ASHRAE TECHNOLOGY AWARDS APPLICATION FORM (Page 1)
APPLICATION MUST BE COMPLETE TO BE CONSIDERED FOR JUDGING
(Required for Society-Level Competition)

18

(For ASHRAE Staff Use Only)

I. Identification (0 Points)

Name of building or project: [redacted] Airport Pre-Conditioned Air

II. Category - Check one and indicate New, Existing, or Retrocommissioning (RCx)

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

III. Project Description (0 Points)

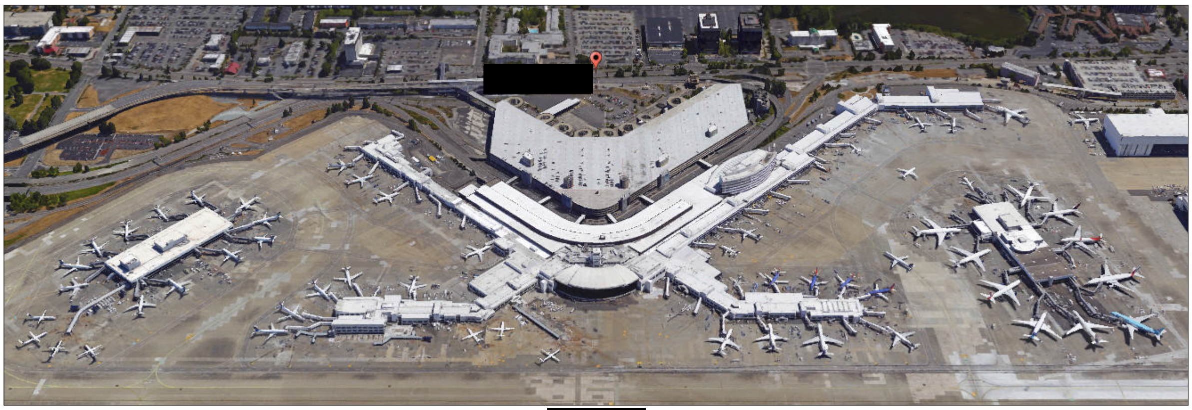
1. Type of building or process: Airplane HVAC served from the terminal building
2. Size – gross floor area of building (ft. sq. or m. sq.): ____
3. Function of major areas (such as offices, retail, food services, laboratories, guest/patient rooms, laundry, operating rooms, warehouse/storage, computer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

   Centralized mechanical plant inter-tied to existing building central plant
4. Project study period: 10/15/09 (Begin date (mm/yyyy)) to 6/1/10 (End date (mm/yyyy))
5. Project Occupancy and Operation Period: 2/1/14 (Begin date (mm/yyyy)) to 2/1/15 (End date (mm/yyyy))

INTRODUCTION

[redacted]

The [redacted] Century Agenda sets a vision of reducing carbon emissions and air pollutants, increasing energy conservation, being socially and fiscally responsible and exceeding customer expectations. [redacted] International Airport's [redacted] Preconditioned Air (PC Air) project is an important step in the [redacted] meeting a Century Agenda Objective of being the greenest, most energy efficient port in North America.

