

## 2014 ASHRAE TECHNOLOGY AWARD CASE STUDIES

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The King County Housing Authority Central Annex renovated a former big box retail store into a typical modern office. The building uses energy recovery ventilation with EC motors and a variable capacity heat pump system with 50 zones. Another feature is low lighting power design.

**SECOND PLACE**  
COMMERCIAL BUILDINGS, NEW

# Revamping *Ho-Hum Strip Mall*

BY SHAWN ORAM, P.E., ASSOCIATE MEMBER ASHRAE

### BUILDING AT A GLANCE

#### King County Housing Authority Central Annex

**Location:** Tukwila, Wash.

**Owner:** King County Housing Authority

**Principal Use:** Office

**Includes:** Private and Open Offices, Conference Rooms, Restrooms, Break Room

**Employees/Occupants:** 118 people

**Gross Square Footage:** 35,200

**Conditioned Space Square Footage:** 35,200

**Substantial Completion/Occupancy:** December 2012

**Occupancy:** 100%

Revamping a ho-hum strip mall building into a high performance office building with a modest budget is possible if designers are focused on energy efficiency and costs from the beginning. King County Housing Authority turned a 1978 building into a high performance office and achieved a low energy use intensity (EUI) of 26.7 kBtu/ft<sup>2</sup>·yr (303 MJ/m<sup>2</sup>), making it one of the most energy efficient office buildings in the region. This was accomplished with a total construction budget of only \$95/ft<sup>2</sup> (\$1023/m<sup>2</sup>) of which \$14/ft<sup>2</sup> (\$151/m<sup>2</sup>) was spent for a 50-zone HVAC system.

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ABOVE Controls system.

LEFT Open office space.

## New Home for a Public Housing Agency

The King County Housing Authority jumped at the opportunity to purchase a former big box retail store that became available next door to its existing headquarters in Tukwila, Wash., (11 miles south of Seattle). At that time, the public housing agency's Section 8 program employees were housed in leased office spaces dispersed throughout the Seattle area. The purchase of the 34-year-old building would bring together previously separated departments and promote an integrated agency culture. However, the timeline and budget were extremely constrained to complete the renovation before the existing leases expired.

The 35,200 ft<sup>2</sup> (3270 m<sup>2</sup>) remodeled space contains all major functions of a typical modern office. The project goals were to create an affordable, energy efficient, net zero energy ready building. The design team delivered on this goal, turning an otherwise unremarkable and inefficient existing building into one of the most energy efficient office buildings in the region for a total construction cost of \$95/ft<sup>2</sup> (\$1023/m<sup>2</sup>).

## Targeted Measures for Proven Performance

Because of the compressed timeline and modest budget, in-depth energy modeling was not an option. Therefore, the design team chose to target proven energy-efficiency measures using careful design and readily available off-the-shelf technology assembled with an explicit focus on performance. The entire HVAC system construction budget came in at less than \$14/ft<sup>2</sup> (\$151/m<sup>2</sup>).

The existing headquarters building in the adjacent property and the new expansion are nearly identical in size and heat loss characteristics, yet differ dramatically in energy use and equipment approach. The existing headquarters is operating at an EUI of 80 kBtu/ft<sup>2</sup>·yr (908 MJ/m<sup>2</sup>·yr). The new expansion is

operating on less than one-third of the energy budget at an EUI of 26.7 kBtu/ft<sup>2</sup>·yr (303 MJ/m<sup>2</sup>·yr). This is 70% less than the Commercial Building Energy Consumption Survey (CBECS) 2003 national average for office buildings of this size at about 93 kBtu/ft<sup>2</sup>·yr (1056 MJ/m<sup>2</sup>·yr).

The primary driver for this extremely low energy use is a "Design for Off" approach to the HVAC systems. The HVAC systems were selected and designed to be shut off whenever possible. Ventilation is provided with a dedicated outdoor air system (DOAS) that operates during all occupied hours. Heating and cooling is provided in 50 separate small control zones. This allows for the heating and cooling equipment to be turned off completely unless there is a call for heating or cooling at the zone level. Controls are set up to create a 5°F (2.7°C) dead-band between heating and cooling setpoints to eliminate cycling of equipment between heating and cooling. These measures dramatically reduce the HVAC distribution energy as seen in *Figure 1*.

