Achieving High Satisfaction in High Performance Buildings

Kurt Herzog, Acutherm, LLC.
Wes Sullens, StopWaste
Michael Ivanovich, AMCA International
Heather Perez, Acutherm, LLC.

ABSTRACT

This paper delivers research of AMCA (Air Movement and Control Association International) HPAS (High Performance Air Systems) Task Force. HPAS provides office buildings with superior comfort, energy efficiency, IAQ, acoustics, and reliability. All are required to serve the needs of occupant health, comfort, and productivity. HPAS are the modern equivalent of variable air volume (VAV) systems, updated to have better and easier controls; right-sized and efficient fans; low pressure drop non-leaky air distribution; and small zones of temperature control delivering a higher rate of individual comfort.

HPAS provide the ultimate in comfort with small zones of individual temperature control. Several energy-reducing features distinguish HPAS, which are discussed along with energy comparisons to ductless and other ducted systems. HPAS use better air filtration for improved IAQ and centralized fans to reduce noise and maintenance in occupied spaces. For sustainability and reliability, HPAS easily adapt to new layouts and integrates heating/cooling with ventilation resulting in lower first costs.

The latest industry trends from the work by AMCA HPAS Task Force, USGBC (LEED Materials & Resources Technical Advisory Group and Supply Chain Optimization Working Group), and ASHRAE (Standard 189.1 committee for High-Performance Green Buildings) is presented along with a case study of a real world high performance building, StopWaste Headquarters, the world's first certified LEED Platinum under Version 4.

Introduction

A survey aimed at exploring how the indoor environment in buildings affects human comfort reports that “Thermal comfort is ranked by building occupants to be of greater importance compared with visual and acoustic comfort and good air quality. It also seems to influence to a higher degree the overall satisfaction with indoor environmental quality compared with the impact of other indoor environmental conditions.” (Frontczak and Wargocki 2011) With thoughtful design, most commercial office spaces can be designed to provide thermal comfort and also use less energy. This paper summarizes trends in the energy design of office buildings that are favoring low-energy HVAC designs which also offer enhanced indoor air quality, better occupant health, and increased productivity.

Trends

Today’s commercial buildings are increasingly asked to do more with less. Investors want their building portfolios to be beacons of sustainability, easily recognizable by validated labels and dashboards that provide real-time updates about a buildings’ performance. Government agencies and utility companies want the building stock to be smarter, more energy efficient, water-wise, and able to respond to emergency signals like demand response in short order. And owners demand that buildings are assets for employee satisfaction, productivity, and organizational pride, all without spending more than normal. Most importantly, the occupants of today's buildings want comfortable and safe spaces—with access to quality natural light, fresh air, and free from harmful pollutants in the indoor air.

The trends towards greater environmental awareness coupled with higher occupant satisfaction are apparent from progressive sustainability drivers in the public and private sectors. Governmental policies that require green building codes or rating systems like LEED as part of normal practice are more and more common. The new ASHRAE Standard 189.1-2014 (ASHRAE 2014), IGCC (International Green Construction Code), and the WELL Building Standard are some of the latest examples.

Truly, achieving high satisfaction in high performance buildings is something that goes hand-in-hand with sustainability and valuation of buildings. But high-performance buildings do not always correspond to high satisfaction. A building that is not energy intensive but has poor indoor air quality as a result will not be preferred by anyone. Or a drafty and cold building may have low fractions of indoor air contaminants, but occupant comfort complaints will be high and so will the energy bills. How, then, will today's building stock balance all these objectives? One answer is by improving the design, construction, operations, and maintenance of building HVAC including the ventilation air. Because currently no other organization is exclusively representing air systems holistically, AMCA is going beyond the traditional focus on product/manufacturer issues and is establishing a platform for international education and communications about air systems.[1]

During 2014, AMCA began by forming a HPAS (High Performance Air Systems) Task Force to apply modern design approaches with leading edge products and technology for the purpose of optimizing the energy efficiency, comfort, and indoor air quality of commercial building HVAC air systems. High performance air systems are not a product but, in effect, a result of industry professionals thinking differently about air systems in new construction and substantial renovations, to deliver better comfort, lower energy use and competitive installation cost.

In 2015 the initial results were published in a white paper, High Performance Air Systems, that provides additional details to the guidelines in the ASHRAE Advanced Energy Design Guide for Small to Medium Office Buildings – Achieving 50% Energy Savings (ASHRAE et al. 2014). HPAS incorporate heating, cooling and ventilation in a single ducted delivery system. They are the modern equivalent of conventional variable air volume (VAV) systems, updated to provide the benefits of superior comfort/health, low energy use, sustainability and low cost (AMCA 2015).

Benefits of HPAS

We must never forget that the primary purpose of HVAC is comfort and IAQ to ensure

[1] The AMCA (Air Movement and Control Association International Inc.) is a not-for-profit trade association with more than 350 member companies worldwide representing more than $3 billion in annual revenue. Established in 1917, AMCA's mission is to advance the health, growth and integrity of the air movement and control industry, with programs like certified ratings, verification of compliance and international standards development. AMCA also advocates for model codes, regulations and utility incentive programs that promote efficiency and life safety. For more information about AMCA, visit www.amca.org.

the high satisfaction of the building occupants. Small zones of temperature control, each with both an air supply and an air return, are the key to achieving comfortable temperatures. In addition to comfortable temperatures, HPAS provides a healthier indoor air quality (IAQ) and a quieter environment. Fortunately, comfort, healthy IAQ, acoustics, and saving energy all go together hand in hand with HPAS. The same small zones that raise the chances of occupant comfort satisfaction also reduce the chances of overcooling or overheating which lowers fan speeds and lowers the central conditioning requirement both of which result in lower energy use. The ultimate is a zone for each building occupant providing temperature satisfaction and avoiding the energy waste of any overcooling or overheating. Small zones can also eliminate an unexpected energy use when occupants bring in fans and electric heaters to be more comfortable. As will be seen later when describing the features, HPAS low energy use depends on low horse power fans, low cooling requirements and robust controls.

