Greening Vivarium HVAC Systems

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Vivariums present many unique challenges to design and construction professionals. Due to the stringent environmental and construction requirements, designers and builders have their hands full ensuring the facility meets the numerous standards regulating these spaces.

In the struggle to meet these challenges, compromises are often required to stay within budget, meet the physical constraints of the building, or satisfy the schedule. All too often, one of these compromises is energy efficiency; however, given today's rising fuel costs and concern for greenhouse gas emissions, energy efficiency merits a higher priority. Therefore, it is essential to examine all established design standards and "rules of thumb" and look for every opportunity to reduce energy consumption, while still maintaining a safe and tenable environment in the vivarium.

Odor Control

The generally accepted method for control of toxic or odor causing gases, such as ammonia, is dilution of spaces using non-recirculated, single-pass air, at a rate of 10-15 air changes per hour (ACH).[1] Based on this criteria, a common design for a typical holding room, without regard to animal population or caging system, is constant volume reheat at a rate of 15 ACH. There are a number of ways to challenge these criteria and maintain acceptable conditions within the space. By designing the space as variable volume, the air change rate can be easily raised or lowered based on occupancy, thus reducing the air change to a minimum rate in spaces that are not in use or in spaces with small populations. Furthermore, spaces with ventilated rodent cages, "effectively address the ventilation requirements of animals without the need to ventilate secondary enclosures [holding rooms] to the extent that would be needed if there were no independent primary-enclosure [ventilated cage]."[1] Therefore, it should be possible to reduce air change rates in spaces with ventilated cabinets to a much lower level, perhaps 6 or 8 ACH. Another approach to reducing vivarium air change rates is demand controlled ventilation. See Gordon P. Sharp's "Dynamic Variation of Laboratory Air Change Rates" (*ALN* vol.7, no. 8) for an excellent discussion on this topic.

Heat Recovery

Reducing air change rates, either strategically or dynamically, is only part of the energy efficiency puzzle in the vivarium. As previously noted, supply air to vivariums is not recirculated, so all the energy spent conditioning this air is exhausted out of the building. There aremany heat recovery solutions on themarket to recover energy fromthis exhaust in order to preheat or precool supply air streams. It is essential to recognize that any solution with the potential for cross contamination, such as energy recovery wheels, should be avoided. Unfortunately, in eliminating energy recovery wheels, energy recovery effectiveness is also severely limited, by almost 50%, since other types of energy recovery only recover sensible heat. However, even with limited efficiency, with high airflows and 24 hour per day operation, sensible only heat recovery should be utilized to reduce energy usage and shave peak demand loads. Reducing peak demand has the added benefit of reducing required capacity of central cooling and heating equipment or the impact on campus chilled water and steamsystems.

Environmental Conditions
The environmental conditions required for vivariums pose additional energy challenges. *The Guide for the Care and Use of Laboratory Animals* and NIH guidelines require space temperatures to be adjustable between 64° F and 79° F while maintaining relative humidity between 40% and 70%. The low range is a particular problem. In order to maintain 64° F with a reasonable relative humidity (40-50%), supply air needs to be dehumidified to a dewpoint of approximately 40° F. This level of dehumidification is impossible with conventional chilled water systems. One method to achieve this performance is to use glycol chilled water systems, which cool the air to 40° F using water temperatures in the low 30° Fahrenheits, and then reheating this air to maintain space temperature (Figure 1). This approach results in 25% to 35% greater energy use over a conventional system. A second option is to use a side stream desiccant dehumidifier to significantly dehumidify a portion of the airstream to maintain design conditions (Figure 2). This option is also energy intensive, using approximately 15% to 25% more energy than the base design. Manufacturers are currently working to address this energy use challenge, too. One such approach is the Trane CDQ unit, which uses a series desiccant wheel to improve the dehumidification ability of a cooling coil (Figure 3). The CDQ wheel transfers the latent load off the cooling coil and passes it through the cooling coil again, essentially dehumidifying the air twice. This option uses approximately 20% less energy than the conventional system, while maintaining conditions at AAALAC standards, which the conventional system cannot do.