## Envelope Performance

Early design efforts focused on maximizing the energy performance of the building and to provide high indoor air quality within the project budget. The largest energy efficiency expense was replacing the existing single-pane aluminum frame glazing with high performance low-e glazing with a U-factor 20% better than ASHRAE/IESNA Standard 90.1-2007 requirements (U 0.40). The glazing SHGC of 0.18 is less than half the maximum allowed by Standard 90.1-2007 and was specifically selected to reduce cooling loads from the large West-facing façade. Triple-glazed translucent skylights were added to provide daylighting to interior corridors and office zones without significantly increasing heating and cooling requirements.

Construction schedule and budget precluded significant improvement to the rest of the existing building

envelope. Existing walls were insulated with R-11 fiberglass. Some exterior walls were furred out and brought up to R-19. The roof is insulated to only R-20 (no work was done on the roof). These insulation levels are well below current Washington State Energy Code for new construction and below Standard 90.1-2007 requirements. After a cost-benefit analysis, it was determined that investing in a high performance HVAC system could offset the relatively poor performance of the building envelope.

### Dedicated Outdoor Air System

The built up energy recovery ventilation (ERV) system was designed and selected for very low fan energy and high heat recovery effectiveness. The ECM fans provide 100% outdoor air ventilation at less than 0.75 W/cfm. The ERV system needs only small (inexpensive) ducts to deliver air directly to all habitable spaces while continuously exhausting stale air from specific high pollution locations (conference rooms, large offices, restrooms, kitchen, copy room, janitor, server room) during occupied hours.

The apparent sensible heat recovery effectiveness of the ERV is greater than 86%. This allowed the elimination of a reheat system in the ventilation supply airstream. Even at design-day temperatures (24°F [-4°C]), the ERV delivery temperature is in the 60s.

### Zoning for Energy Efficiency and Control

The variable capacity heat pump (VCHP) system was designed with 50 discreet control zones, allowing for a high degree of individual occupant control and comfort. Since the design completely separates the ventilation system from the heating and cooling system, this allows the fans for the zonal VCHP system to cycle only when there is a call for heating or cooling in the serviced zone. Fan energy for the delivery of heating and cooling is thereby reduced to a small fraction of a typical building. In addition, most spaces are served with ductless T-bar ceiling mounted indoor heat pump equipment. Ductless high efficiency fans in this equipment operate at a small fraction of the fan energy required by typical fully ducted fan coil systems or VAV systems.

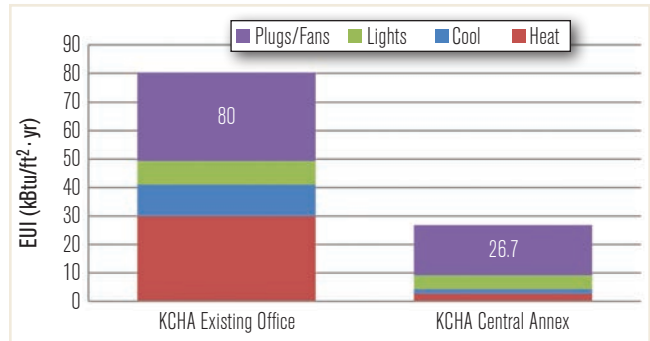


FIGURE 1 KCHA energy use comparison.