Other benefits of HPAS are sustainability and low cost. The sustainability of HPAS flows from easy maintenance, adaptability and reliability. Both first costs and life cycle costs for HPAS are low.

Low Energy Building Design

Before describing the features that produce the HPAS benefits, a comment should be made about the effect of building design on low energy use. HPAS are sized to service the HVAC load and that load -- and in turn the HPAS energy requirement -- can be significantly reduced by following these guidelines:

- Increase insulation to lower thermal transmittance values.
- Increase thermal mass for roofs and walls.
- Use cool roofs with high thermal activity.
- Use high performance window glazing.
- Provide exterior shading on south facing windows
- Limit window area facing east and west.
- Use north facing clerestories instead of flat skylights.
- Use high performance lamps and advanced luminaires.
- Use photo sensors to dim or turn off electric lights.
- Use occupancy sensors to turn on lights
- Avoid over-sizing design loads
- Eliminate the need for reheat by adding insulation to the building envelope until the heat loss through the envelope at outside temperature below winter design is less than the heat gain of the occupants and other internal loads in perimeter spaces. Warm-up heating may still be required. More about this strategy in the StopWaste example described later.
- Eliminate the need for reheat by using separate air handling units for each heating zone such as one for each exposure and one for the interior.

HPAS Features

This review of the HPAS features that accomplish the HPAS benefits will both describe the HPAS and provide a design guide for implementing building air systems that seek to achieve the outcomes desired by prominent international green building standards, rating systems, and codes.

Comfort and Health

Occupant comfort is ensured with multiple, small temperature control zones, which can be as small as one office, using VAV diffusers sized to be quiet. Occupant health is well served with a superior filtration of ventilation air possible in larger central air handling units and with refrigerant centralized for minimal risk of leakage. See Figure 1.

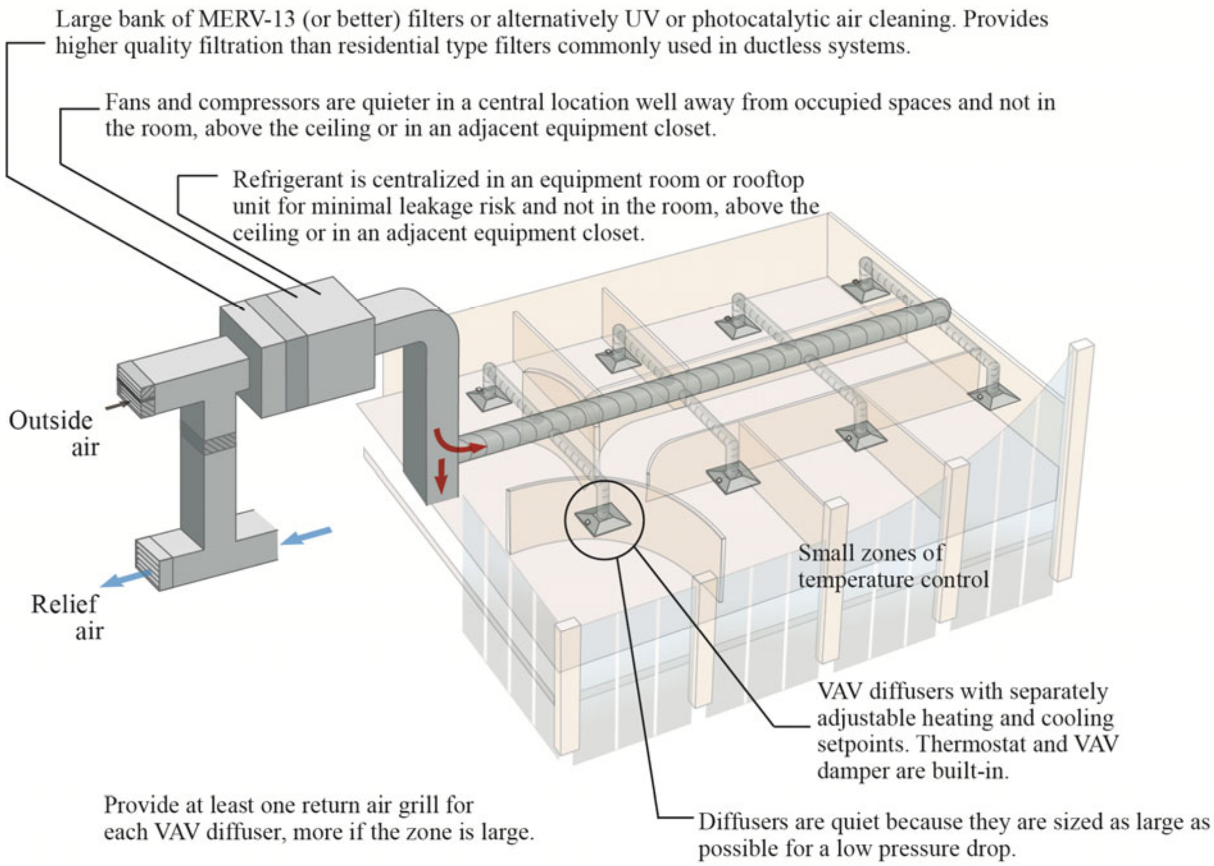

Figure 1. Schematic of high performance air systems (HPAS) showing comfort/health features of HPAS

Low Energy Use

HPAS low energy use stems from several features. Reduction in fan energy begins with a reduction of system design static pressure (fan external pressure) by more than 1-in wg. Up to one third of this is due to elimination of the pressure drop over the VAV box gained by using VAV diffusers. The remainder is from a low pressure drop air system using large filter banks, large coils, low pressure drop duct design, aerodynamic ducts (large radius elbows and fewer transitions and joints) and plenum returns. No valuable floor space is required, as all of the system is above the ceiling or on the roof with the exception of risers and any equipment room. Fans are selected for the highest efficiency and the lowest power (not always the lowest cost, or the smallest fan). See Figure 2. A variable speed drive (VSD) is able to turn the fan down to an airflow approaching the minimum ventilation requirement because the VAV diffusers do not have a low velocity limitation. See Figure 3.

