ASHRAE TECHNOLOGY AWARDS APPLICATION FORM (Page 1)

APPLICATION MUST BE COMPLETE TO BE CONSIDERED FOR JUDGING

(Required for Society-Level Competition)

(For ASHRAE Staff Use Only)

I. Identification (0 Points)

Name of building or project: King County International Airport Terminal Deep Green Retrofit

II. Category - Check one and indicate New, Existing, or Existing Building Commissioning (EBCx)

☐ Commercial Buildings	☐ New	☒ Existing	☐ EBCx
Institutional Buildings:			
☐ Educational Facilities	☐ New	☐ Existing	☐ EBCx
☐ Other Institutional	☐ New	☐ Existing	☐ EBCx
☐ Health Care Facilities	☐ New	☐ Existing	☐ EBCx
☐ Industrial Facilities or Processes	☐ New	☐ Existing	☐ EBCx
☐ Public Assembly	☐ New	☐ Existing	☐ EBCx
☐ Residential (Single and Multi-Family)			

III. Project Description (0 Points)

1. Type of building or process: Passenger Terminal
2. Size – gross floor area of building (ft. sq. or m. sq.): 26,500
3. Function of major areas (such as offices, retail, food services, laboratories, guest/patient rooms, laundry, operating rooms, warehouse/storage, computer rooms, parking, manufacturing, process, etc., or industrial process description:

   Offices, Passenger Terminal, Cafe
4. Project Design Period: 01/2016 (Begin date (mm/yyyy)) to 01/2017 (End date (mm/yyyy))
5. Project Occupancy and Operation Period: 01/2002 (Begin date (mm/yyyy)) to Present (End date (mm/yyyy))
6. ASHRAE Standards referenced during design (this information will not be shared with the Judging Panel):

   ASHRAE 62.1, ASHRAE 55, ASHRAE 90.1

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1. **Name of Building or Project:** King County International Airport Terminal Deep Green Retrofit

2. **Entrant (Required to be an ASHRAE member with significant role in project):**
   a. Name: Heller, Jonathan (Last / First / Middle)
   Membership Number: 7979859
   Chapter: Puget Sound
   Region: XI
   b. Entrant's Design Firm/Company: Ecotope, Inc.
   c. Address (including country): 1917 First Avenue, Suite 300
   Seattle (City) WA (State) 98101 (Zip) USA (Country)
   d. Telephone: (O) 206-322-3753 Email: jonathan@ecotope.com
   f. Entrant's Role in Project: Principal
   g. List the names of Design Team Members (A maximum of three may be listed; only ASHRAE members will be recognized as team members)
      1. Henry Odum
      2. Jonathan Heller
      3.

3. **Certification of entrant (0 Points) (If multiple entrants, all must be listed on this form)**

   I certify the information submitted is correct, and that this entry satisfies the requirements of the ASHRAE Technology Award competition.

   Typed Name: Jonathan Heller Title: President

   Signature: Jonathan Heller Digitally signed by Jonathan Heller DN: C=US, E=jonathan@ecotope.com, O=Ecotope, CN=Jonathan Heller Date: 2019.04.24 10:22:59-07'00' Date: 04/24/2019

4. **Building Owner's release (0 Points) (Building Owner cannot be the same person as the Entrant)**

   I certify that I am the owner or the authorized representative of this project, and hereby grant permission to ASHRAE to use all the enclosed data and information in the judging and subsequent publicity of this project.

   Typed Name: David Broustis Title: Energy Manager

   Signature: ______ Date: ______

   (Signatures must be on form submitted to ASHRAE)

   Company: King County Department of Natural Resources and Parks (DNRP)
   Address: 201 S Jackson St Rm 700
   Seattle (City) WA (State) 98104 (Zip) USA (Country)
   Telephone: (O) 206-477-4544 Email: david.broustis@kingcounty.gov

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5. **Engineer of record:** Required unless a written explanation is provided why the engineer of record will not grant his/her consent.

   I consent to the presentation of this project for consideration in the ASHRAE Technology Awards Program.

