Technology Innovation Project

Closing Project Brief

TIP 341: Waste Water Heat Pump Design and Pilot Study

Context

The largest single energy use in new mid- and high-rise multifamily buildings in the Pacific Northwest is domestic water heating. With the regional shift towards growing residential urban centers, the Northwest is seeing a boom in new apartment construction. This project follows directly from a previous Ecotope project developing the use of air-source heat pump water heaters, or reverse cycle chillers (RCC), located in below-grade parking garages of mid-rise multifamily buildings in Seattle. That project effectively delivered systems with annual coefficients of performance (COPs) of 2.6-2.8 using the underground garage as a heat source. In response, multifamily developers in Seattle are asking for RCCs as the system of choice in their new buildings. This project will produce hot water from a much warmer reservoir (~70°F) potentially yielding overall COPs of 5-6.

Description

Ecotope, in partnership with Vulcan Real Estate, and Seattle City Light, planned to design, pilot, and verify, a heat pump water heating system for large multifamily buildings using the building sewage as a heat source. The waste water heat pump (WWHP) was to recover waste heat streams from the building and heat water for domestic use at extremely high performance levels. The system was built in a large multifamily building with approximately 400 apartment units.

The equipment under study solves the issue of increasing the space-heating load of residences served by integrated heat pump water heaters. Using CO_2 refrigerant technology promises to provide cost-effective high performance over a wide range of temperatures, representing a significant increase in heat pump water heater performance over existing technology.

To develop the WWHP system, Ecotope and partners completed the project in three parts:

1) Feasibility research with design concept and Building Energy Flow Model;

2) Full system design for building installation and supporting calculations for incentive funding; and

3) Pilot construction and installation; measurement and verification; and project reporting.

Benefits

The project involves design of an improved water heating technology and will research better heat recovery optimization controls and algorithms. Building off lessons learned in the RCC project, this project further optimizes the control of the heat pumps and hot water storage and the handling of the hot water recirculation. Development of these control pieces is crucial to the further development and optimal performance of air and water-source heat pump water heating systems in large buildings

Accomplishments

This project taps a previously unutilized, large, concentrated source of heat energy in multifamily buildings. The amount of heat rejected to the sewer directly matches the demand for heat in the domestic hot water system. With this technology the heat from hot water going down the drain will be captured and recycled back into the building hot water.

The project designed and piloted a new, extremely low energy water heating system that can be deployed by designers and developers in buildings across the Northwest. The concept is to locate a waste water holding vault on the ground floor or first level of parking in the building. All sewage from the multifamily units was directed to the vault which will provide the heat source for a heat pump water heater. The vault houses stainless steel heat exchanger plates, used by the heat pump, to extract heat from the vault and heat a bank of domestic water storage tanks.

Deliverables

Part 1 deliverable was the feasibility study. The study reports on the background research, system sizing results, schematic design, and the potential for energy savings and incentives

Part 2 deliverables included Calculations of predicted costs and benefits of the system.

Part 3 deliverable is the Final Report on the Waste Water Heat Pump Project summarizing system design, costs, and verified savings. Additionally the report includes system design guidelines which can be used in future buildings to achieve the most efficient systems. Likewise, the report includes suggestions for revised hot water system sizing guidelines.

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Project Start Date: October, 2015

Project End Date: January, 2021

For More Information Contact:

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Reports, References, Links

Participating Organizations

Ecotope
Vulcan Real Estate
Seattle City Light

Conclusions and Recommendations

The design and implementation of a wastewater-based heat pump water heating system is complicated, but the underlying physics of the process have proven out at Sitka Apartments. The system was designed as a single-pass system, where the primary heating loop includes R134a water-to-water heat pumps and a heat exchanger system installed inside the wastewater vault. The heated water is stored in several large, well-insulated tanks. The tank and piping layout optimize the primary heat pump efficiency via tank stratification (which means the coolest water is consistently heated by these heat pumps). To keep water consistently at desired service (tap) temperatures, a separate air-to-water heat pump is used rather than passing this warm water back through the primary loop. This design was arrived at after several alternate designs had been engineered and metered by Ecotope. Ecotope also designed and oversaw installation of a measurement and verification systems that allowed remote access to data and calculation of real-time operational efficiency.

When the primary water heating loop and recirculation (temperature maintenance loop) are running as designed, the system meets the demand of the 500-occupancy apartment complex using only heat pump heat transfer; the overall system efficiency in these conditions is about 2.6 (with the primary equipment efficiency alone operating with a COP of about 2.9). Given the cost of the system and the energy savings vs an electric resistance system, the overall simple payback for the added cost of the system (included added engineering) is less than 5 years (using the Northwest's very low commercial electricity rate of $0.08/kWh).

Because of the amount of custom engineering required for this system, and because of ongoing concerns about the condition of the primary heat exchanger and control components, the type of system cannot be regarded (yet) as a turnkey solution for efficient heating of hot water in multifamily buildings. In mild climates like Seattle, wastewater heat pump systems do not yield sufficient efficiency improvement compared to air-source CO2 systems.

Several additional points deserve mention

- Alarm notifications and feedback loops (M&V) are essential for new technologies and systems like this.
- System sizing is critical for all HPWH systems serving Multifamily buildings with a central heat plant configuration. One such tool, optimized for multifamily buildings, is found at Ecosizer.ecotope.com.
- Wastewater management is a significant challenge in wastewater heat recovery systems like the one at Sitka. More mitigation techniques are likely needed to prevent fouling of the source heat exchanger system. These are needed for turn-key systems. The product manufactured by Sharc industries is likely a viable technology for turn-key applications.
- The technology is more applicable to cold climates since it provides a relatively constant high temperature source of heat on an annual basis. Therefore, the heat pumps do not have to be oversized to meet the DHW load at cool ambient air temperature while operating at a reduced capacity and efficiency.