Cooling/heating for HPAS is provided either by a high efficiency chiller/high efficiency boiler combination or a gas-fired high EER VAV rooftop unit. HPAS features for a low refrigeration/heating energy requirement range from low leakage dampers to outside air economizers to supply air reset controls. See Figure 4. Controls do little to reduce design energy requirements (design fan HP and design refrigeration/heating loads) but can help lower energy needs during turndown due to part loads. See Figure 5.

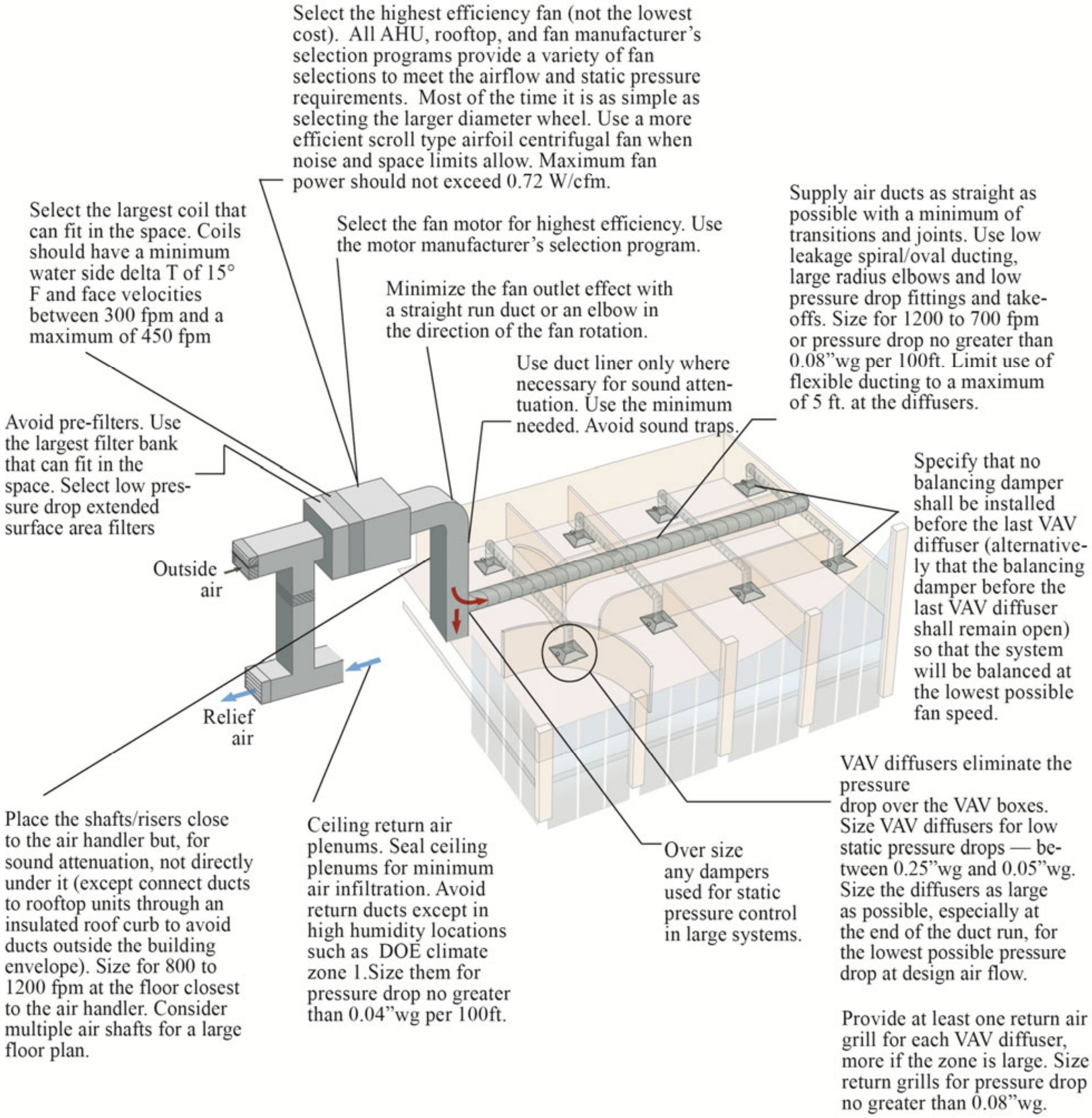

Figure 2. Low energy use – low HP fan features of HPAS

