The final cost of Fire Station 72 in Issaquah, Wash., was about $6.6 million, $1.4 million under the original cost estimate by the city. The utility costs for this station are low with bills reduced to less than one quarter of a typical regional station.

FIRST PLACE

OTHER INSTITUTIONAL, NEW

Fire Station *Rescue*

BY JONATHAN HELLER, P.E., MEMBER ASHRAE; AND CARMEN CEJUDO, ASSOCIATE MEMBER ASHRAE

BUILDING AT A GLANCE

Eastside Fire & Rescue Station 72

Location: Issaquah, Wash.

Owner: City of Issaquah

Operator/Tenant: City of Issaquah /Eastside Fire and Rescue

Architect: TCA Architecture · Planning

Principal Use: Fire Station

Includes: Offices, exercise room, living quarters, three truck bays, and support spaces

Employees/Occupants: Six at any given point (three rotating shifts – 24/7)

Gross Square Footage: 11,400

Conditioned Space: 6,050 ft^2 fully heated and cooled, remainder heated to 60°F only

Substantial Completion/Occupancy: October 2011

Occupancy: 100%

National Distinctions/Awards: "Top Engineering Projects of 2012" by Plumbing Engineer Magazine

Fire Station 72 (FS72) in Issaquah, Wash., is a new 11,400 ft^2 (1022 m^2) 24-hour facility that meets the *Architecture 2030 Challenge* target of 70% reduction in energy use compared to typical regional fire stations. The project met these ambitious goals using super-insulation, energy recovery ventilation, a ground source heat pump system for space conditioning and domestic water heating, solar water preheat, high-efficiency appliances, and advanced lighting design and controls.

The station, operated by Eastside Fire and Rescue, houses three rotating shifts of six fire fighters at a time. It includes offices, living quarters, three truck bays, and support spaces. It received LEED v3.0 Platinum certification.

ABOUT THE AUTHORS

Jonathan Heller, P.E., is a firm principal and lead mechanical engineer, and Carmen Cejudo provides engineering design and project management support to Ecotope's engineers in residential and commercial HVAC and plumbing systems design.

ABOVE A 30 kW solar array contributes 5 kBtu/ft^2·yr of energy to the building.

LEFT A custom tailpipe exhaust system is connected to the trucks as they enter the equipment bay to keep exhaust fumes out.

The project includes an 8,500 gallon (32 200 L) rainwater cistern for toilet flushing, laundry, irrigation, and truck washing to reduce potable water use by 60% over a standard fire station.

Energy modeling tools were used to optimize the design and systems. Utility bills from a similar neighboring LEED Silver fire station were used to calibrate the baseline energy model to reflect actual fire station energy use patterns. The design team then evaluated every energy-using component of the building to develop an optimized energy-efficiency package. After all lower cost energy-efficiency measures were incorporated, the project had enough budget left to incorporate an electric grid-tied 30 kW solar array.

Design Collaboration

The design process was a highly collaborative effort that included close, constant input from the owner, City of Issaquah, and Eastside Fire and Rescue. The City's goal was to have a building that could eventually produce as much energy with on-site renewables as it consumes in a year (net zero energy). Achieving this goal in the most cost effective manner, and within the limits of the building site, required an exceptionally energy-efficient building. In addition, occupants had to be willing to alter some of their standard practice for operations. This led to a give and take between designers, owner, and occupants that ultimately produced a comfortable, highly functional, and low energy fire station.

One of the early suggestions for reducing energy use was to use radiant heating and cooling rather than forced air distribution. This required the occupants to accept that they would not be able to manipulate the thermostats frequently and expect quick changes in temperature. The fire fighters were originally opposed to this. At times, after extremely stressful and physically demanding emergency response calls, the fire fighters wanted to be able to lower their core body temperature by resting in a relatively cold room. To accommodate this request the sleeping rooms are equipped with four-pipe fan coils with rapid response individual temperature controls. The rest of the facility is held at constant temperature with radiant heating and cooling.

Another example of early collaboration is the design of the automatic controls. Since fire fighters often have to leave the building quickly, they do not have time to turn off equipment and lights. Therefore, every room has vacancy sensors for shutting off lights and unnecessary equipment. The plug receptacles that are switched from the vacancy sensors are color coded so that all non-critical equipment can be turned off with vacancy.