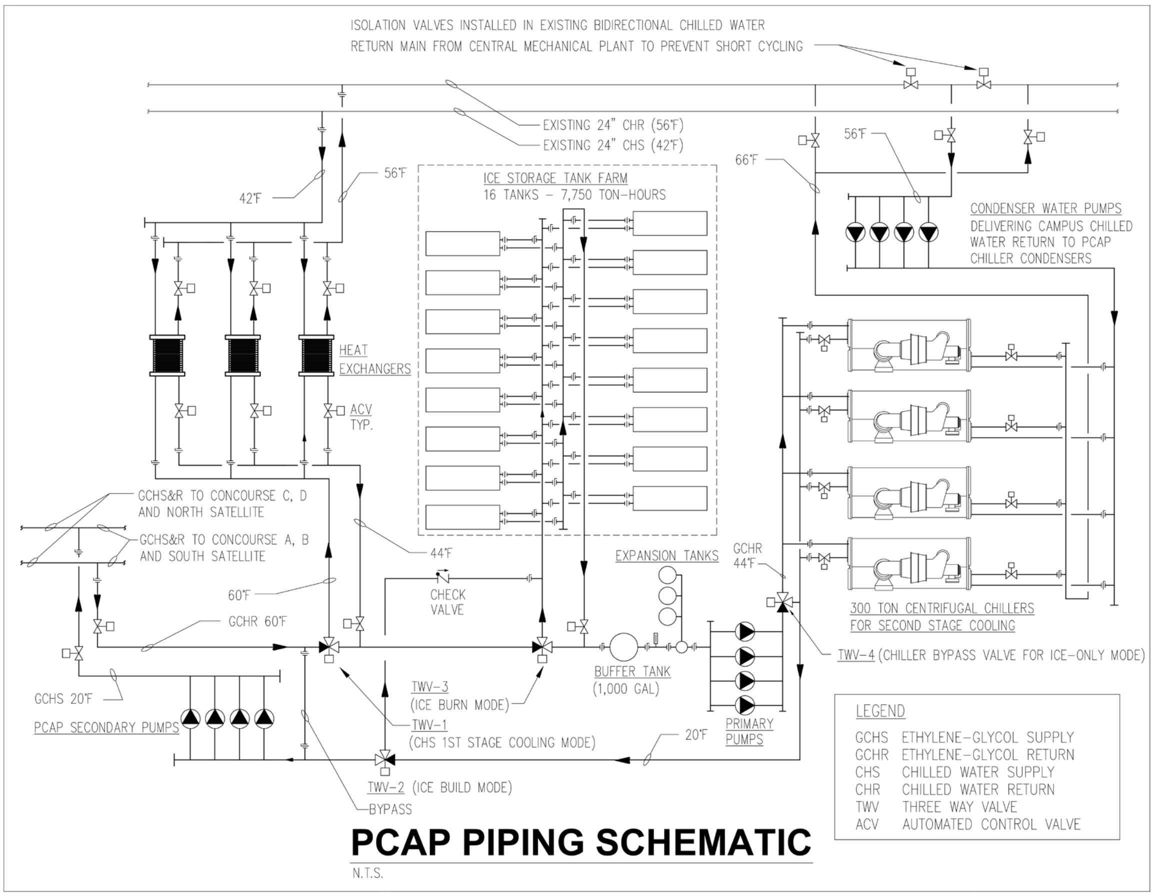


[redacted] International Airport, Courtesy Google Maps

The PC Air system includes a Preconditioned Air Plant (PCAP), piping and air handlers to provide cooling and heating for airplanes during boarding and deplaning to reduce costs for airlines, improve air quality, reduce noise and increase energy efficiency throughout [redacted]. The PCAP delivers sub-cooled glycol / water through 15 miles of piping to each of the 73 airplane gates in the existing facility, to serve the complete airplane HVAC needs. The PC Air system allows airplanes to shut off their jet-fueled on-board Auxiliary Power Units (APUs), resulting in jet fuel savings and reductions in CO^2 and other gas emissions.

PCAP Chillers and Thermal Storage Farm

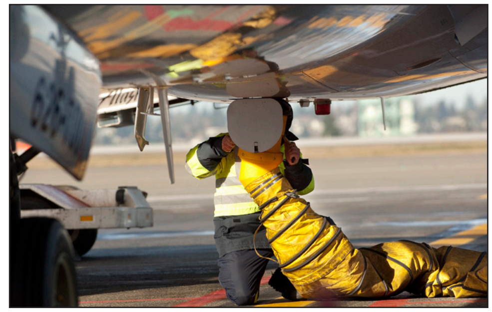
The PCAP uses multiple stages and sources of cooling to serve the airplanes' unique requirements and provide system operational flexibility. The first stage of cooling can be accomplished through the use of either a 7,750 ton-hour thermal ice storage farm (with 16 tanks) or [redacted] campus chilled water system (through heat exchangers). Two 1500 ton chillers were added to the campus' Central Mechanical Plant (CMP) to serve the PC Air system's chilled water requirements and maintain campus redundancy. The second stage of cooling in the PCAP is provided by four (4) 300 ton chillers that cool the ethylene-glycol mix down to 20 degrees F to serve airplanes and / or recharge the thermal tank farm. In order to maximize system efficiency, these four chillers utilize the campus's CMP return chilled water (at 56 degrees F) as their condenser water source. Four secondary pumps circulate the sub-freezing chilled liquid through dedicated piping to the gates for cooling.



