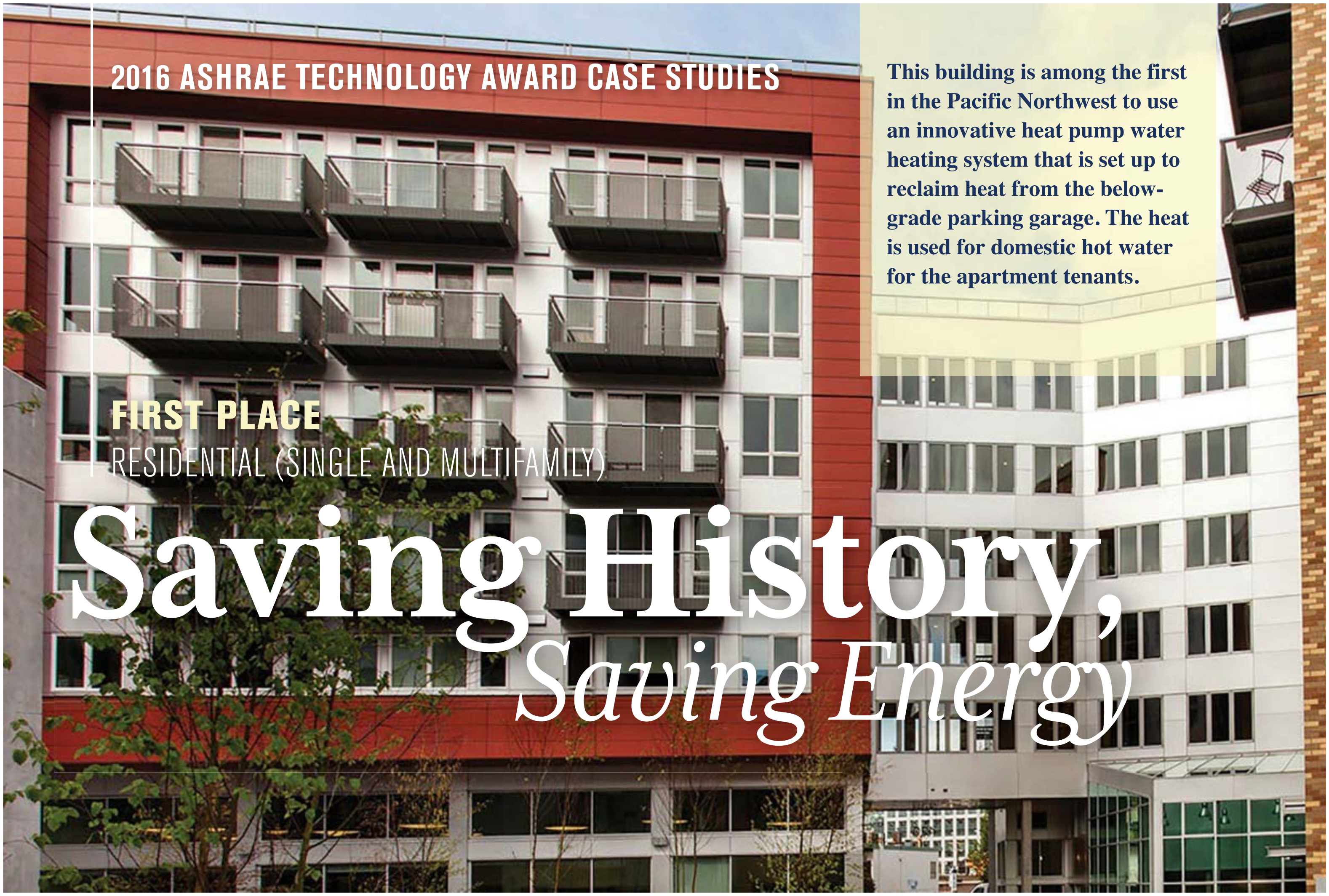


2016 ASHRAE TECHNOLOGY AWARD CASE STUDIES

This building is among the first in the Pacific Northwest to use an innovative heat pump water heating system that is set up to reclaim heat from the below-grade parking garage. The heat is used for domestic hot water for the apartment tenants.