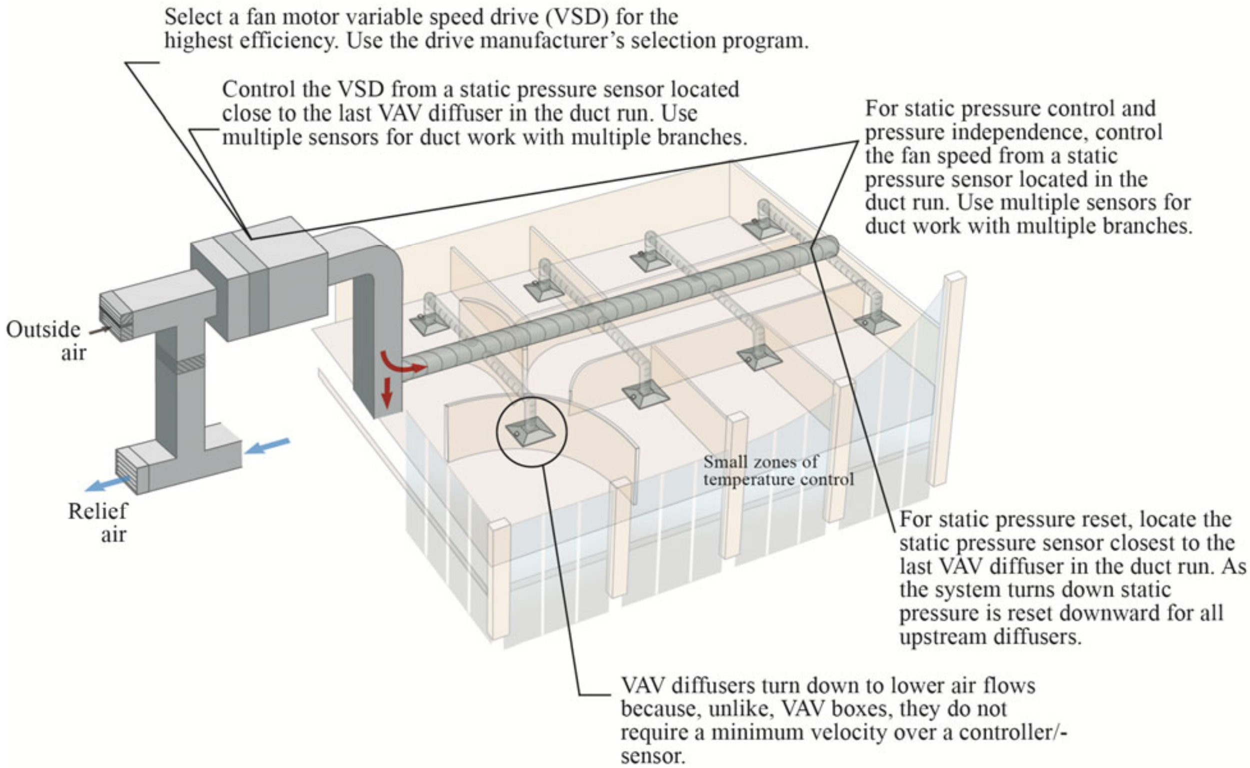

Figure 3. Low energy use – low fan turndown features of HPAS

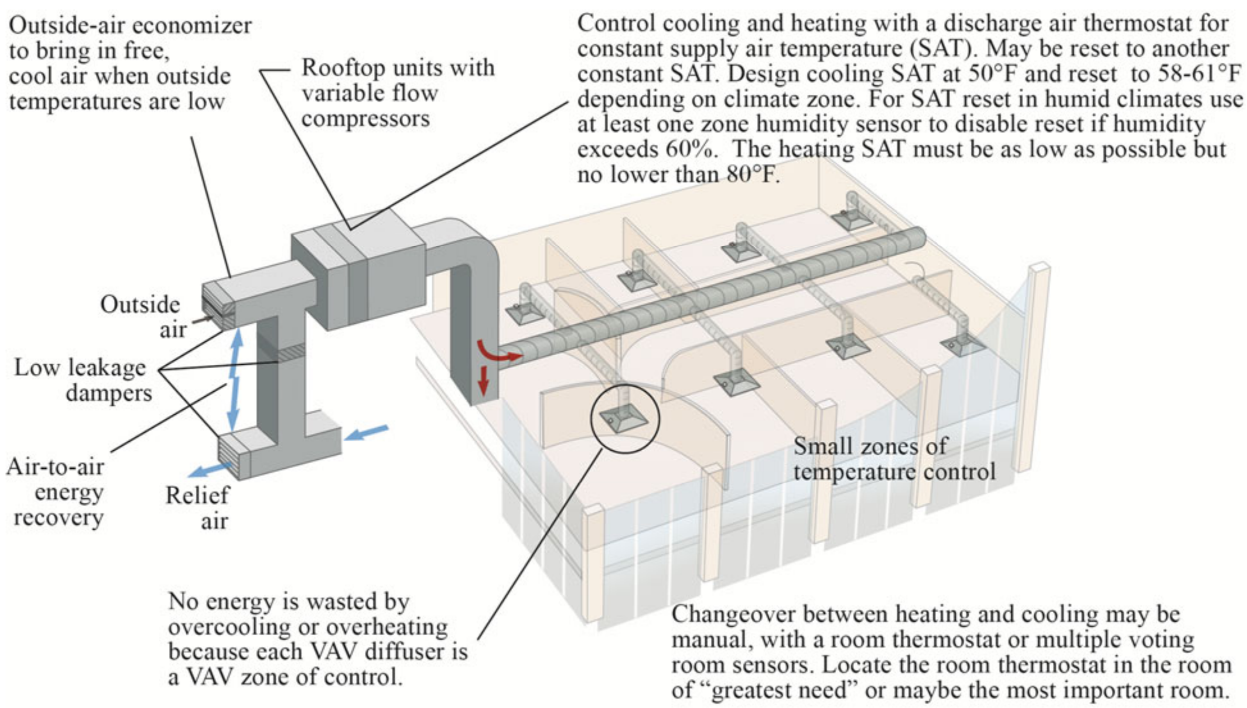

Figure 4. Low energy use – low refrigeration/heating energy features of HPAS

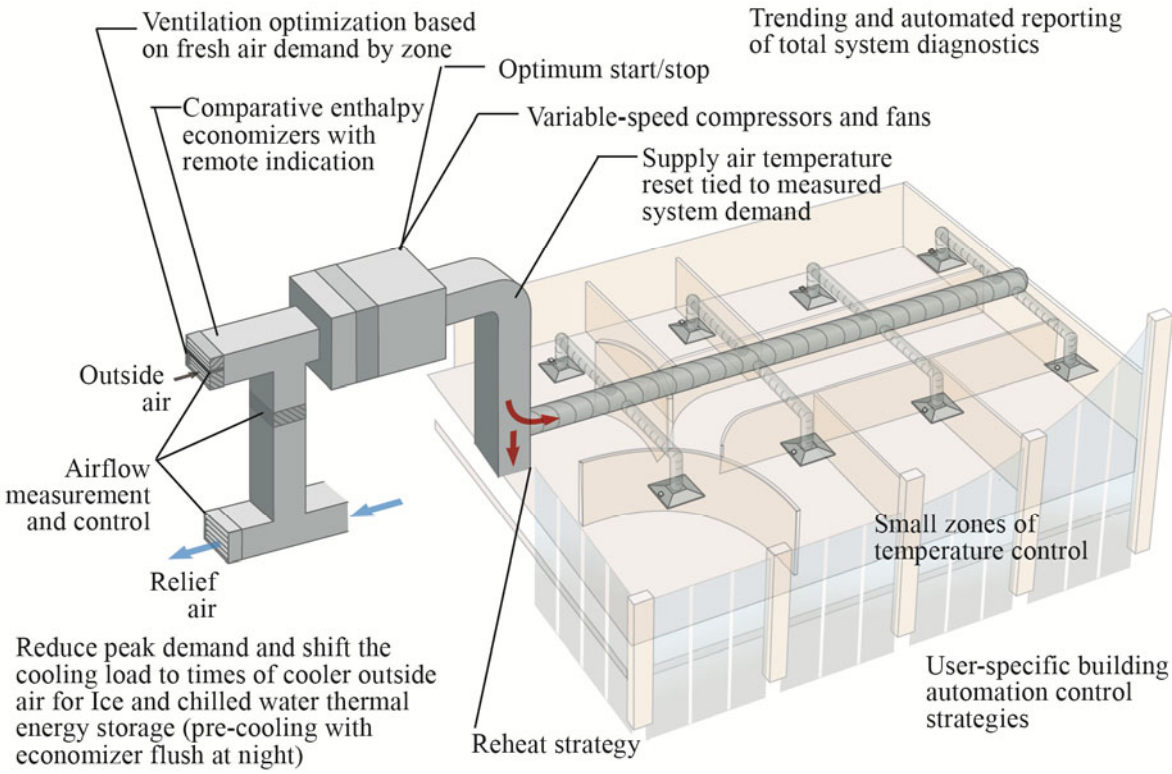

Figure 5. Low energy use---advanced control features of HPAS

Simulated HPAS Energy Savings

Computer modeling must be used when making comparisons of energy savings because it is rare to find identical buildings with identical loads each with a different heating/cooling system. The following graph shows the results of a model