The aircraft heating system uses existing centralized steam at various locations throughout the airport, employing steam-hot water heat exchangers and variable flow hot water distributed to each gate PC Air unit.

[redacted] PRECONDITIONED AIR SYSTEM

Gate PC Air unit, telescoping duct and hose


Flexible duct connection to airplane


PC Air unit and TAD

The PC Air unit mounted at each gate delivers and directs conditioned air through a double-wall telescoping air duct (TAD) mounted to the passenger loading bridge, through a flexible duct that connects to the bottom of the aircraft. The cooling or heating air is then distributed through the airplane's cabin air system.

ENERGY EFFICIENCY

PC Air systems are unique. Each individual airplane can demand from 20 to over 100 tons of cooling utilizing 100% outside air to provide proper passenger ventilation. In order to work with the airplane air distribution system, the discharge temperature from the air handling units must be close to or below freezing. Cooling options for aircraft in use today run across a wide spectrum from the inefficient jet fuel powered APU on the plane, diesel powered mobile units, to slightly more efficient Dx PC Air units with up to six compressors each, to [redacted] highly efficient centralized system employing the PCAP with glycol fluid piped to each airplane gate. On a design summer day, the glycol delta T on the PC Air unit air handler coil is 40 degrees F. The cooling medium from the PCAP operates down to 20 degrees F to serve the airplane effectively. Energy efficiency in the system is crucial as the temperatures of the fluid are more extreme than building systems.

[redacted] PCAP plant has several modes of cooling in order to provide peak energy efficiency throughout the year:

1. The first mode is designed to use heat exchangers connected to the campus chilled water system for the first stage of cooling, bringing the PCAP return fluid down from 60 to 44 degrees F. The PCAP chillers then perform the second stage of cooling to bring the temperature down to 20 degrees F. Supply temperature is reset upward by [redacted] based on the ambient weather to save energy.
2. The second mode uses the 7,750 ton-hour thermal tank farm to perform the first stage of cooling. The farm's capacity is able to perform this function throughout [redacted] worst case design day. The PCAP chillers then perform the second stage of cooling, as described above. Further energy savings are gained by extending the farm's time between recharges to multiple days during off-peak weather periods and by capturing spare chiller capacity to recharge the farm while simultaneously serving the PC Air units.
3. During the shoulder season, the thermal farm alone can meet the entire daily aircraft cooling need with 36 degree F fluid supply to the gates. In these situations, [redacted] is able to shift all PCAP chiller operation to off peak hours to recharge the farm, saving electrical demand costs.
4. The PCAP was strategically sized to balance the size of the farm with the PCAP chiller capacity to manage first costs, while also supporting future growth of up to 100 gates in the year 2030.

Typical central PC Air systems are limited to 200 ton screw chillers at approximately 1.1 kw/ton due to the high lift requirements of producing 20 deg cooling fluid with 85 degree entering condenser water. [redacted] PCAP chillers instead use chilled water return from the campus CMP (at 56 degrees F) for their condensers. This solution improves CMP and PCAP efficiencies in the following ways:

1. The CMP operates at a higher chilled water temperature differential
2. Full-load PCAP chiller efficiency of 0.605 kw/ton design and 0.56 kw/ton installed

PCAP chillers

3. CMP chilled water supply can provide the first stage of PCAP cooling at 44 degrees F evaporator entering glycol temperature

4. Lower risk of fouling in the PCAP chillers from closed loop condenser water supply

The PC Air heating system is tailored to [redacted] climate and [redacted] existing facility infrastructure. Most airport PC Air systems use either electric heat or a 2-pipe changeover system. Both of these solutions cost less to install than the 4-pipe system used [redacted], but have significant operational downsides. [redacted] electrical infrastructure at each gate is limited. Therefore, electric heat would have required significant infrastructure enhancements and resulted in higher operational costs compared to using the existing steam / heating water system. The use of a 2-pipe changeover approach was also undesirable due to [redacted] rapidly changing weather conditions which make it very difficult to choose a date to switch operation from heating to cooling and vice versa. Based upon life cycle analysis and customer service objectives, [redacted] chose a 4-pipe distribution system with steam-to-hot-water conversion at each concourse. The PC Air unit manufacturers modified their equipment to provide heating and cooling coils in the limited space inside the cabinets to meet this requirement.

