, reflecting the combined cooling requirements of the building's occupied spaces. The system's primary generation units, two heat pumps, operated with a setpoint of 25 °C and achieved a Seasonal Energy Efficiency Ratio (SEER) of approximately 7.1, conservatively derated to account for actual operating conditions. Their estimated electrical consumption over the measurement period was 962 kWh.

The secondary WLHP terminal units, responsible for delivering cooling to individual zones, operated within a nominal temperature range of 30–35 °C, but were derated to reflect actual operating conditions of 25–30 °C. These units achieved a SEER of approximately 6.1, with an estimated electrical consumption of 941 kWh. The total electrical input for the system during the monitored period was therefore 1,903 kWh, while the cooling energy delivered to the spaces was measured at 5,738 kWh, resulting in a conservatively estimated system EER of 3.0.

These results compare favorably with the original design assumptions, which projected an annual cooling demand of 9,236 kWh and an annual electrical input of 3,192 kWh, corresponding to a design EER of 2.89. When benchmarked against the reference energy model, which estimated a cooling demand of 4,729 kWh for June and 7,223 kWh for the combined period of June and one-third of July, the actual delivered cooling energy of 5,738 kWh was approximately 20.6% lower than the modeled demand. This discrepancy suggests a more efficient system performance than anticipated.

Importantly, these results were achieved under challenging operating conditions, including high occupancy rates exceeding 90% throughout the measurement period. Indoor temperature setpoints were maintained 24/7, with guest rooms set between 20–24 °C and corridors at 26 °C, which are lower than the design assumptions and imply a higher cooling load. Despite this, the system maintained stable operation and delivered cooling efficiently, with electrical consumption remaining significantly below predicted levels.

The WLHP system has demonstrated better-than-expected energy performance under real operating conditions. The combination of high-efficiency heat pumps optimized hydronic design, and responsive terminal units has resulted in a system that not only meets but exceeds its design targets. Continued monitoring will provide further validation, but the initial data strongly supports the effectiveness of the retrofit and its contribution to improved energy efficiency and occupant comfort. Performance in heating and heating data will be available in 2026 after the first year of operation and will allow for further comparison between projected data and real-life data.

Table 1. System performance data comparison between project design estimations and measured performance

System performance	Designed	Measured	Variance (%)
System EER	2,89	3	103,8
Electricity consumption (kWh)	3192	1903	59,6
Cooling Energy Delivered (kWh)	9236	5738	62,1