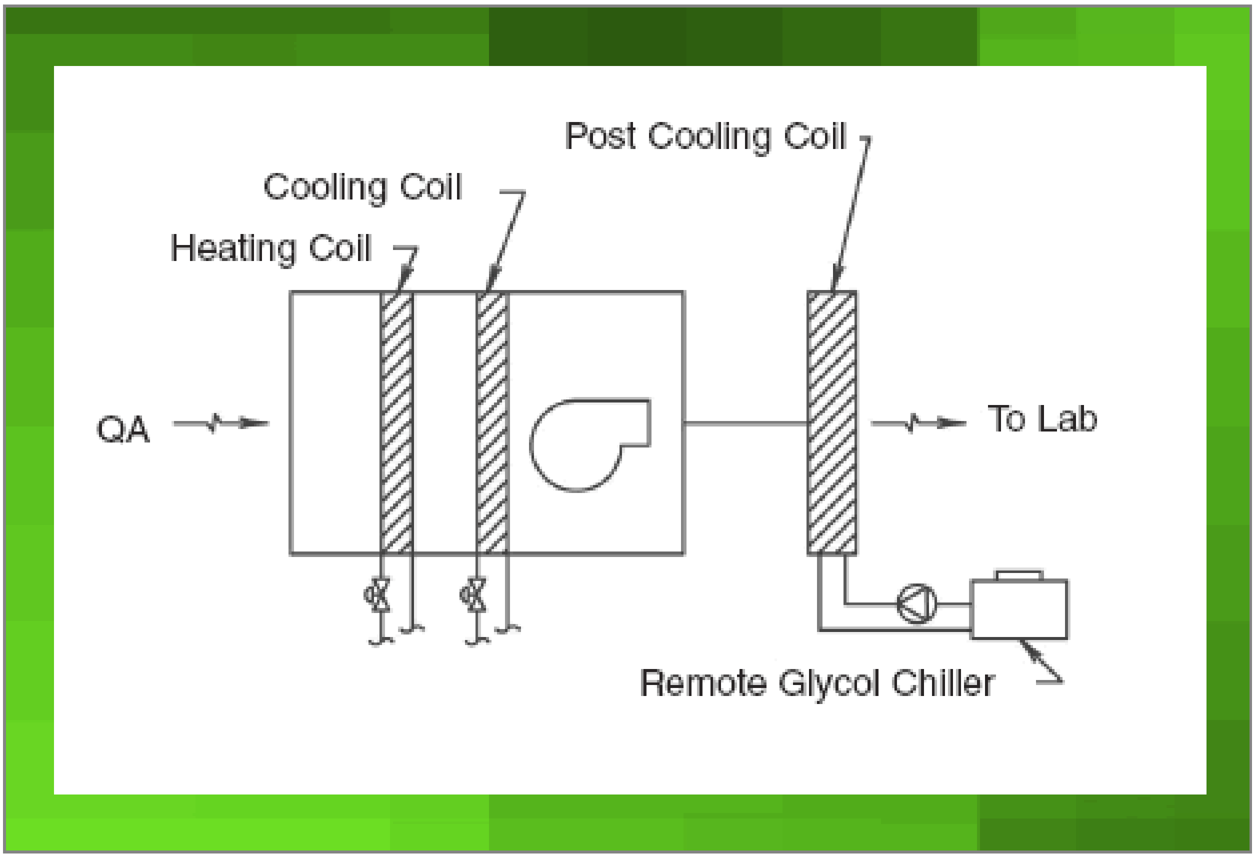

Figure 1: Glycol Cooling System

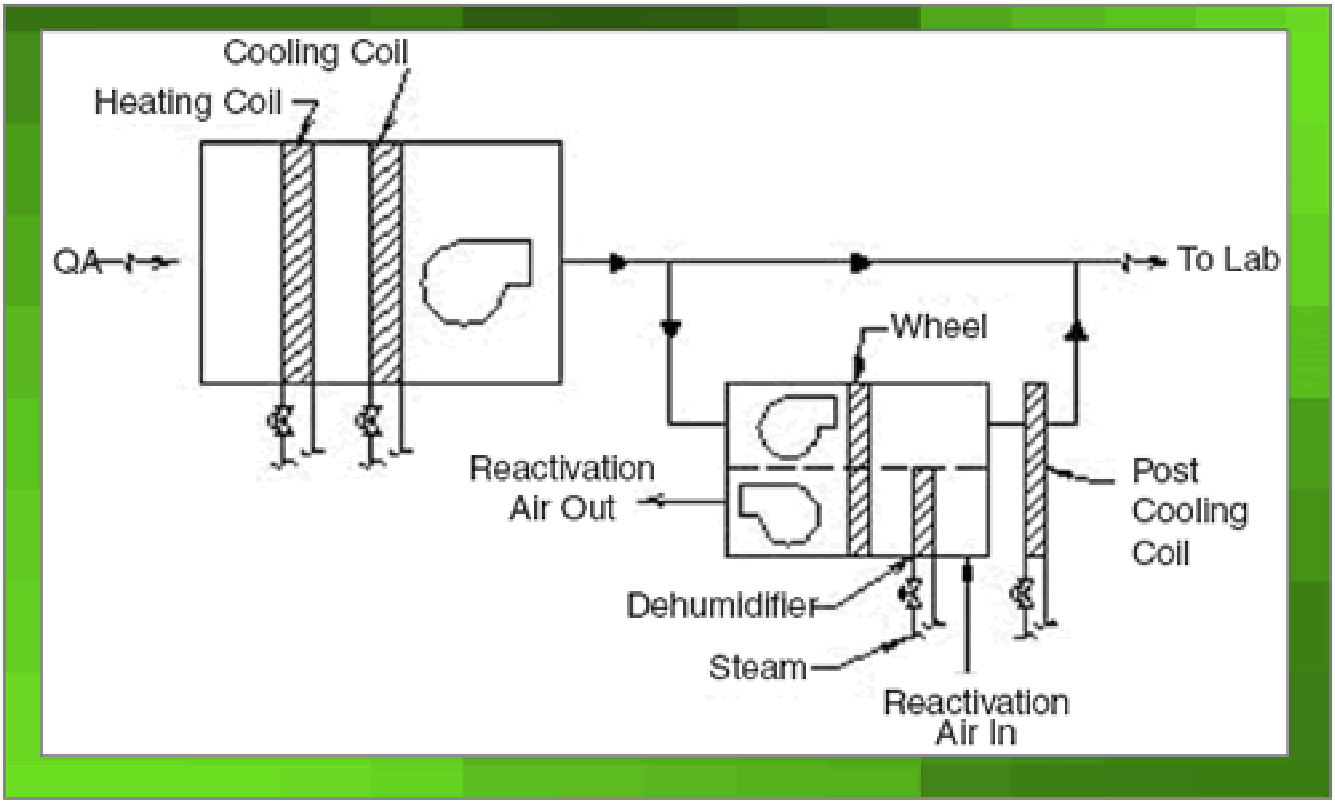

Figure 2: Desiccant Dehumidifier System

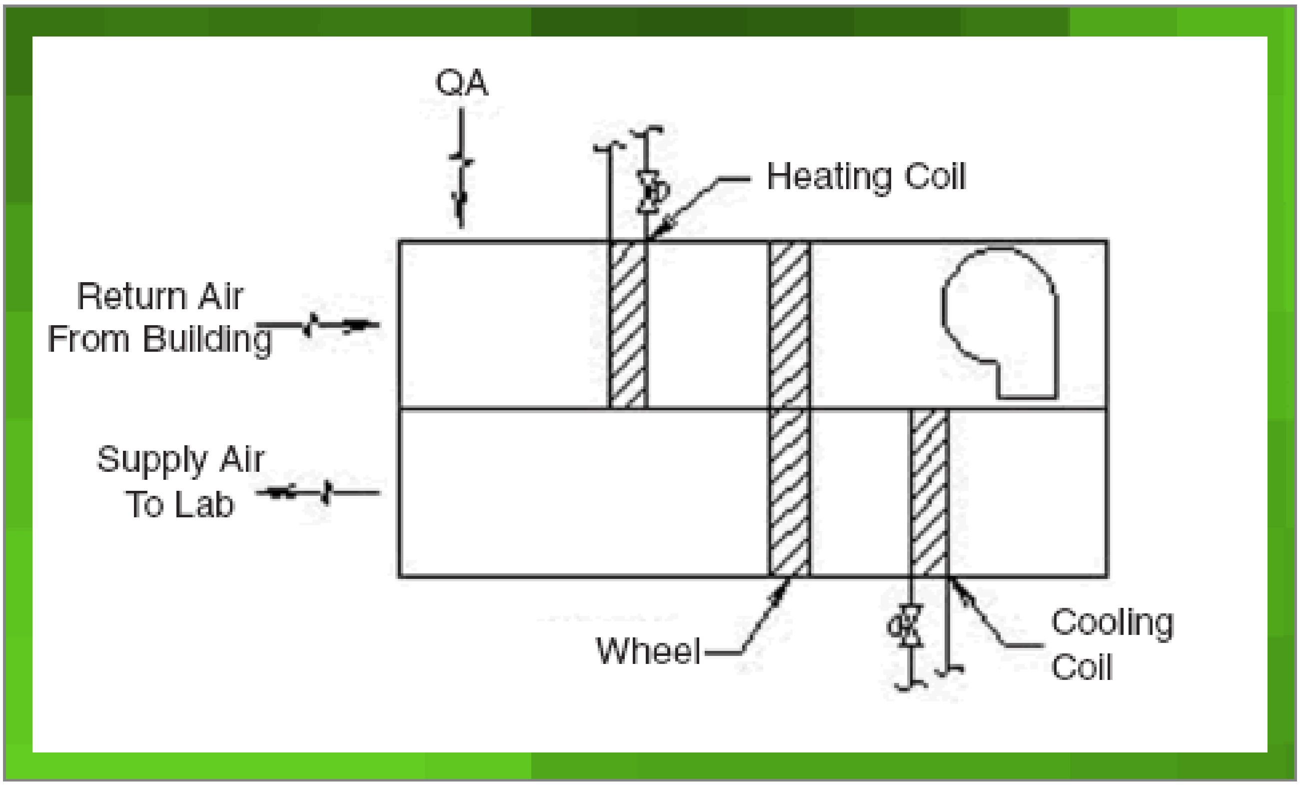

Figure 3: Series Desiccant Dehumidification System

Support Spaces
It is also important to look at spaces outside of the animal holding areas for energy savings opportunities. For example, many vivarium support spaces, such as cage wash equipment alcoves, have high heat loads with minimal odor or toxic off gassing. Rather than using single pass air, chilled water fan-coil units or DX split system units can be used to manage the heat load. There are great benefits to this approach. In addition to the substantial energy savings that can be realized, house equipment capacity (which is likely 100% redundant) can be reduced. Canopy hoods are another item to target in the support spaces. Typically, canopy hoods can exhaust as much as 1500 to 2500 cfm continuously. If the exhaust air were interlocked with cage wash equipment, this exhaust