Typed Name: David Happe Title: Mechanical Engineer

Signature: [signature] Date: 4/24/19

(Signatures must be on form submitted to ASHRAE)

Company: Emerald Aire, Inc.

Address: 5108 D St NW

City	State	Zip	Country
Auburn	WA	98001	USA

Telephone: (O) 253-872-5665 Email: davidh@emeraldaire.com

The topics below should be addressed on separate pages and formatted according to the requirements listed in the overview.

1. **Energy Efficiency (15 Points)**
2. **Indoor Air Quality (15 Points)**
3. **Innovation (15 Points)**
4. **Maintenance & Operation (15 Points)**
5. **Cost Effectiveness (15 Points)**
6. **Environmental Impact (15 Points)**
7. **Quality of Presentation (5 Points) (No response required)**

Return Completed Application to your Chapter Technology Transfer Committee Regional Vice-Chair.

For additional information, contact:

Candace DeVaughn
Chapter Programs Manager
678/539-1128
cdevaughn@ashrae.org

Project Description

The 26,500 ft^2 King County International Airport Terminal Building (KCIA) is the main passenger terminal for the county airport, known as Boeing Field. The building was erected in 1928 and served as Seattle's main airport until 1940. In 2002 the building underwent a major remodel to upgrade the building envelope, interior, and lighting systems. The multizone rooftop air handlers were relatively new at the time, so they were reused in the upgraded building. Despite the significant investment represented by the remodel, the building was operating with an Energy Use Index (EUI) of 169 $kBTU/ft^2/yr$ and high annual energy bills of about $68,000.

Figure 1: Historic photo of Boeing Field Terminal Building

In 2016 it was apparent that the HVAC systems were nearing the end of their useful life, the existing building management system (BMS) was approaching obsolescence, and both needed replacement. The County was preparing to replace the multizone airhandlers and BMS with a “like-to-like” replacement. Ecotope was invited through the King County GreenTools program to provide a third-party recommendation for system replacement. Ecotope recommended replacing the multizone air handlers with Variable Refrigerant Flow (VRF) heat pumps and a Dedicated Outdoor Air System (DOAS) with highly efficient heat recovery ventilators. Ecotope provided an Investment-Grade Audit as well as a Basis of Design at the Design Development level. The mechanical contractors (Emerald Aire) then took over as Engineer of Record in a Design-Build capacity to complete the renovation. Ecotope was able to assist the County in obtaining grant money set aside for highly energy efficient projects from the Washington Department of Commerce, along with energy conservation incentive money from local utility Seattle City Light.

Figure 2: KCIA during renovation, 2002

Multizone air handlers were replaced by three rooftop Energy Recovery Ventilators (ERVs)—these were installed on the existing rooftop curbs and used the building's existing ductwork to provide ventilation air in accordance with AHSRAE 62.1 standards. Carbon and MERV 13 filters were used on the fresh air supply to remove jet fuel pollutants present at the airport and provide a high level of indoor air quality.

Figure 3: KCIA in 2016 prior to the renovation, with aging multizone rooftop units

The 2016 retrofit replaced the HVAC system and a portion of the lighting system while the building maintained regular operation. The refrigerant piping and ceiling cassettes were installed above the exiting ceiling tiles for a very low impact retrofit that was accomplished after hours with full building occupancy and minor disruption to the building's operational schedule. The environmental impact of this project eliminated the use of fossil fuels for heating and reduced overall energy use by 70%, as measured in its first year.

Energy Efficiency

The pre-retrofit multizone equipment had extremely high energy use. The units cycled heating and cooling year round to meet the demands of the various indoor zone thermostats, and the single-speed fans ran continuously to maintain distribution and ventilation. By using "Design for Off" principals[1], the post-retrofit building's mechanical systems ventilate and condition the building at dramatically reduced fan-power levels, while elminating the simultaneous heating and cooling seen in the previous mechanical system design.