comparing HPAS energy savings to the ASHRAE 90.1-2013 baseline. See Figure 6 (Bulger 2016, 6).

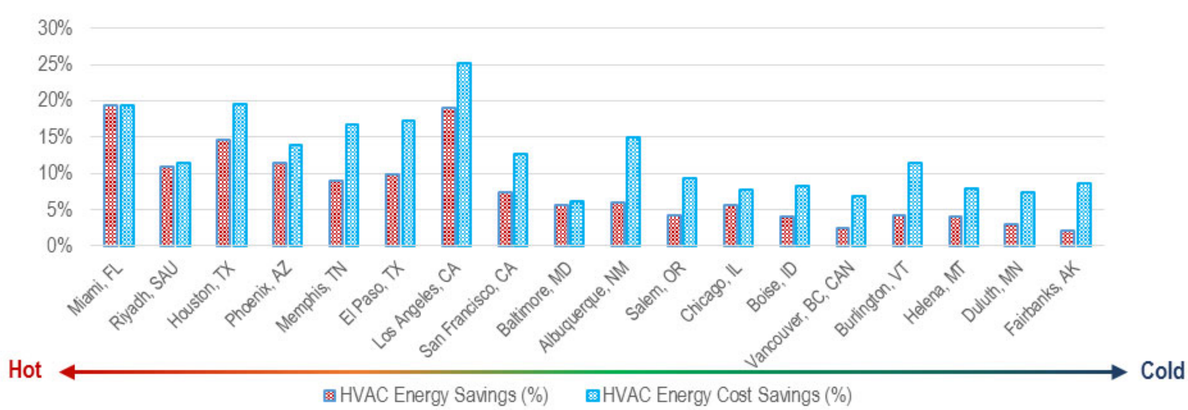

Figure 6. Percent HVAC energy and energy cost savings of HPAS over the ASHRAE 90.1- 2013 baseline. An ASHRAE 90.1 2013 compliant energy model using a EnergyPlus v8.3.0 thermal engine with energy consumption simulated in OpenStudio for each of the ASHRAE climate zones. *Source:* Bulger 2016.

Comparisons can also be made to other non ducted HVAC systems. The graph that follows models the energy use of three HVAC systems in four cities. See Figure 7 (AMCA, 2013, 9).