The VCHP system achieves an average annual COP of about 3.0 in heating without the need for any auxiliary heat source. The heat pumps maintain nearly full output capacity to temperatures well below Seattle's outdoor heating design temperature of 24°F (-4°C). The building includes both interior and perimeter zones and during

the swing seasons the VCHP system has the ability to provide direct heat recovery if some zones are in heating while others are in cooling. While the VCHP heat recovery option has the potential to significantly increase efficiency, in practice we have found that the system rarely enters this heat recovery mode. When the building loads are controlled, the true benefits of VCHP are realized: excellent efficiency at full and part load operation and low fan power energy. No DDC

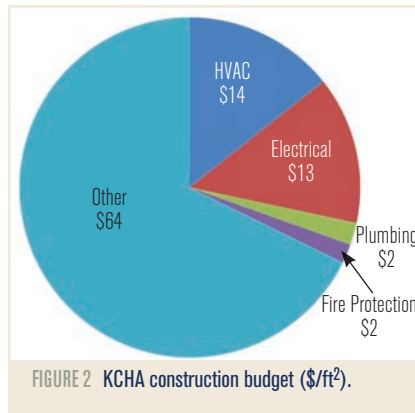


FIGURE 2 KCHA construction budget (\$/ft²).

system was needed as the VCHP control system was used as the building control system for the ERV and heating and cooling scheduling.

### Indoor Environmental Quality

Indoor environmental quality was an important design requirement expressed by the client in the predesign phases. The project sought to provide ample filtered outdoor air, low off-gassing materials, daylighting in main circulation spaces, low noise variable speed equipment, and occupant control of their spaces.

The building uses three highly efficient counter-flow air-to-air energy recovery ventilators for all zones, with 100% outdoor air sized per Standard 62.1-2010. Budget constraints didn't allow for variable airflow volumes in conference rooms and modeling confirmed that the

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1970s strip mall was transformed into a high performance office building.

slight hit for delivering peak airflow to empty conference rooms was not going to impact system performance if conditioning of this air is not required and the heating system has a COP of 3.0. This DOAS constant volume design decision simplified the design significantly and was a key piece to reducing costs. The ERVs are located in an isolated mechanical mezzanine for sound control. Fans are isolated from the structure and ducts have flexible connections in addition to sound lining within the mechanical space. Outdoor air is filtered to MERV 10 and delivered to all zones on a continuous basis during occupied hours.

Zero VOC paints and carpets are used throughout each space; all woodwork is non-composite with zero VOC finishes. Ample daylighting is provided for all main circulation areas via high efficiency skylights located above specially designed lightshelves to further reduce lighting energy. General building lighting was designed at 0.55 W/ft<sup>2</sup> (5.9 W/m<sup>2</sup>) with task lights provided at each work station.

### Operations & Maintenance

O&M is extremely simple for this system. The VCHP controls are scheduled to run the ERV system from about one hour before opening until about one hour past closing. The indoor temperature setpoints toggle between occupied and unoccupied setpoints. Each of the 50 interior zones has an accessible thermostat with separate heating and cooling setpoints that can be directly adjusted temporarily by the occupants. This significantly reduces temperature-related complaints as each zone has individual control of the thermal comfort.

The ventilation system requires little regular maintenance. The ERVs are centrally located in an easily accessible mechanical mezzanine above the restrooms.

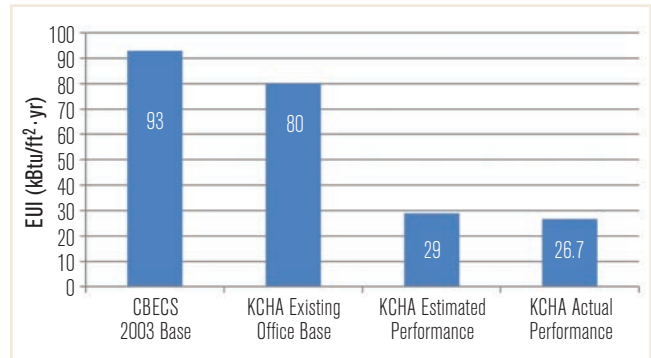


FIGURE 3 KCHA EUI comparison.

The mezzanine has ample head room, lighting, and working clearances. To keep the heat exchange cores of the three ERV units clean, filters are located before each side entry/exit location (four filters total, three on each exhaust run and one shared larger filter on the outdoor air intake). These filters require quarterly replacement.