FIRST PLACE
RESIDENTIAL (SINGLE AND MULTIFAMILY)

Saving History, *Saving Energy*

BY JONATHAN HELLER, P.E., MEMBER ASHRAE

BUILDING AT A GLANCE

Stack House Apartments

Location: Seattle

Owner: Stack House Acquisition LLC

Principal Use: Multifamily residential

Includes: Apartments, lobby, club room, business center, fitness, parking garage, retail, restaurant, office

Number of Employees/Occupants: 370

Gross Square Footage: 428,300

Conditioned Space Square Footage: 330,500

Substantial Completion/Occupancy: January 2014

Occupancy: 100%

National Distinctions/Awards: LEED for Homes Platinum certification; 2013 LEED for Homes Project of the Year.

The Stack House Apartments project is setting the tone for high levels of energy efficiency and sustainability in the rapid redevelopment of South Lake Union, one of the fastest growing neighborhoods in Seattle. It includes two new multifamily buildings and one adaptive reuse of a historic laundry building.

The project includes 278 new apartment units and covers an entire city block. The apartments are among the most energy efficient in the Pacific Northwest with measured energy use intensity (EUI) of 20 kBtu/ft^2·yr (227 MJ/m^2·yr) for the West Building and 27 kBtu/ft^2·yr (306 MJ/m^2·yr) for the Southeast Building.

Jonathan Heller, P.E., is president of Ecotope, Seattle.

Photo: Spike Mafford

Photo: Spike Mafford

ABOVE Reverse cycle chillers in parking garage.

LEFT Hot water distribution piping with digital thermostatic mixing valves.

The project also saved a beautiful 100-year-old commercial laundry building as office and restaurant space to help retain some of the historic character of the neighborhood. This includes a monumental old smokestack that was reinforced and retained as a landmark and gives the project its name.

Innovation

Stack House incorporates innovative mechanical systems such as a central heat pump water heating system in the largest of the two multifamily buildings, compartmentalization of the central circulation areas, and rainwater catchment and reuse for urban agriculture on the roof.

The historic Supply Laundry Building took part in the City of Seattle's pilot of an outcome-based energy code; the first program in the nation to predicate energy code compliance on post-occupancy proof of highly efficient operations. The project also participated in a storm water treatment pilot project with Seattle Public Utilities by including two biofiltration swales providing primary treatment to storm water runoff from a 6 ft (1.8 m) diameter storm water pipe draining street runoff from the Capitol Hill neighborhood before discharging to Lake Union.

The project achieved ambitious targets for energy and water use reductions. These included:

- 50% energy reduction over ASHRAE Standard 90.1-2007 baseline for multifamily buildings; and
- 60% water use reduction over baseline for multifamily buildings.

These targets were achieved by focusing the design on known areas of high energy use:

Domestic Hot Water. The largest end-use in typical new Seattle midrise multifamily buildings is the DHW system.[1] The project uses an innovative reverse cycle chiller (RCC) system for the larger West Building to reduce the DHW energy use by a factor of three compared to individual electric water heaters or a central gas boiler.[2]

Apartment Space Heating. The majority of mid-rise apartments in Seattle are heated with electric resistance. Space heating energy use was reduced by improved glazing and by providing ductless heat pumps (DHPs) for 33% of the apartments. Apartment units facing south and west on upper floors were selected to receive DHPs, as these apartments have the highest seasonal cooling loads. DHPs reduce heating energy by approximately a factor of 3.0 while adding only a very small amount of cooling energy in the relatively mild Seattle summer.