The PC Air units operate in heating, cooling or an economizer vent mode depending on outside air temperatures. Variable Frequency Drives on PC Air unit fans maximize energy conservation by varying airflow according to the size of the airplane at the gate.

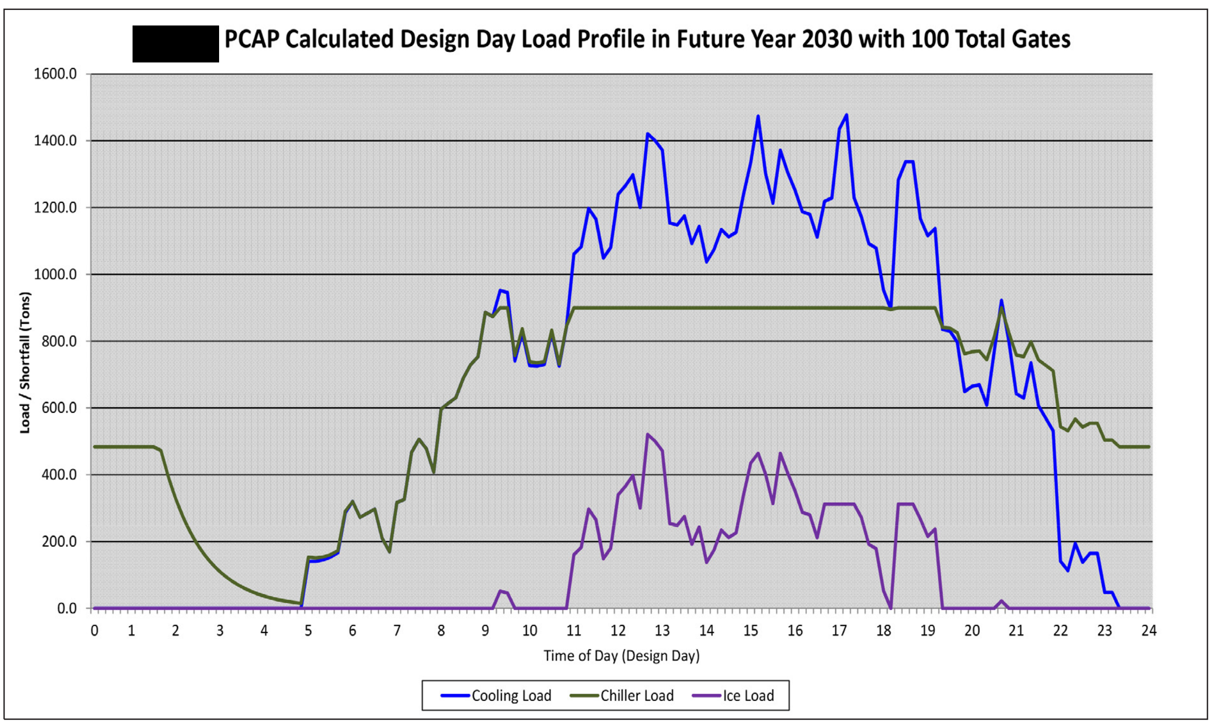
IAQ AND THERMAL COMFORT

With 100 to 500 people occupying each of the 73 airplanes parked at the gates, thermal comfort and indoor air quality are important considerations. ASHRAE 161-2013 and FAA 14CFR Part 25 prescribe the indoor air quality and thermal comfort of airplane cabins. The PC Air units at [redacted] deliver MERV 8 filtered, 100% outside air to the airplane cabin, exceeding the above requirements. [redacted] is also replacing combustion ground service equipment (GSE) with electric powered GSE, which increases the outdoor air quality drawn into the PC Air units. Maintaining thermal comfort in airplane cabins to ASHRAE 55-2013 is a challenge given that the airplanes are not physically connected to the terminal facility. During boarding and deplaning operations, flight attendants place a temperature sensor in the airplane cabin, modulating supply air temperature from the PC Air units for passenger comfort.

Ventilation and thermal effectiveness is continuously evaluated and improved by airport staff thorough data trending and programming enhancements providing IAQ and thermal comfort rivaling the adjacent terminal building concourses. The decision to implement the PC Air program at [redacted] responds to airline tenant and customer service initiatives and ASHRAE Society By-laws and Code of Ethics to benefit the general public and enhance public safety and welfare.