- Ventilation is separated from the heating and cooling distribution system and is provided through a Dedicated Outdoor Air System (DOAS) configuration that uses high-efficiency energy recovery ventilators. Near 90% heat recovery on the exhausted ventilation air significantly reduces the heating load. Fan energy is considerably reduced, both by cutting the volume of supply air by over a factor of five (as the delivery air is 100% outside air meeting ventilation loads only) and designing with high-efficiency ECM motors.
- Heating and cooling is provided by a heat pump-based zonal system that cycles only on calls from the zone. The zonal ductless ceiling cassette fan coils cycle off when the thermostat is satisfied. This greatly reduces distribution fan energy and all but eliminates simultaneous heating and cooling.

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[1] Oram, S. and C. Cejudo. *Designing for Off*. ASHRAE High Performance Buildings Magazine. Summer 2013. Heller, J., D. Baylon, and S. Oram. *Design for Off: Key Mechanical Engineering Design Features for Significant Energy Savings*. American Council on an Energy Efficient Economy. Summer Study 2014.

- By “right sizing” and utilizing heat recovery on the ventilation air, the HVAC capacities can be significantly reduced. Output capacity of the heating and cooling equipment was reduced from the original 95 tons to only 32 tons of capacity.

The Figure 4 shows the energy bills from the KCIA prior to the retrofit. The bills show strong seasonal dependency, with gas use (heating) peaking in the winter and electric use (cooling) peaking in the summer. However, the bills show a large amount of overlap with both heating and cooling happening simultaneously for much of the year. This is typical of a multizone HVAC system, which attempts to satisfy all zones from a single central piece of equipment.

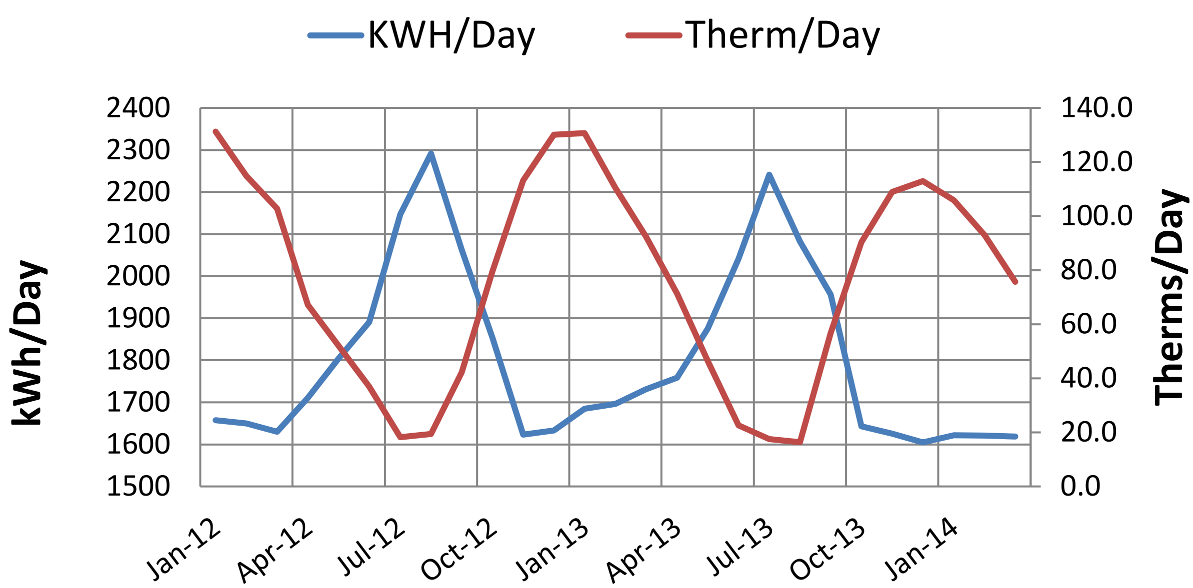

Figure 4: Pre-Retrofit Energy Bills Showing Simultaneous Heating and Cooling

In contrast, Figure 5 shows the post-retrofit electric bills. Note that there is a much reduced heating peak in the winter and no clear cooling spike. Note also that the electric base load is reduced by nearly 50% due to fan energy reduction.