Common Space Heating. Tempering of ventilation air for the residential corridors in a typical new Seattle apartment with double-loaded corridors consumes as much energy as all of the apartment heating put together.[1] This is due to relatively large quantities of ventilation air continuously tempered by rooftop makeup air units; typically more than double the air required by ASHRAE Standard 62. The Stack House project targeted this portion of the energy use in a couple ways.

First, the primary circulation stairs and elevator core are unconditioned and separated from the double-loaded corridors by weather-stripped doors. This creates a transition buffer zone between inside and outside for primary circulation, significantly reduces the envelope heat loss, and eliminates the leakiest portions of the corridors from the heated space (the stair and elevator towers). The ventilation in the fully conditioned portion of the corridors is limited to 150% of the ASHRAE Standard 62 minimum requirement, and the corridors are conditioned with ductless heat pumps.

Lighting and Appliances. No incandescent lighting was used in the project. LED and fluorescent lights allowed lighting power to be reduced to less than half of the code allowable levels. Motion sensors were used to control lights throughout residential common areas and in the drive aisles of the parking garage. All appliances are Energy Star rated. Low-flow plumbing fixtures were also used throughout.

Table 1 details the modeled and actual energy use for the residential portion of the project shown as energy use intensity (EUI) in kBtu/ft^2·yr.

This building is among the first in the Pacific Northwest to use an innovative heat pump water heating system set up to reclaim heat from the below-grade parking garage to heat domestic hot water for the apartment tenants (*Figure 1*).

In 2009, the author's firm completed a feasibility study for the Bonneville Power Administration's Emerging Energy Efficient Technology program.[3] The study examined the use of reverse cycle chillers (RCC) to produce domestic hot water for multifamily buildings in the Pacific Northwest.

An RCC is commercial chiller technology set up to operate in reverse as a heat pump water heater and equipped with a double-walled copper heat exchanger so that it can process potable water directly. The RCCs selected use R-134a refrigerant, which has performance limitations at supply air temperatures below about 40°F (4.4°C), but is able to produce water hot enough for residential domestic water purposes (120°F to 160°F [49°C to 71°C]). The primary innovation in this design is to take advantage of the thermal buffering effects of the below-grade parking garage to allow the use of this heat pump technology year-round in the Seattle climate.

Rainwater cistern and historic smokestack in public courtyard.

Spike Mafford

The thermal buffering of the garage derives from the heat provided by the lights, warm vehicles, heat loss from the building and piping systems, and most importantly from the large concrete surface area connected to the ground. Deep ground temperature in the Seattle area is constant at about 52°F (11°C). Temperature measurements of a similar system in a nearby building have not dropped below 50°F (10°C) in the parking garage, even during peak winter cold snaps. 50°F (10°C) is well within the very efficient operating range of these heat pumps.

TABLE 1 Modeled, actual energy performance (kBtu/ft^2 · yr).

BUILDING	90.1 BASELINE	PROPOSED	ACTUAL	PERCENT SAVINGS
Southeast	41	29	27.1	34
West	48	28	19.8	59
Total	46	28	22.2	51

By using the parking garage air as the source, these heat pumps function year-round at an average delivered coefficient of performance (COP) of about 2.6. An electric resistance commercial water heater is used only as emergency back-up in the event of equipment failure. Since the RCCs take garage air and exhaust it directly to the outside, they also act as the first stage of garage exhaust; harvesting heat out of the air before exhausting it to the outside. This allowed the garage exhaust fans to be downsized significantly, and they function only as back-up (they are rarely triggered by the CO control system).

The configuration of the hot water storage and the controls of the RCCs is another innovative aspect of this design. The storage is designed as a series of small tanks to increase the ability to maintain temperature stratification from the cold entering water end to the hot supply water end. The RCCs are set up in a "single-pass," rather than a "multi-pass," mode. This means that instead of a constant flow and constant ΔT through the RCCs, they are set up with a modulating flow control valve and a refrigerant pressure setpoint.