4. Scaling up building renovation in Europe, multiple applications for WLHP

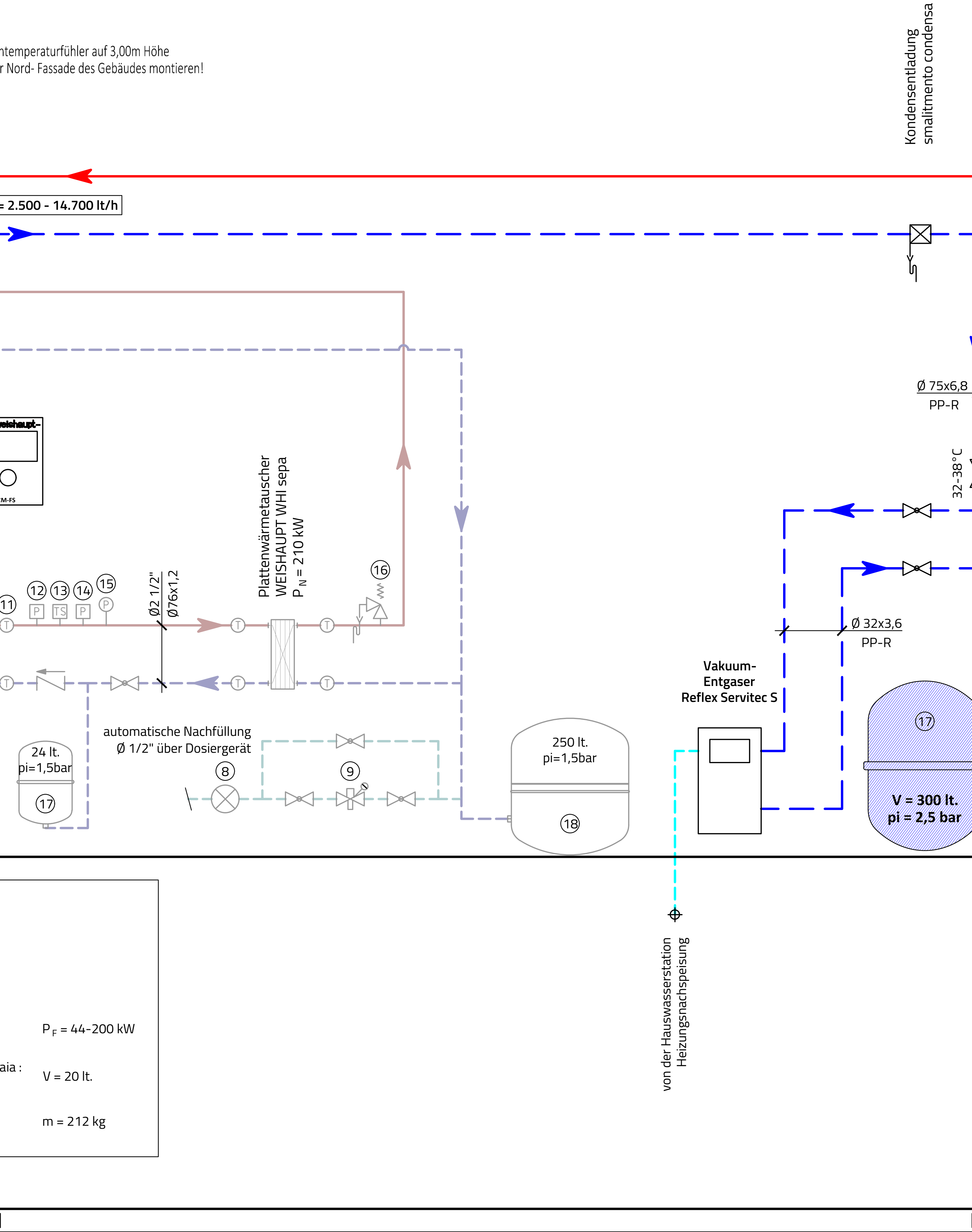
Retrofitting existing buildings with modern, renewable-based heating and cooling systems presents a range of technical and logistical challenges, particularly when the original infrastructure is based on a 2-pipe heating-only configuration. More conventional cooling and heating solutions typically require substantial modifications to the building's mechanical and architectural systems. These include the installation of new supply and return lines, integration of generators or condensing units with terminal units in individual rooms, construction of condensate drainage networks, and often invasive work involving walls, ceilings, and floors. In operational buildings such as hotels or multi-family residences these interventions can be highly disruptive and difficult to schedule without affecting occupants. The WLHP system offers a technically robust alternative by enabling the conversion of a 2-pipe heating system into a functional 4-pipe heating and cooling system without major structural work. The existing high-temperature heating pipes are repurposed into a low-temperature water loop, circulating fluid at neutral temperatures (typically 20–30 °C). This loop acts as a shared thermal reservoir for decentralized water-to-air heat pump units installed in individual rooms and common areas. These units operate independently, providing heating or cooling based on local demand, and are designed to replace radiators with minimal spatial and acoustic impact.

From a hydronic and thermodynamic perspective, the WLHP system introduces a bidirectional energy exchange mechanism. Each terminal unit can either extract heat from or reject heat into the loop, depending on the mode of operation. This allows for simultaneous heating and cooling across different zones and supports energy recovery during intermediate seasons. For example, heat rejected by units in cooling mode can be utilized by units operating in heating mode, improving the overall system coefficient of performance (COP) and reducing net energy input. In renovation contexts, WLHP systems offer significant advantages. They preserve the existing distribution infrastructure, avoiding the need for demolition or reconfiguration of risers and branches. Terminal units are installed in place of radiators, and the central heat source can be replaced with high-efficiency heat pumps, either air-to-water or connected to district heating/cooling networks. This approach eliminates the need to modify the building envelope, which is often the costliest and technically complex aspect of retrofit projects.

The system architecture supports decentralized control, allowing each room to be conditioned independently. This is particularly beneficial in buildings with variable occupancy patterns, such as hotels or residential complexes. Thermo-hygrometric comfort, including heating, cooling, and dehumidification, is achieved without the need for centralized air handling units or ductwork, simplifying maintenance and improving operational flexibility. WLHP systems are also compatible with collective renewable energy sources. In multi-family buildings, they can be coupled with centralized air-to-water heat pumps, enabling efficient load distribution and peak shaving. In district energy networks, WLHP terminals can reduce the required capacity of central plants and facilitate a transition to low-temperature distribution, which enhances system efficiency and supports decarbonization goals.

5. Conclusions

The WLHP technology provides a technically sound and minimally invasive pathway for upgrading legacy heating systems to modern, renewable-compatible climate control solutions. Its modularity, compatibility with existing infrastructure, and support for decentralized operation make it particularly suitable for renovation projects where conventional solutions are not always practical or economically interesting. Measured performance data from operational WLHP installations indicate energy efficiency gains in the range of 20–30% compared to conventional systems. These gains are achieved through improved part-load performance, energy recovery, and reduced distribution losses. Additionally, WLHP systems contribute to improved building energy ratings and lower operational costs, without requiring envelope upgrades or architectural modifications.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