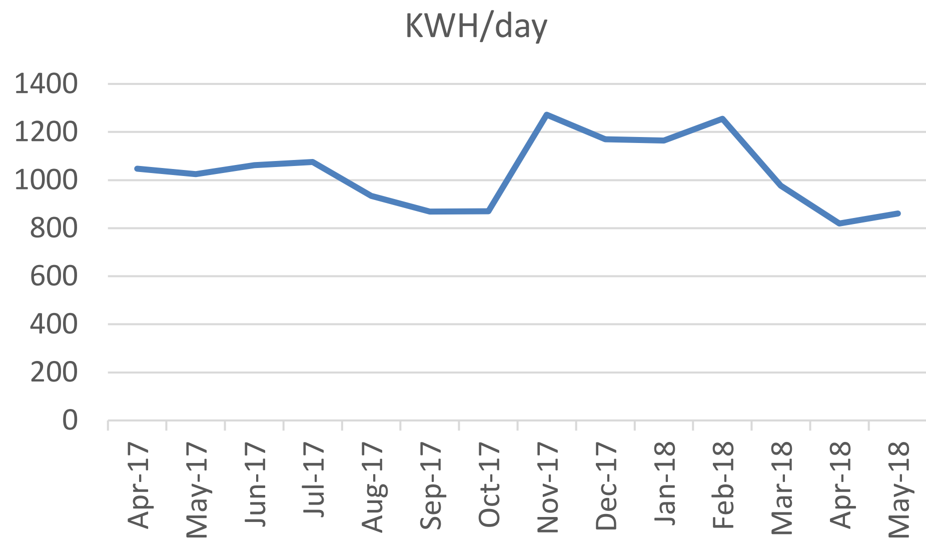

Figure 5: Post-Retrofit Electricity Bills

Total energy use was reduced by 70%. Gas energy use was reduced 99% (a small amount of gas is still used by a café on the ground floor).

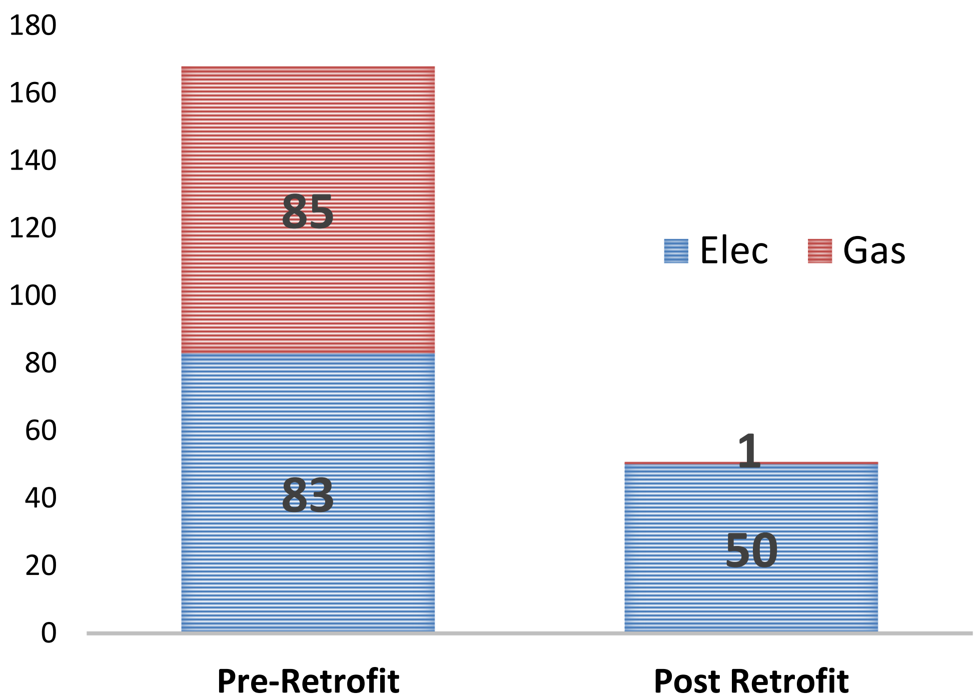

Figure 6: Energy Use Intensity Pre and Post Retrofit (kBTU/ft^2/yr)