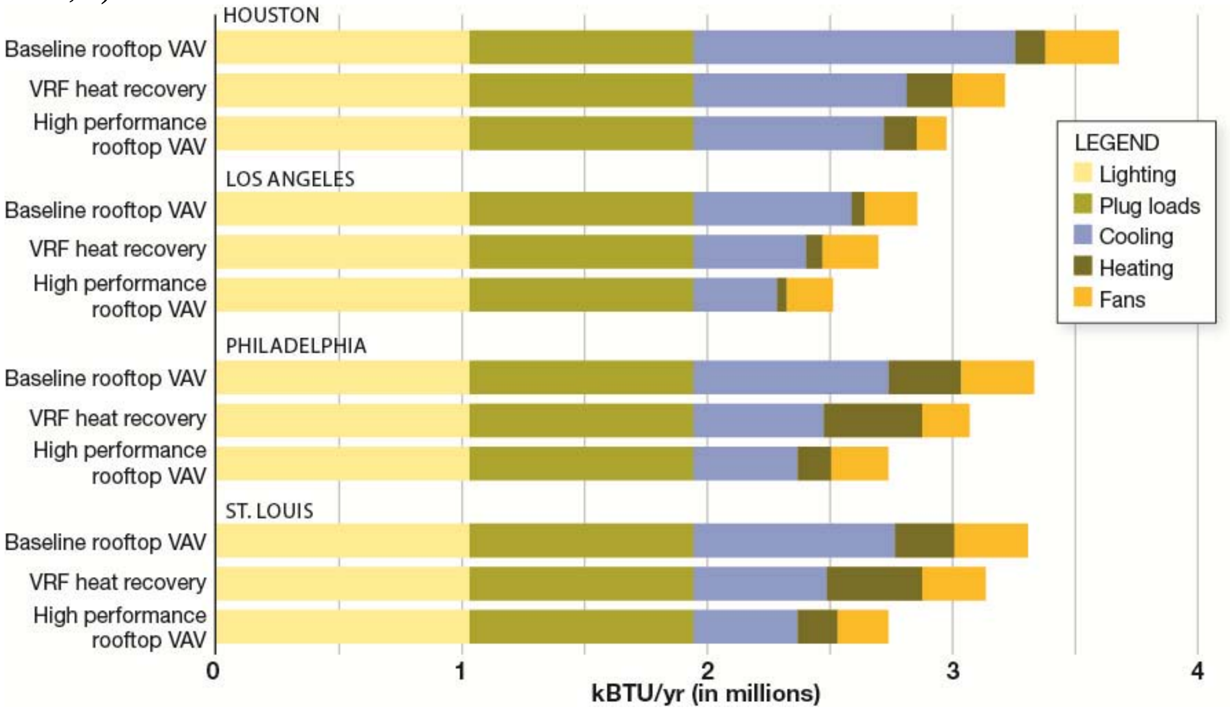

Figure 7. HPAS more energy efficient. Annual building energy use. TRACE energy model of four cities representing different climate zones and HVAC system approaches. Energy use data from 2013 national averages Courtesy of Trane/Ingersol Rand. *Source:* AMCA 2016.

Another study compares the HVAC energy cost of three systems in Los Angeles. Figure 8 (Bulger 2016, 7). See Figure 8. Both compare the energy use of a conventional VAV system, a variable refrigerant system (VRF) and a HPAS.

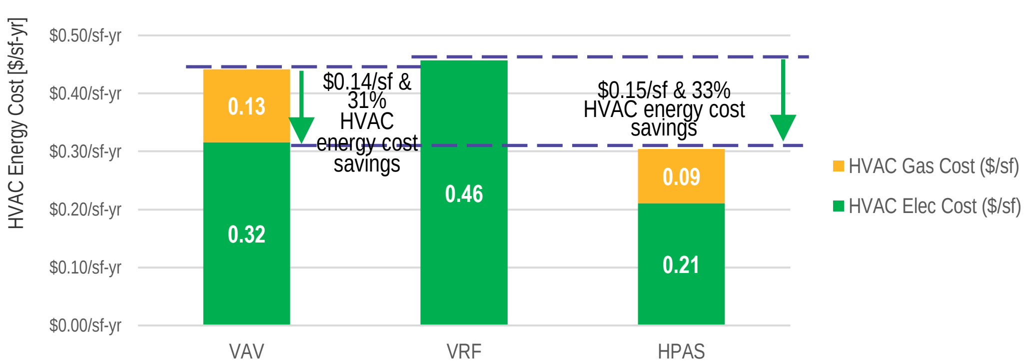

Figure 8. HPAS more cost efficient. Los Angeles, CA - building HVAC energy cost ($/sf-yr). An energy model using a EnergyPlus v8.3.0 thermal engine with energy consumption simulated in OpenStudio for a typical four story building in the Los Angeles climate zone. *Source:* Bulger 2016.

Sustainability

Buildings are sustainable when they serve owners and occupants over time usually in the form of easy maintenance and tenant flexibility. The parts of HPAS needing the most service (compressor, fan and filters) are all in a central location, either on the roof or in an equipment room, away from occupants and easily accessible at any time for maintenance. In addition, the small zones easily adapt to moved walls or other office layout changes. See Figure 9.

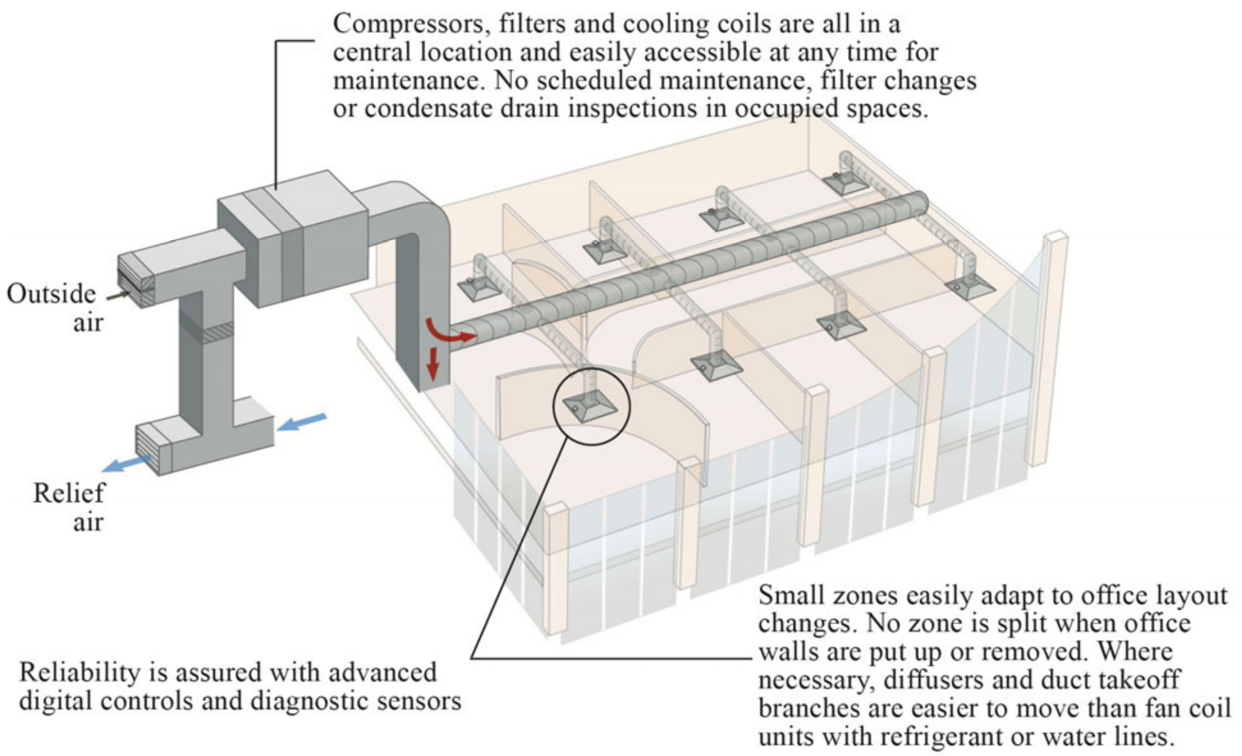

Figure 9. Sustainability features of HPAS

Low Cost

Integrated heating/cooling/ventilation systems have lower first costs than ductless systems. Ductless systems combine first costs for two systems: heating/cooling and ventilation. As a result, the installed system cost for a ductless system can be nearly twice that of an HPAS system in some applications. See Figure 10 (Trane 2013).