INNOVATION

PC Air system operation is very different than most building systems. Throughout the day, six to ten different airplanes are connected and disconnected from each of the 73 gates. When just a single Boeing 747 is connected to the system, the PCAP cooling load can increase by nearly 100 tons in a matter of moments. The PCAP centrifugal chillers require relatively stable entering evaporator temperatures to perform their duty. Using either the thermal farm or CMP chilled water for the first stage of cooling provided this assurance. As an additional precaution, a 1,000 gallon buffer tank with internal baffles was installed after the first stage of cooling to further limit the rate of change of glycol temperature into the PCAP chillers.



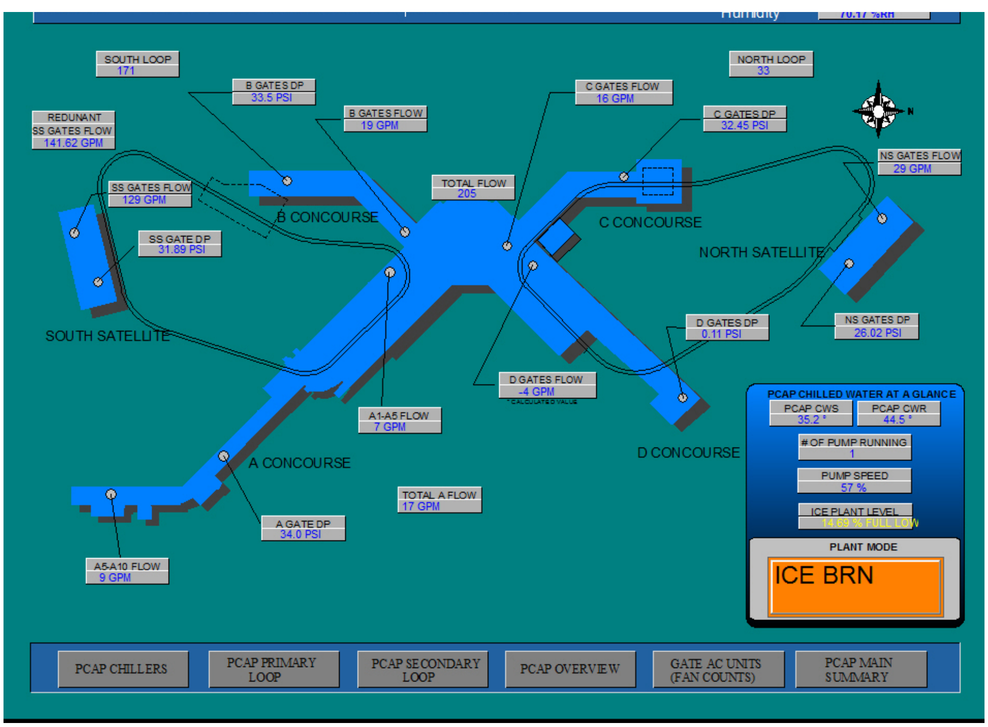
Thermal Storage is sometimes employed for peak shaving on central PC Air systems. Given the focus on system energy efficiency at [redacted] a thermal farm was implemented to provide nearly half of the PCAP cooling service on summer days, and all the aircraft cooling on spring and fall days.

The PCAP system is connected to the campus CMP through heat exchangers. The arrangement is designed to in the future allow the PCAP to be used as a redundant primary cooling plant for campus HVAC building loads, if necessary. The innovative capability of coupling of the two systems provides flexibility in the campus chilled water system to maximize infrastructure assets in the future.

MAINTENANCE AND OPERATION

The life cycle cost analysis of PC Air options included maintenance as a major selection factor. A Dx system would have required nearly 200 scroll compressors, all located in PC Air units suspended from the passenger boarding bridges and exposed to the outdoors where they would deteriorate more rapidly and be difficult to access with ongoing aircraft operations. The Central PC Air system uses four centrifugal chillers in a protected interior space in the terminal building. The PC Air units have only fans, filters, coils and controls to maintain.

The entire PC Air system is integrated into [redacted] Direct Digital Control (DDC) system. Staff may view and modify temperatures, various setpoints and operation modes at any time of day. They also trend the operation of the PC



Air units at each gate and compare this data to the aircraft operations to assure that the airline partners are using this energy and emissions-saving system effectively.