air could be reduced to a minimal amount during non-washing periods of the day. Heating loads can then be served by dedicated units as thus described, minimizing the time expensive single-pass air is used.

Out of the Box
A more radical approach is to provide a system that recirculates the air within the vivarium during peak cooling periods only. Peak is defined as outside air temperatures greater than 80° F. Looking at four cities within different climate zones, it can be seen that with one exception (Phoenix), the peak cooling load occurs only for a small fraction of the annual operating cycle (Table 1). Based on this data, the proposed system would operate conventionally (100% outside air) during the majority of the year. When ambient temperatures exceed a threshold value (approximately 80° F), control dampers would switchover to a bank of HEPA and carbon filtration to remove airborne particles and ammonia odors from the "return air" (Figure 4), which would then be mixed with a smaller fraction (25-30%)

of outdoor air. When temperatures again drop back below the threshold value, the system would return to the conventional mode. Energy savings with this hybrid approach of recirculation and 100% outside air range from 5% of total cooling load to almost 25% depending on climatic location (Table 2). What's more, the likely scenario is that the recirculation mode would only occur during daytime hours when temperatures exceed the threshold value, as the sun sets and temperatures drop, the system would return to 100% outside air mode, allowing the vivarium to be "flushed" prior to the next day. By taking this approach one step further and lowering the threshold value of recirculation to 72° F, even greater energy savings can be realized in climates such as Atlanta and Boston. However, decreasing the threshold value does increase the number of hours the system would be in recirculation mode (14% vs. 38% in Atlanta and 5% vs 17% in Boston). Energy savings in these climates can be increased to 36% and 29% of the total cooling load, respectively.