This allows for a nearly constant output temperature of ~135°F (57°C) regardless of the incoming water temperature. This allows the heat pumps to provide 100% of the water heating energy by eliminating the need for a "finishing tank" because water of usable temperature is delivered directly to the top of the last tank, recovering usable water immediately rather than slowly reheating the entire storage volume in a multi-pass configuration. A buffer tank was added upstream of the RCC to ensure that it is always receiving the coldest water possible (*Figure 2*).

As stated earlier, the Supply Laundry Building was the first to participate in a pilot Outcome-Based Energy

Code.* This means that the typical prescriptive energy code requirements for the building were mostly waived in favor of a promise from the developer that the building would achieve a performance of at least 50% better than the ASHRAE Standard 90.1-2007 baseline. This performance must be proven with 12 months of actual bills from the fully occupied building. If the building falls short of the target, an energy audit and repairs must be completed to address the increased energy use. This method ensures that not only is the building designed to be efficient, but focus is placed on guaranteeing that the operations and maintenance actually deliver energy-efficient operations.

Another innovative aspect of this project is its participation with the Seattle Public Utilities to include a large biofiltration swale along two sides of the property. The swales drain the storm water runoff to daylight from the Capitol Hill neighborhood and run it through a series of swales planted with wetland plant species selected for their ability to absorb contaminants from the storm water before it is discharged to Lake Union.

The swales will treat an average of 190 million gallons (719 million L) of runoff annually, providing a planted buffer between the project and the street and cleaning up the urban lake, which is on the migration path of endangered regional salmon species.

FIGURE 1 Reverse cycle chiller configuration in parking garage.

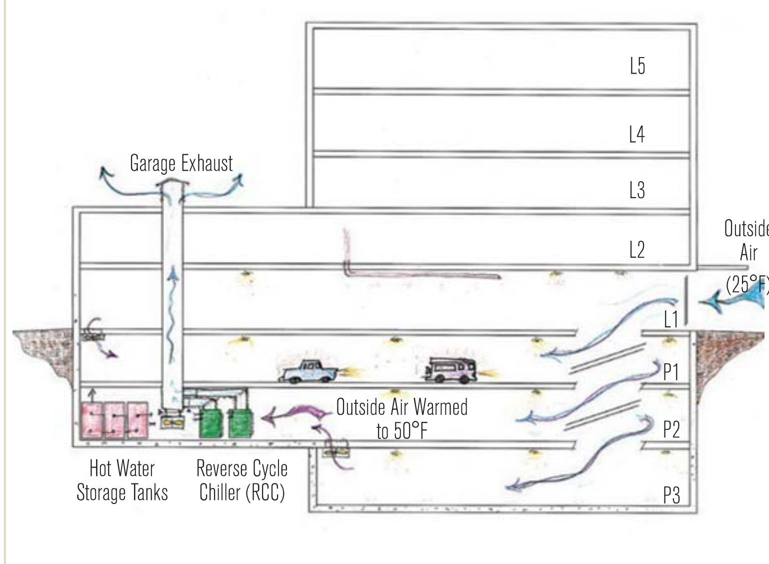
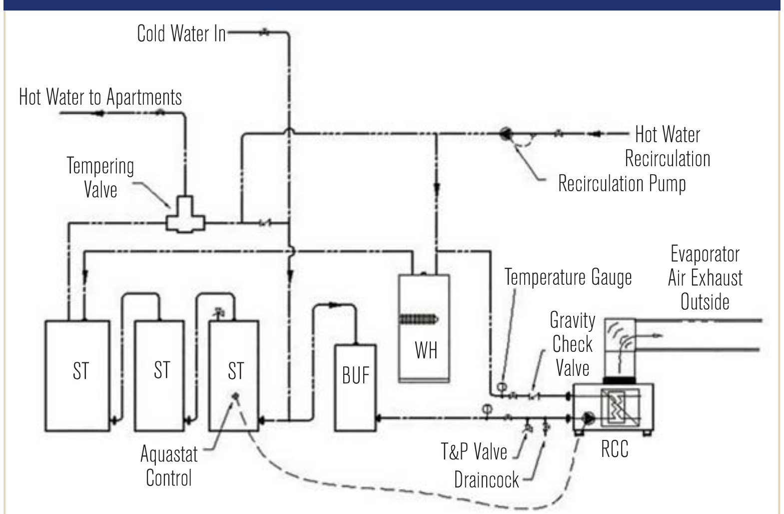


FIGURE 2 Reverse cycle chiller.