The indoor fan coil units associated with the VCHP system cycle only on a call for heating or cooling, so their filters require cleaning only in the spring and fall. The heat pump compressors are located on the roof and require diagnostic tests and refrigerant charge check every two years.

### Cost Effectiveness

This project was extremely cost effective. The entire renovation was completed for a construction cost of \$95/ft<sup>2</sup> (\$1023 m<sup>2</sup>). The HVAC system was installed for \$14/ft<sup>2</sup> (\$151 m<sup>2</sup>). This is significantly less than installation of a traditional VAV system for about \$20/ft<sup>2</sup> (\$215/m<sup>2</sup>). In addition, the project will save roughly \$35,000/yr in energy operating costs compared to a typical office building design. This demonstrates that careful design, sizing, and energy conservation measures can allow the HVAC system to be smaller, simpler, cheaper, and more energy efficient.

The electric utility provided energy conservation incentives to help pay for the lighting controls, improved glazing performance, and commissioning services.

### Environmental Impacts

With an additional investment of less than \$20/ft<sup>2</sup> the building could accommodate enough solar panels to generate as much energy as the building uses annually. The roof structural system was evaluated and is capable of supporting the 265 kW of solar panels (76% of the roof area) necessary to make this building net zero energy.

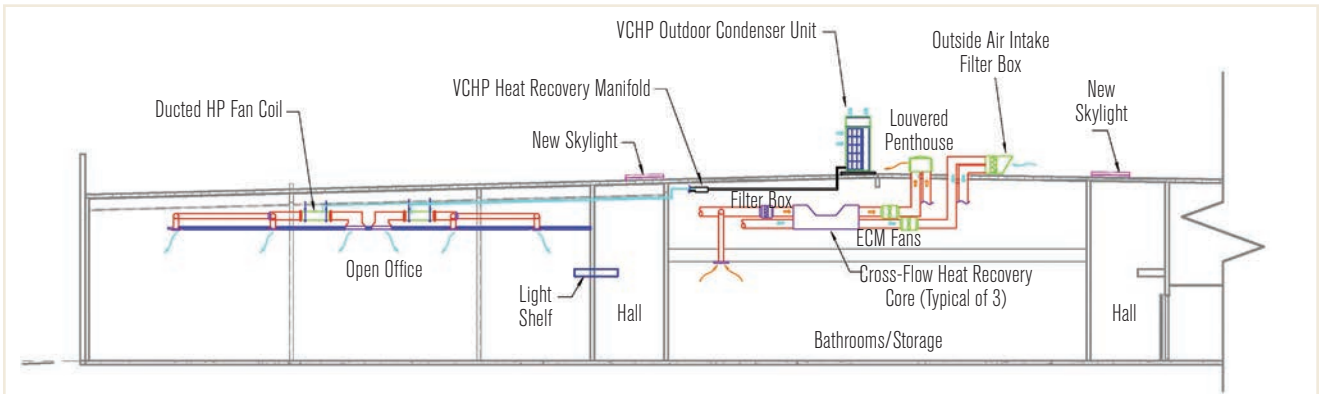


FIGURE 4 KCHA central annex mechanical schematic.

Electrical conduit was run and space was allocated in the electrical room for future solar electric components. The intent of the client is to offer the roof area for community-owned solar panels.

This project saves about 685,000 kWh/yr or roughly 890,000 lbs CO<sub>2</sub> (404 metric tons) per year compared to a typical office building of the same size. Water use by low flow plumbing fixtures is about 30% less than typical;

saving roughly 55,000 gallons (209 000 L) of potable water per year. At an EUI of 26.7 kBtu/ft<sup>2</sup>·yr (303 MJ/m<sup>2</sup>), the King County Housing Authority's Central Annex is operating more efficiently than 98% of all office buildings nationwide. This project demonstrates older existing buildings do not have to be demolished to make way for more efficient new buildings and that this level of energy efficiency is accessible within a modest renovation budget. ■

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