Indoor Environmental Quality

Outside air quantities are provided per ASHRAE 62.1 standards during all occupied hours. Indoor air quality was a high-priority design element for this facility due to the proximity to the airfield as well as the heavily trafficked Interstate 5 Freeway. To address these outside air pollutants, MERV 13 particle filtration and activated carbon filtration, to remove organic compounds from combustion of jet fuel, were installed on the ventilation systems. The ventilation system is designed to supply at a maximum of ASHRAE 62.1 standards; eliminating the economizer cooling cycle which would require large amounts of outdoor air. Economizer cooling would not provide significant additional energy savings for this building due to the local climate, as can be seen by the lack of a significant summer peak in the electric bills shown in Figure 5 above.

Innovation

This project provides a blueprint for replacing central HVAC systems in existing buildings. The primary innovation represented by this project allowed for a complete replacement and restructuring of the HVAC system, delivering a factor of three reduction in annual energy use, without disrupting the normal operations of the building. This was accomplished with a shift from a central all-in-one concept to a ventilation-only distribution system with zonal fan coils providing heating and cooling. The VRF fan coils were able to be installed throughout the building with refrigerant piping installed in the existing dropped ceiling cavities. The rooftop units were replaced during the shoulder season when operable windows could be used for ventilation. New high-efficiency energy recovery ventilation units were installed on the existing curbs with the original supply/return ducting being reused and rebalanced to provide ventilation per ASHRAE 62.1 Standards.