Redundancy is provided in the PCAP through N+1 capacity in the heat exchangers, pumps and chillers. This assures that maintenance can occur during normal work hours and minimizes risk of loss of system effectiveness.

Operation of the cooling system occurs in different modes selected by the operator, based on outside air temperature, weather forecasts, thermal storage capacity and time of day. [redacted] staff continues to monitor and improve the PCAP's operational settings to maximize energy efficiency and customer satisfaction with this airport-wide system.

The system employs temperature reset strategies to determine the mode of operation of the PC Air units, including an economizer vent mode, and allows for field verification of actual aircraft cabin temperatures to assure a comfortable customer environment. The heating system is programmed to setback supply temperatures based upon ambient weather conditions with startup and shutdown of the heating loops based on heating valve status at the PC Air units.

COST EFFECTIVENESS

The lowest first cost option to the [redacted] would have been to do nothing, continuing to require airlines to operate on-board APUs to provide cooling and power while airplanes are parked at the gate. While minimizing costs, this produces significant ongoing fuel consumption and emissions impacts to [redacted] airline partners and community. [redacted] staff holistically evaluated different alternatives including APUs, mobile diesel-powered Dx PC Air units, gate-mounted electric Dx units, and centralized PC Air over a life cycle of 30 years to choose the most fiscally responsible system for the entire 'curb to gate' experience. The study included equipment first cost, energy consumption cost, maintenance cost, equipment replacement cost and energy rate escalation. The calculated payback for the centralized system was determined to be 4.3 years, assuring this investment benefits the economic vitality for the entire region. [redacted] took advantage of the largest federal grant of its kind to off-set the costs of the $43 million project through a $24 million Voluntary Airport Low Emissions (VALE) Grant provided by the FAA and the EPA. Airport Development Funds, which come directly from fees charged to airlines, covered the balance. These fees are offset over the life of the system through decreased airplane gate operating costs.

PC Air Life Cycle Cost Analysis Summary	PC Air Provided By:			Difference POU v Central System	Operating Months 10/1/2014
	APU Ongoing	Point of Use 7 yr Cycle	Central System 20 yr Cycle		10
All Gates *					
30yr Lifecycle Total (NPV)		**$ 84,387,275**	**$61,472,425**	**($22,914,850)**	
Initial Program		$ 32,852,000	$33,240,000	$388,000	
Energy - Lifecycle		$ 43,135,146	$18,263,353	($24,871,793)	
Maint - Lifecycle		$ 31,723,134	$33,826,865	$2,103,731	
Annual Costs					
Energy - Annual	$ 15,454,401	$ 1,042,429	$442,157	($600,272)	
Maint - Annual	$ 2,971,100	$ 766,640	$817,480	$50,840	
Annual Debt Service		$ 2,726,716.00	$ 2,758,920.00		
Total Annual Cost	**$ 18,425,501**	**$ 4,535,785.42**	**$ 4,018,557.31**	**($517,228)**	**% Payback as of 10/1/14**
Payback Months		**72.9**	**51.2**		**20%**

Payback is based on 30 Lifecycle/(APU Annual-Central Plant Annual)