Pre-Design Billing Analysis, Modeling, and Optimization

In the pre-design phase, a recently constructed LEED Silver station, also operated by Eastside Fire and Rescue, was surveyed. The utility bills were collected and analyzed to develop a detailed energy end use analysis. A calibrated eQuest model was used to test a range of efficiency measures that would reduce energy use to the lowest level practical. The end uses analyzed included: heating, cooling, ventilation, interior and exterior lighting, hot water, cooking, appliances, office equipment plug loads, equipment bay plug loads, and elevator. Since the ultimate goal of the project is to reach net zero energy, the cost effectiveness of each potential energy conservation measure was evaluated compared to the cost of solar electric panels on a life-cycle basis.

Energy Efficiency

Energy efficiency was a primary design driver from the beginning of the project. The building was designed to use 70% less energy than a typical fire station before on-site energy production was taken into account.

With a super-insulated building and ground source heat pumps for heating and cooling, domestic hot water (DHW) heating became the largest single end use in the building. This is driven by three shifts of six people living in the building continuously, cooking, laundering clothes, and showering. To reduce the high DHW load, low flow plumbing fixtures and six large solar thermal preheat panels were used. The ground source heat pump system finishes heating the hot water.

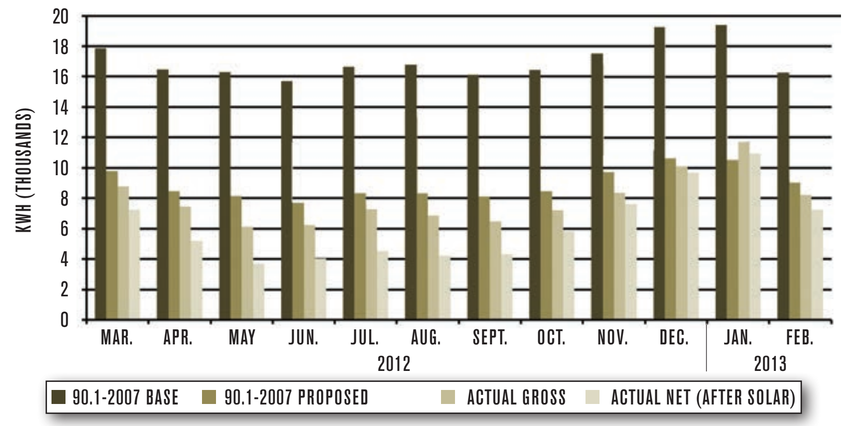

FIGURE 1 Eastside Fire and Rescue Station 72 modeled and actual energy use.

The proposed building energy model performs 58% better on a cost basis than the base case building modeled using the LEED 2009 Performance Rating Methodology (ASHRAE Standard 90.1-2007 Appendix G). The base building energy model predicted an energy use intensity (EUI) of 61.3 kBtu/ft^2·yr (193 kWh/m^2·yr). The proposed building model, including on-site generation, came in at 24.3 kBtu/ft^2·yr (77 kWh/m^2·yr). Actual bills indicate that before the contribution of the solar electric system the building is performing at an EUI of 28.4 kBtu/ft^2·yr (90 kWh/m^2·yr). With the contribution of solar panels, the EUI is reduced to 22.3 kBtu/ft^2·yr (70 kWh/m^2·yr).

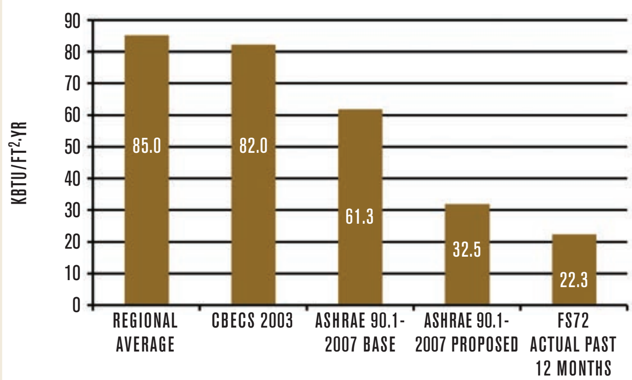

FIGURE 2 Comparison of regional fire stations' net EUI.