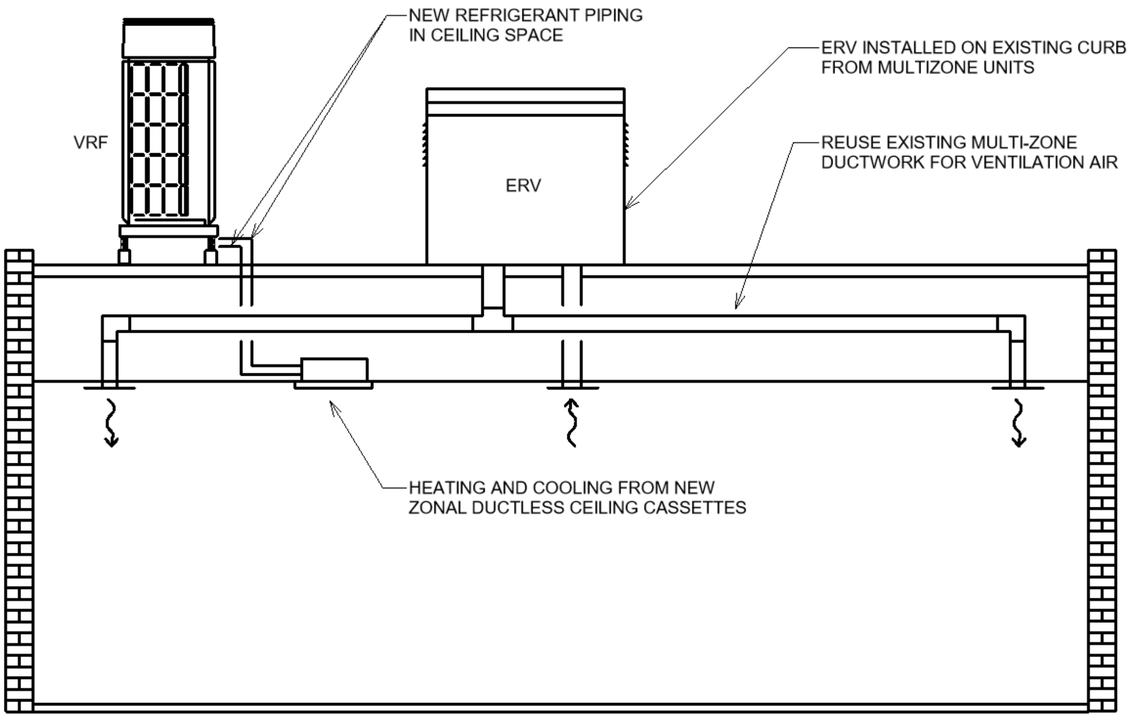

Figure 7: HVAC System Schematic

The ERV used in this project was part of the Very High Efficiency Dedicated Outdoor Air System (VHE DOAS) pilot project of a new technology supported by the Northwest Energy Efficiency Alliance.[2] The VHE DOAS concept delivers 100% outside air from an ERV with a heat recovery effectiveness of about 85%. This eliminates the need to provide any secondary tempering and the ventilation air can be delivered directly to the space without creating cold drafts. This generally requires a full counterflow heat exchanger. Extremely high efficiency fans at about 2 CFM/Watt are used to further reduce fan energy.

[2] https://betterbricks.com/case-studies/innovative-hvac-approach-helps-airports-energy-savings-take-off

Another innovative element of the project was the integration of the new with the old. The two-story lobby space includes a large skylight element and upper balconies with very distinctive handmade art deco light fixtures. There was some concern that the reduced airflow in the space could lead to stratification in the upper balcony areas, so a high-volume, low-speed (HVLS) ceiling fan was added to provide air distribution and destratification. To mitigate distraction from the unique lighting, the project manager commissioned the original artist to design a base for the fan that would match the artistic intent of the lights. The result is a fan that looks as though it was installed along with the lights.

Figure 8: HVLS fan with a custom designed base mount

Operations & Maintenance

The existing HVAC system was failing and requiring a large amount of maintenance, time, and money in the last few years of its life. The carbon filters used in the large rooftop units were expensive and time-consuming to replace. New equipment is much smaller and moves much less air, therefore filter maintenance on the new ERVs is much less costly and time consuming. Furthermore, the equipment itself is much simpler and runs less, often further reducing maintenance requirements.

Figure 9: The new rooftop equipment is a fraction of the size of the original

Cost Effectiveness

The project was completed under the State Department of Enterprise Services Energy Savings Performance Contracting through use of an Energy Service Company (ESCO). In order to make use of this program, the County was required to show a cost-effective project with the ESCO providing a guarantee of the savings. The complete HVAC replacement was completed for approximately the same budget as was anticipated to be spent on a simple like-for-like replacement of the rooftop units and control system upgrade. The HVAC construction budget for the project was just $25/ft^2$ and the total project costs were less than $40/ ft^2$. Because of the high-performance nature of the retrofit, the County was able to obtain grant money set aside by the State of Washington Department of Commerce and receive energy efficiency rebates from the local electrical utility. Annual energy savings are about $35,000/yr.

Environmental Impacts

The renovation reduced energy use by 70% and reduced fossil fuel use by 99% with only a small amount of natural gas still used by the café for cooking. The electrical utility serving the project (Seattle City Light) is a carbon neutral utility; therefore, the retrofit effectively reduced the building's carbon footprint by 99%, removing 120 metric tons of carbon emissions per year.

Lessons Learned

1. Wireless controls do not always live up to their promise. In this case continued communication problems with the wireless zone thermostats resulted in the contractor returning and replacing them with hardwired thermostats.

2. It is the little things that count. The project manager went the extra mile to track down the original artist involved in the previous building renovation. That artist was able to incorporate the new destratification fan in a way that makes it an artistic element in the space as opposed to a distraction from the original artistic intent.
3. Existing ductwork can be used effectively for retrofit to ventilation only. There was some early concern that the existing ducts were much too large for the greatly reduced ventilation-only airflow of the DOAS system. However, with simple damper controls near the terminals, the HVAC contractor was able to balance the flow to the satisfaction of the occupants.