<u>Major Assumptions</u>

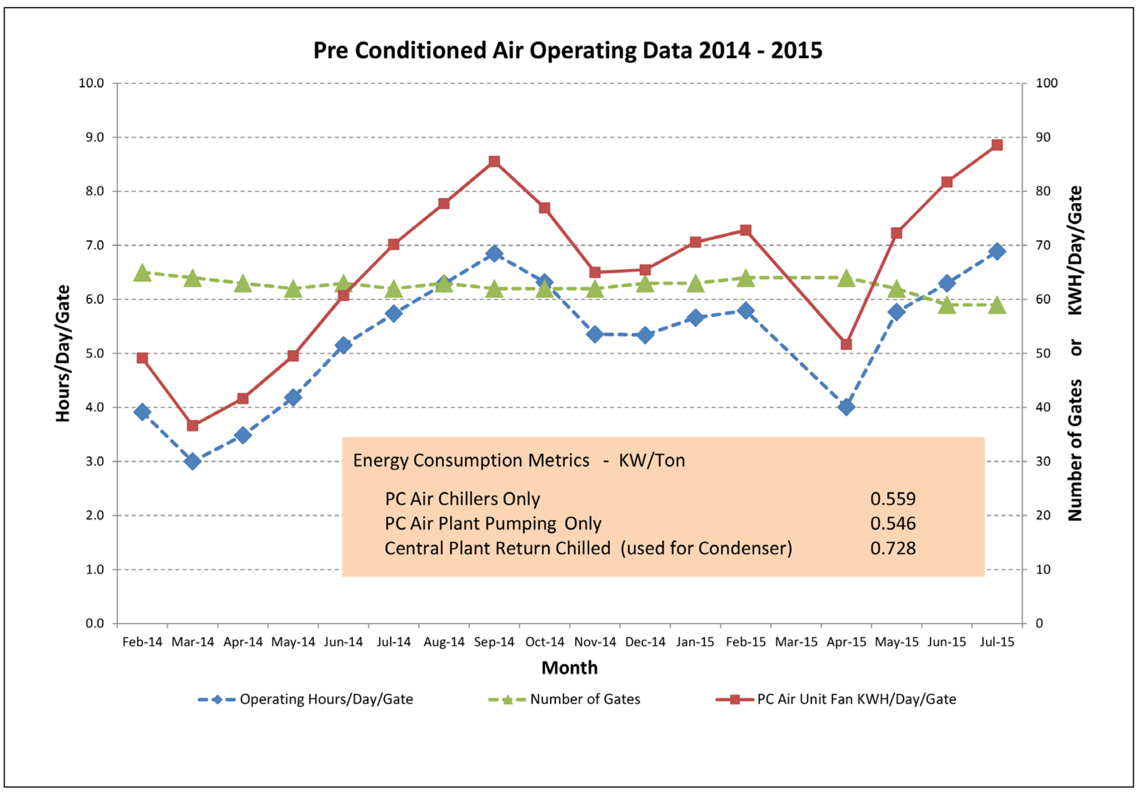
1 5 Hrs operating time per day per gate for each system

2 **<u>APU Cost calculation</u>** - 365 days per yr X 5 hr per day in operation X [$22 per hr maintenance cost per hour of operation + (175 lb per hr Fuel Flow / 6.6751 lb/gal Jet Fuel Density X $4.75 cost per gallon Jet-A] X 68 gates = $18.4 mil per year.

3 The Point of use alternative uses up all the spare capacity in the power centers.

Life Cycle Cost Summary of PC Air System Options

The system has been in operation for over a year. Operational hours / gate / year are slightly above the design estimate indicating that the life cycle cost benefit will be realized. Use of the PC Air system quickly grew as the airline partners gained familiarity with it, as demonstrated in the chart below.



ENVIRONMENTAL IMPACT

PC Air provides environmental and financial benefits in support of the [redacted] Century Agenda goal of reducing the airport's carbon footprint and energy demand through conservation and use of renewable sources. Centralized PC Air reduces the reliance of on-board APUs, saving fuel consumption and associated emissions. The FAA and EPA believe so strongly in these types of technologies that they created the VALE Grant program to support implementing strategies like PC Air.

The reductions realized through centralized PC Air at [redacted] benefit the [redacted] region with annual savings of:

- An estimated five million gallons in fuel; a $15 million savings in airline fuel costs
- 40,000 metric tons of greenhouse gases (CO^2), the pollution that causes global warming, the equivalent of removing 8,000 cars from the road
- 73 tons of nitrogen oxides (NOx), a nationally regulated air pollutant,
- Noise pollution from aircraft parked at the gates operating their APUs

CONCLUSION

The [redacted] and its partners have invested in a centralized PC Air system that provides fuel, economic, noise and environmental savings for [redacted], it's airline partners and the flying public. The new system was carefully interconnected to the existing infrastructure and balances efficiency, lifecycle, redundancy and maintenance. After one year of operation, the system is widely utilized by the airlines and has capacity to serve the airport's projected growth. Airlines continue to use the system even during fluctuating fuel costs, confirming the exceptional benefits of this project. The [redacted] is leading the way in decreasing fuel expenditures, consumption and associated greenhouse gases, while providing better health and comfort to the flying public. This project sets a high standard by employing unique technology and design toward making the [redacted] the greenest, most energy efficient port in North America.