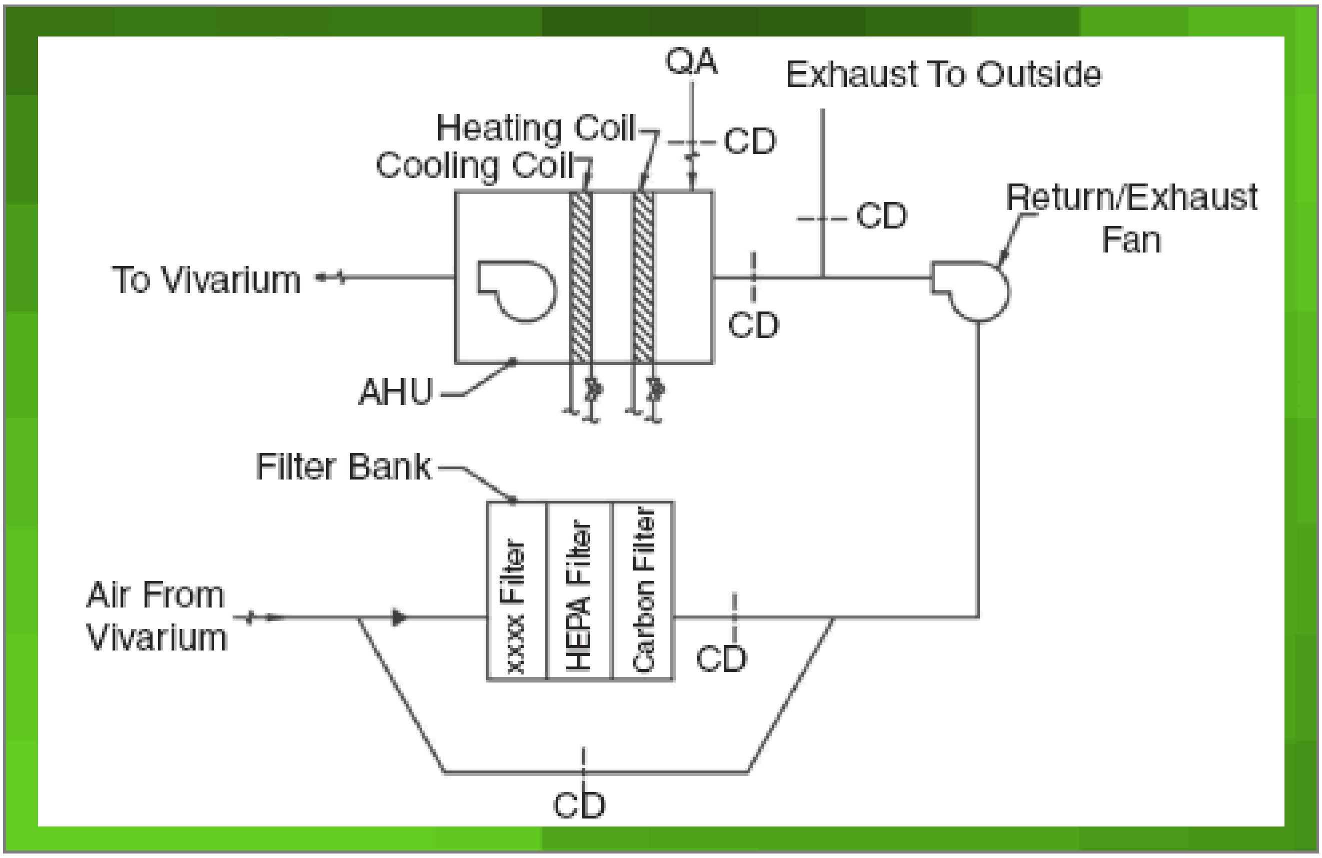

Figure 4: Filtration System for Part-Time Recirculation

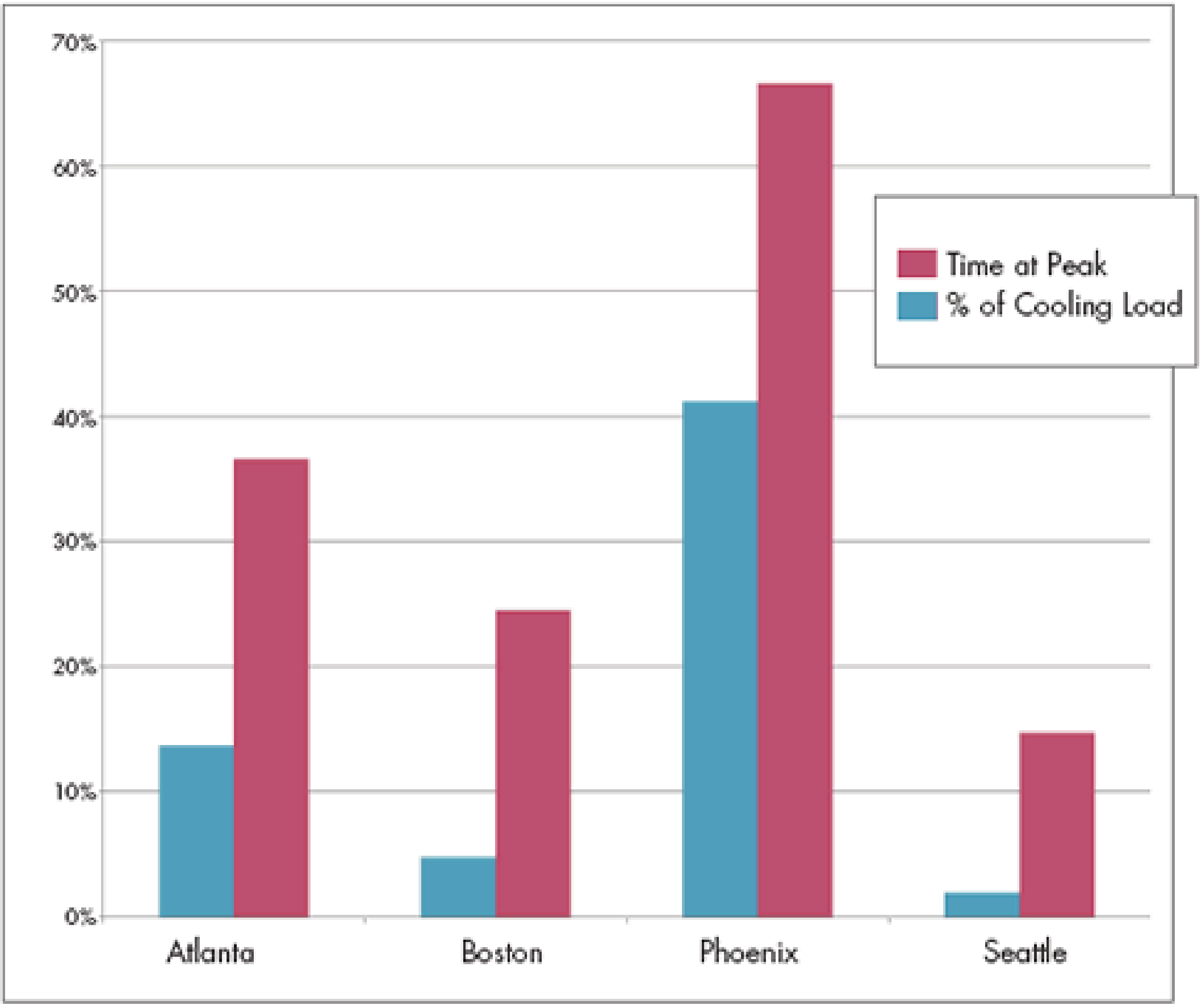

Table 1: Percentage of annual operating cycle spent above 80° F compared to percentage of total cooling load