It should be noted that, in addition to saving energy, the benefits of a VAV zone for each occupant include higher worker productivity and improved ability to lease the space. Expensive office workers are more productive when there is no distraction from being uncomfortable. Also, the ability to lease office space is much better when offering a thermostat for each person. These should be included in any payback calculations.

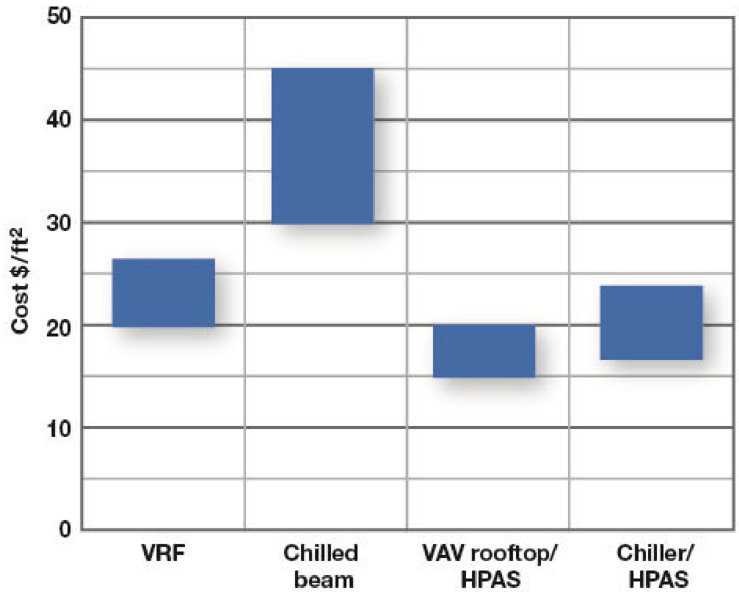

Figure 10. Typical installed system costs. Installed HVAC system cost comparison. *Source:* Trane nationwide study 2013.

StopWaste Case Study

Many buildings with HPAS larger than StopWaste are LEED certified but few have two LEED firsts (Murray 2014). StopWaste is an example of the complexities that surround high satisfaction in high performance buildings that utilize HPAS. The 14,000 ft^2 building was originally built in 1927 and was purchased and then renovated by StopWaste, a local government agency of Alameda County, California and located in downtown Oakland. StopWaste's sustainable design goals for the major renovation resulted in the project earning a LEED Platinum certification in 2007: the first major renovation project in the nation to earn LEED v2.2 Platinum by the USGBC (USGBC 2007). At that time energy modeling software showed that the building outperformed Title 24-2005, the stringent California energy code, by 47%. Subsequent to that, StopWaste has monitored and tracked performance.

Since initial certification, the owners have operated a lean and green building: sipping water, conserving energy, and minimizing their waste stream. The building has earned numerous awards for their performance, including a Water Smart award from their water utility, Green Power Partnership status and Energy Star certification from the EPA, and local Green Business certification.

In late 2013, StopWaste sought their second LEED rating for Existing Building Operations & Maintenance. StopWaste registered as a beta project in the newest LEED Rating System version (LEEDv4), and got to work. By August of 2014, the building had achieved another first: Platinum certification – the first Platinum LEEDv4 project in the world (USGBC 2014).

Lots of valuable features and elements contribute to the building's low energy use. Photovoltaic solar panels are sized to provide at least 10 percent of the electricity needs. Several features help reduce the HVAC energy requirement during part load conditions. Seventy-five percent of the workspaces are daylit and the high efficiency fluorescent lights are turned off with photosensors when there is adequate daylight. Also bi-level switching reduces light levels when full brightness is not needed. The controls also notify occupants when conditions outside are optimal for opening windows to provide natural ventilation

However, one specific feature significantly reduced HVAC energy need. A unique rain catchment system required a resloping of the roof which, in turn, resulted in increased thermal insulation. That combined with installation of high efficiency windows reduced the heat loss through the building envelope eliminating the need for reheat. Reheat is not necessary when the heat loss through the building envelope at outside temperature below winter design is less than the heat gain of the occupants and other internal loads in perimeter spaces.

The engineer's duct layout drawing for the second floor of StopWaste, see Figure 11, shows some of the HPAS features that provide comfort, quiet operation and low HVAC energy use.