Figure 2 shows the EUI of a sample of regional Northwest fire stations. These stations were part of a stratified random sample of commercial buildings evaluated under the NW Regional Commercial Baseline Assessment. The EUI of Fire Station 72 is 30% of the regional average and less than 50% of the 2003 national benchmark for fire and police stations (in the Commercial Building Energy Consumption Survey [CBECS]).

Indoor Environmental Quality

Interior finishes were selected that provide a healthy indoor environment, including hard, durable, cleanable surfaces that prevent dust buildup. Polished concrete floors are used throughout for ease of cleaning, as well as more efficient heating/cooling transfer from the radiant slab. Small area rugs are provided in sleeping rooms for comfort. The station is built with 77% Forest Stewardship Council (FSC) certified wood. At least 20% of the finishes are made from recycled content, and more than 90% of the construction waste was recycled. All materials and finishes are also extremely low in volatile organic compounds (VOCs).

The ventilation system was designed to meet ASHRAE Standard 62 requirements with 100% outside air supplied continuously to all habitable spaces via an energy recovery ventilation (ERV) system. Continuous exhaust is provided to depressurize areas where air pollutants are expected including bathrooms, copy area, storage closets, and the exercise room. A custom tailpipe exhaust system is connected to the trucks as they enter the equipment bay to keep exhaust fumes out. These pipes detach automatically as the trucks are driven out for an emergency call and continue exhausting for two minutes.

Radiant heating and cooling throughout maintains a constant comfortable temperature with no drafts or air delivery noise. ASHRAE Standard 55 design calculations indicated the radiant slab could maintain comfort criteria for all but a few cooling design hours each year. Actual performance has exceeded design expectations. While initially skeptical, the fire fighters have reported

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they are extremely happy with the thermal comfort provided by the radiant slabs.

Innovation

The design process invested in early energy modeling and analysis. A full energy audit was conducted of a neighboring fire station to determine standard practice and how energy use could be reduced in all areas. Economic decisions about energy efficiency measures were made with a long-term net zero energy perspective in mind. This focus on individual energy uses and the close involvement of the building occupants throughout the design process made this building project extremely successful.

An 8,000 gallon cistern provides water for toilet flushing, laundry, irrigation, and truck washing. A 30 kW solar array reduces the station's EUI to 22.3.

The design team developed an innovative approach to small-system, variable speed pumping. The system includes three identical nominal 5-ton (17.5 kW) water-to-water heat pumps; one for domestic hot water, one for heating, and one for cooling. A single 5-ton (17.5 kW) heat pump can meet the heating or cooling load under a majority of conditions; however, the heating and cooling heat pumps are valved so that during peak events when one heat pump cannot keep up, the cooling heat pump can switch over to back up heating and vice versa. This provides safety and redundancy while keeping the mechanical equipment as small and simple as possible. Each heat pump requires 15 gpm (0.95 L) of water flow. The control system monitors how many heat pumps are operating and sets the variable speed pump system to supply either 0, 15, 30 or 45 gpm (0, 0.95, 2, 3 L/s).

Another innovation is the interconnection between the solar thermal and ground source heat pump systems. A large solar thermal array was included due to the high amount of hot water use in a fire station. One challenge with solar thermal systems is what to do with excess heat if the heat supply is larger than the hot water demand on a summer day. In this case if the solar preheat water tanks are satisfied, the excess heat collected by the solar thermal system is discharged to the geothermal loop field to recharge the ground temperature.

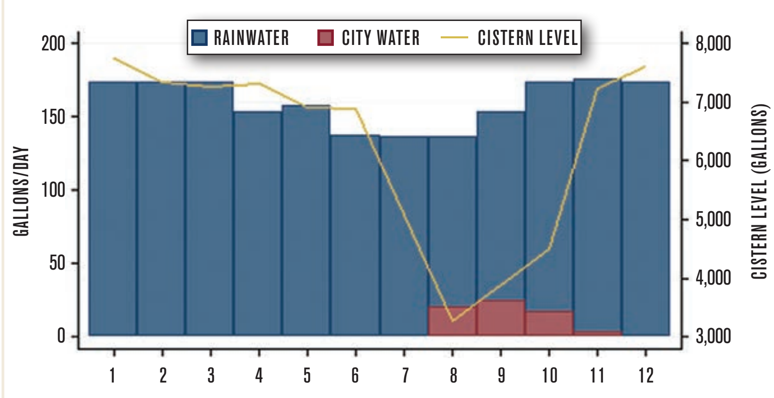

FIGURE 3 Average monthly rainwater and city water use for non-potable uses.