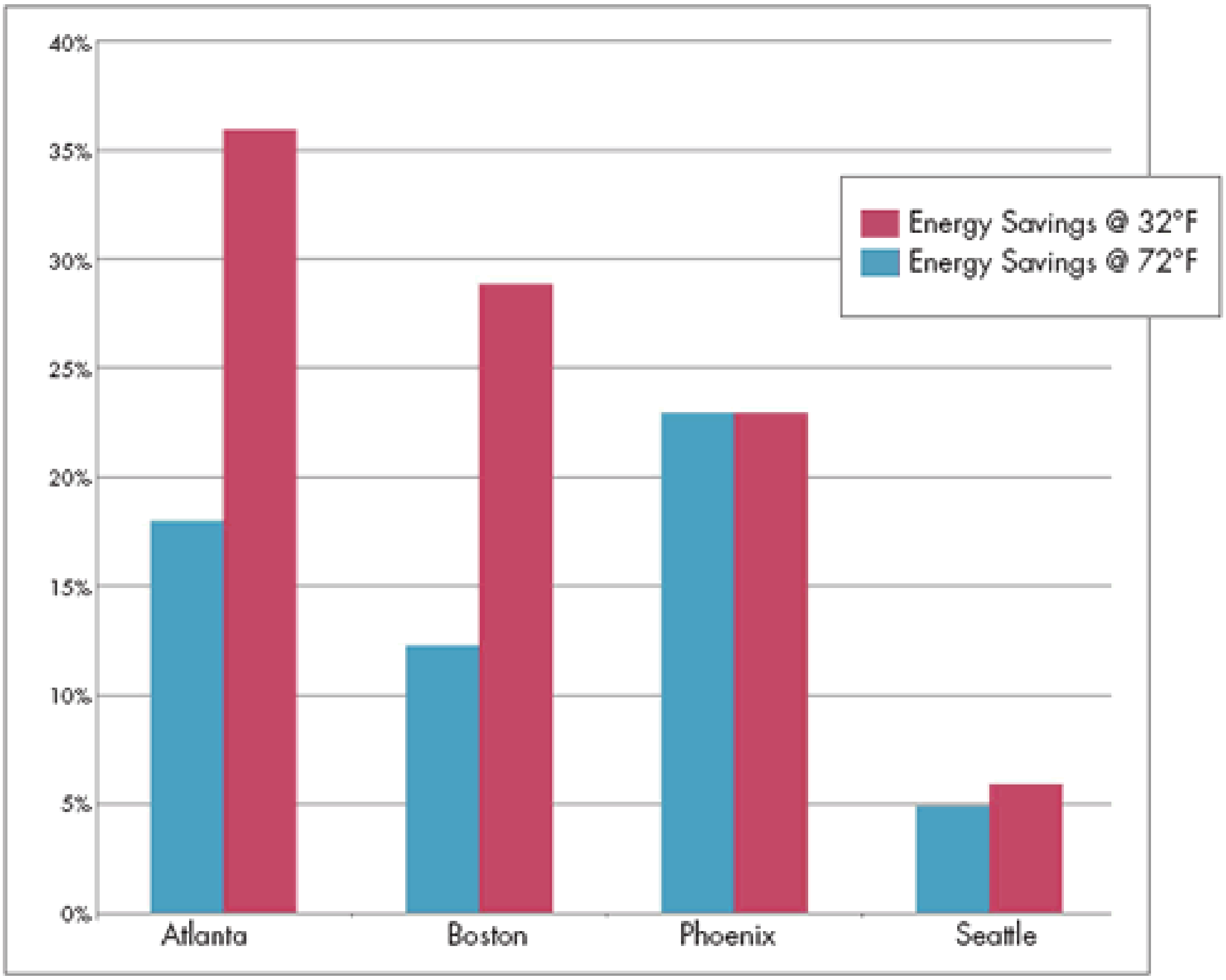

Table 2: Recirculation System Energy Savings

Conclusion

While vivariums have typically been notorious for energy usage due to many factors, there are many approaches to reduce consumption. Reducing air change rates where feasible, whether by taking a second look at existing standards or using new technology, can have a significant impact. Likewise, it is important to evaluate all heat recovery and dehumidification options to deliver air to the space in the most efficient manner possible, as well as the manner in which those spaces are served. Finally, the energy savings achievable due to recirculation warrants further review in the design community.

Reference

1. Guide for the Care and Use of Laboratory Animals. Washington, D.C.: National Academy Press, 1996.

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has presented at Labs21, the Greenbuild Conference and Laboratory Design conferences. He has had mechanical design responsibilities on over 80 projects. He co-authored the article "Innovative Design Strategies for Vivarium HVAC Systems" in the January/February 2005 issue of ALN® Magazine.

Todd Mowinski will be presenting "Greening Vivarium HVAC Systems: Strategies to Reduce Energy Consumption while Maintaining the Full Range of AAALAC Guidelines" at the 2009 TurnKey Conference to be held April 14-15, 2009 in San Antonio, Texas.

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