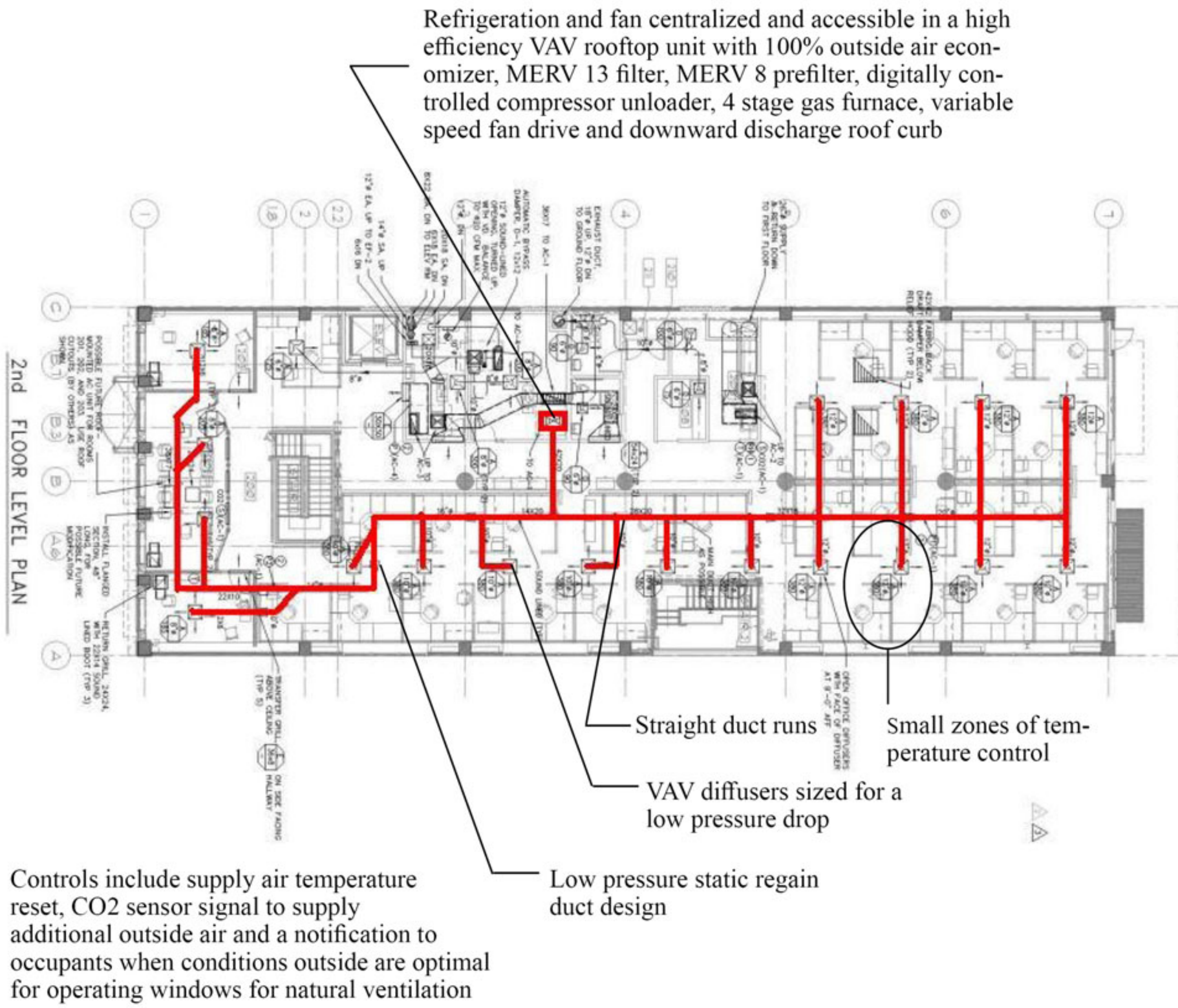

Figure 11. StopWaste second floor HPAS features

StopWaste was awarded 54 total points for the LEEDv2.2 certification. HPAS impacted 14 of those points. Low fan and refrigeration energy use contributed to 10 out of 10 points in the Energy and Atmosphere – Optimize Energy Performance category. The other 4 points were in the Indoor Air Quality category; 1 each for Outdoor Air Delivery Monitoring, Controllability of Systems (thermal comfort), Thermal Comfort (Design) and Thermal Comfort (Verification).

Finally, in 2016 StopWaste set up an online tracking system via the LEED Dynamic Plaque to monitor energy, water, waste, transportation and occupant satisfaction. Clearly, StopWaste has walked the walk when it comes to high performance.

Project Summary
Size: 14,000 sf
Use: Commercial Office
LEED v.4 Certified: 1 August 2014

HPAS Features

- Four master zones: first floor, perimeter and board room; second floor, perimeter and core;
- Perimeter and core conditioned using a high efficiency packaged DX, gas heat and variable speed fan;
- Master zones subzoned with VAV diffusers;
- Four carbon dioxide sensors increase or reduce the amount of outside air.

LEED Facts
For LEED O+M: Existing Buildings (v4)

Certification awarded Aug 2014

Platinum	**80**
Location & transportation	**15/18**
Sustainable Sites	**4/10**
Water efficiency	**7/12**
Energy & atmosphere	**31/38**
Material & resources	**4/8**
Indoor environmental quality	**12/17**
Regional priority credits	**4/4**

Conclusion

A thoughtful design of commercial office HVAC will result both in occupant comfort and lower energy use. This paper presents the design features of HPAS which can be used to achieve better comfort, healthy indoor air quality, low energy use, sustainability and lower cost. The features of HPAS easily adapt to both new layouts and renovation. Applying them will ensure that high performance buildings are designed and maintained in a way that provides high occupant satisfaction once in use and achieves the outcomes desired by the prominent international green building standards, rating systems, and codes.

References

AMCA (Air Movement and Control Association International). 2015. *AMCA International HPAS (High Performance Air Systems) White Paper*. http://www.amca.org/whitepapers

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers), The American Institute of Architects, Illuminating Engineering Society of North America, U.S. Green Building Council, and U.S. Department of Energy. 2014. *Advanced Energy Design Guide for Small to Medium Office Buildings – Achieving 50% Energy Savings*.

———. 2014. *Standards 15, 34, 55, 55.1, 62.1, and 189.1-2014, Standard for the Design of High-Performance Green Buildings*. www.ashrae.org

———. 2013. *Standard 55-2013, Thermal Environmental Conditions for Human Occupancy*. www.ashrae.org

Bulger, N. 2016. *Energy Analysis Report 2016.* Oakland, CA: Integral Group.

Frontczak, Monika, and P. Wargocki. 2011. "Literature survey on how different factors influence human comfort in indoor environments." *Buildings and Environment* 46 (4): 922-937.

Murray, Barbara. 2014. US. Green Building Council, USGBC+ "Leading by Example." *November/December 2014*: 18-21. http://plus.usgbc.org/issues/USGBCMagazine_11-2014.pdf

Trane. 2013. *Intelligent Variable Air: An EarthWise™ System from Trane for packaged DX applications. APP-PRC003-EN.* La Crosse, WI.

USGBC (U.S. Green Building Council). 2014. *LEED Scorecard, StopWaste LEED v4 Platinum Certification.* http://www.usgbc.org/projects/stopwasteorg?view=scorecard

——— . 2007. *LEED Scorecard, StopWaste LEED v2.2 Platinum Certification*. http://www.stopwaste.org/about/about-stopwaste/our-green-building/stopwastes-leed-documentation