Truck washing uses a great deal of potable water in a typical fire station. Fire trucks are washed regularly to reduce transport of potential pollutants and pathogens and to keep the vehicles clean and shiny. To reduce the demand, a rainwater harvesting system collects water from the roof into a large aboveground cistern. This water is then used for all non-potable needs: truck washing, toilet flushing, irrigation, and clothes washing. A dynamic cistern sizing calculator was developed using 10 years of daily rainfall data. This type of analysis is much more accurate for sizing than using monthly averages, or even daily averages. Using actual historical data allows for a better predictor of both large storm events and unusually long dry periods that occur from time to

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time. Use of rainwater at this station is predicted to save more than 58,000 gallons (220 000 L) of potable water each year.

A full measurement and verification plan was incorporated including submetering of individual end uses. Each individual system is metered to allow for optimization of energy performance throughout the building. Data logs from this system were used to identify operational problems during early occupancy and to adjust settings to optimize performance. This system allows for feedback to the occupants regarding energy usage. Even in the most efficiently designed building, occupant habits can drive up energy use. With the M&V system provided, the city manager plans to implement a feedback system that will allow for friendly competition between the three shifts. This attempt to provide feedback directly to the building users and involve them in the energy efficiency of their building will be necessary to achieve truly high performance buildings.

Operations & Maintenance

Primary heating and cooling delivery is through extremely durable and low maintenance radiant slabs. No mechanical equipment is located outdoors. Geothermal bores take the place of outdoor heat exchangers. The ERV is located in the mechanical room, and a split system for elevator cooling is located in the equipment bay. The only mechanical system items exposed to the weather are the solar thermal and photovoltaic panels. Regular maintenance of HVAC equipment only involves cleaning filters of the ERV. Pumps, valves, and water-to-water heat pumps are all relatively long lasting and easy to maintain.

Cost Effectiveness

The high level of energy and water efficiency included in the project fit well within the budget for the station. The final cost of the station was about $6.6 million, which is $1.4 million under the original cost estimate by the city. The utility costs for this station will be low with bills reduced to less than one-quarter of a typical regional station. Investment in measures to achieve low operating costs makes good sense for the fire district as raising money for new capital expenses is generally easier than getting budgets for ongoing annual expenses.

The high level of envelope insulation in this building allowed for the mechanical system to be sized at roughly one-third the capacity of a standard practice approach. This station has only 10.4 tons (36.5 kW) of ground loop capacity to provide all heating, cooling, and hot water. This is about 1,200 ft^2 (112 m^2) of building per ton of installed capacity. Typical rule of thumb sizing in commercial buildings in the Pacific Northwest is about 400 ft^2/ton (10.6 m^2/kW). This approach shifts money from the mechanical system budget into other energy-efficiency features of the building.

Environmental Impacts

The local water supply comes from deep ground wells. This municipal system has a limited capacity and requires a great deal of pumping energy. By capturing and using rainwater for all non-potable uses, the building reduces the impact on the local system by more than 58,000 gallons (220 000 L) per year.

If this fire station were built to typical standards it would use over three times as much energy annually. This translates to a reduction in over 150,000 lbs (680 kg) of CO_2 per year that is not released into the atmosphere. Direct reduction of water, materials, and energy use are very important. However, perhaps the most important environmental impact is the example that it sets for the entire community. Station 72 has a mission of maximum resource efficiency and minimum energy expenditure given its critical role should its community be in crisis. Fire Station 72 is located in downtown Issaquah and abuts a very busy transit center. The station provides community education and a high level of visibility for energy efficiency and sustainable "green" buildings. The rainwater cistern and solar panels are visible from the street and transit station, and there is a reader board kiosk located at the transit station that reports the energy use of the station alongside the energy production of the solar electric system.

Fire fighters are a traditionally conservative group and are almost universally respected by the community. To have the fire fighters visibly embrace sustainable buildings and practices helps to further convince the community that high performance buildings are an appropriate response to climate change and dwindling resources that will impact future generations.

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