Cost Effectiveness

While the highly efficient mechanical systems in this building increased the capital cost of the project, the developer determined that they were well worth the extra investment. The energy-efficiency measures were primarily responsible for the project achieving LEED Platinum certification, which was in turn a major marketing point for the building, helping it to fill up in a very short period of time.

The RCC system was a win-win economic strategy for both the tenants and the developer. The incremental cost of the RCC system was approximately $100,000. The local utility rebated just over 50% of that for a net cost to the developer of $47,000. Including the cost of capital, the developer was able to recoup their investment in the RCC system by charging an additional $3/month in rent per apartment. Meanwhile, the tenants are savings approximately $8/month on its electric bill, so by paying slightly higher rent they are each actually saving $5/month overall. This project was an excellent example of how investments in energy efficiency can benefit both the tenants and the developer.

* This has since been adopted as a path in the Seattle Energy Code, making it the first energy code in the nation to tie the energy performance as measured by actual bills to the energy code compliance of the building.

Environmental Impacts

This project has multiple positive environmental impacts for the tenants, the neighborhood, and the planet. The energy savings are significant; placing this project among the most energy-efficient multifamily buildings in the region.

The project includes 8,000 ft^2 (743 m^2) of green roof. This filters rainwater, reduces the urban heat island effect, and provides bird and insect habitat in the city. Half of one roof is devoted to urban agriculture, with a professional gardener distributing free organic vegetables to the tenants of the building and to local nonprofit charities. This goes a long way toward building tenant loyalty and creating a very low turnover rate.

A rainwater catchment system collects rain from the roof and provides 43,000 gallons (162 773 L) of storage to supply the irrigation for the urban agriculture and other landscaping. This reduces the demand on the city water supply and slows the discharge of storm water to the sewer system. The biofiltration swales significantly reduce the contaminants discharged to the lake, and provide additional greenery and habitat. The project also includes a beautifully landscaped park-like pedestrian courtyard open to the public.

Lessons Learned

RCC System. Since the RCC system is a new application of this type of equipment in the region, the design, specification, procurement, installation, and commissioning of the system was new to everyone involved. Additional time is required in everyone's schedules whenever new technologies are introduced into a project. Balancing the hot water circulation temperature, RCC output water temperature, and supply water temperature from the tempering valves was critical to getting the system to satisfy the tenants' water demands, maintain a high coefficient of performance (COP), and not trigger nuisance high head pressure failures from the compressors.

Commercial building outcome-based energy code. Since space in the commercial portions of the project were leased to tenants who installed their own mechanical systems, it was not possible to have total control over the HVAC system design for those spaces. To ensure a high level of energy efficiency (of particular importance in the Supply Laundry Building due to the outcome-based energy code requirements), tenant guidelines for the HVAC system design were developed. Guidelines must be specific enough to achieve the efficiency goals, but not so restrictive that they discourage tenants from leasing the space. Through the course of this project we learned that spending time on the details of those tenant guidelines is critical to guarantee an efficient outcome. The final HVAC design in this case ended up as a negotiation between Ecotope as the Design-Assist consultants and the engineers hired by the commercial tenant to achieve the targets originally set forth.

The project developer had a clear vision to create a project to showcase cutting-edge environmental strategies. It took big risks by incorporating new and innovative technologies, programs, and designs into the project. But by sticking to its goals and trusting its team, it ultimately produced a great project that provides benefits for everyone.

Acknowledgments

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