improve the environment they will have to enforce changes such as seasonal set points, reduced lighting schedules, night time shutdowns, closing of windows and doors, etc. Educating staff about the reasoning behind these changes and the ultimate goals of preservation and energy savings is essential.

Prevent Inappropriate Adjustments

Human comfort requests should not be the only driver for set point changes – particular in systems that effect collections storage areas. Facilities must continue to inform and educate their staff since they will be on the receiving end of comfort complaints. Often a change made to a set point for one location will affect several others. Your institution's HVAC zone map can be used to ensure that everyone is clear about which systems create environments for collections storage in order to avoid changes that work against the optimization goals of the team.

The Environmental Management Team should determine who has the authority to change temperature and humidity set points and to suggest procedures for handling requests for these changes. As the team gains experience, they may also define seasonal changes in operation such as instituting winter or summer control schedules.

9

CHAPTER 9: Investigate Opportunities for Energy Savings

As stated in the introduction, collecting institutions are dealing with mandates to lower operating costs and institute sustainable energy use practices while maintaining long-term preservation of collection materials. This guidebook is designed to help institutions by providing guidelines and methods to avoid risks to collections while instituting energy saving practices. As we have already noted, the best solutions require input from collection care, facilities, and administrative staff as they work together to develop the optimal situation.

The complexity of the investigation of energy saving opportunities will depend on the size of your institution and the type of building and mechanical equipment you are dealing with. The suggestions included below are broken down based on the building classifications discussed in Section 2B.

9A Energy Saving Suggestions for Class One, Two, and Three Buildings

These building classifications are associated with both standard historic houses and some residential, and religious buildings. Moisture control is generally limited.

Reduce heating and cooling loads

Use shutters, windows, porches, curtains, awnings and shade trees. Pull down the shades on sunny summer days to reduce the heat load. Consider adding storm windows to reduce heat loss. You can improve energy efficiency by using appropriate weather stripping and caulking around doors and windows. Consider installing insulation in attics and basements. Add insulation and vapor barriers to exterior walls only when it can be done without damage to historic building structures.

Minimize lighting operation

When the room is unoccupied, lights should be off. Make sure that emergency circuits are kept to the minimum necessary. If lights are on motion detectors or timers, make sure that the length of time the lights are on corresponds with the average length of time spent in the space. Minimize equipment operation – for conditioned spaces or zones that include a large number of workstations with electronics (computers, copiers, scanners, etc.) be sure to shut equipment off at night and on the weekend.

Lower the temperature where collections are housed to reduce energy use

Dial down the radiators or close the heat vents in winter—but measure the relative humidity to be sure it stays below 55%, in which case you will need to raise the temperature or dehumidify. Check the outdoor dew point averages and use IPI's Dew Point Calculator (www.dpcalc.org) to determine what the best balance you can achieve is. You will want to keep the RH between 25% and 55% to avoid the majority of moisture-related problems.

Deal with any sources of moisture that could cause problems for your collections

Consider the effect of periods of high humidity, rain, local bodies of water, wet ground, leaking pipes and broken gutters, moisture in walls, human respiration and perspiration, wet mopping, flooding, and cycles of condensation and evaporation. Reduce or eliminate these problems to the degree that you can.

Minimize infiltration through the building envelope

Keep doors and windows closed – not only windows and doors to the outside, but interior windows and doors that open between spaces served by different systems with different set points.

Manage RH in Historic Buildings

Initial steps to reduce relative humidity in historic buildings are not at all expensive. Move water away from the building by installing gutters and downspouts, slope the ground away from the foundation, and trim vegetation to at least two feet away from the building.

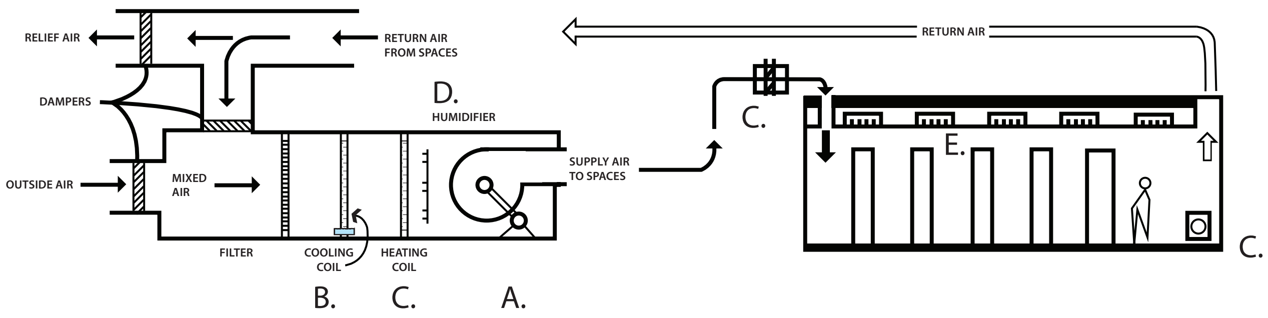
To avoid dangerously low relative humidity levels—below 20%—close your historic house museum from December through March and turn the heat down or even off for these months if water can be turned off and pipes drained. As the temperature decreases, the RH increases, so reducing the temperature from 65° to 55°F will increase RH from a dangerous 20% to a much safer 33%—and you will save on heating bills.

High humidity can be reduced in historic house museums in the spring and fall by controlling the furnace with a humidistat instead of a thermostat. For example, if RH goes above 55% the heat will turn on and run until RH drops back down to 55%.

Richard L. Kerschner, Chief Conservator, Shelburne Museum, Vermont

9B Energy Saving Suggestions for Class Four and Five Buildings

Over a decade of experience in monitoring the behavior of storage area HVAC systems in Class Four and Five buildings and monitoring climate conditions in associated storage areas has demonstrated that these systems can consume more energy than necessary to achieve their desired climates, and that this excess energy consumption can go undetected by normal operating and maintenance practices. You can benefit by visiting each significant energy-consuming element and asking, "Is this element using any more energy than necessary to achieve its intended function?"



A. Air Handling Fans B. Cooling Coil C. Heating Coil D. Humidifier E. Lighting

The figures in the table at the right were included in Section 2D. They are repeated here to illustrate the allocation of annual energy cost in a typical collection storage area. Potentially excessive energy use by the system components (identified in the illustration above) are detailed below:

Component	% of Annual Energy Cost
A. Air handling fans	19%
B. Cooling coil	30%
C. Heating coil	40%
D. Humidifier	5%
E. Lighting	6%

AHU Supply and Return Fans (A)

Many fan motors are equipped with variable speed drives, making it possible to reduce the fan speed (and therefore the rate of energy consumption) at times when the climate can be maintained with a reduced air flow. However, this variable capacity is often underutilized or not used at all. In situations where the fan speed can be controlled by a schedule (e.g., slowed down at night) the schedule is either not used at all or used too conservatively (e.g. , slow down 10% for 3 hours per night when conditions could have been maintained by a slowdown of 50% for 8 hours per night). To get the maximum energy savings from this variable speed capability, facilities staff and collection managers must perform a series of experimental slowdowns to determine when (what time of day, what time of year) and how far the fan speed can be reduced without compromising the quality of storage climates.

Cooling/Dehumidifying (B)

The function of the cooling system is to remove heat that enters the system. Within the storage spaces, heat is added to the air stream by the lights, and operation of the lights should therefore be managed to coincide with occupancy (see E. Lighting). Likewise, doors to adjacent warmer spaces should be open only when necessary.

Cooling Coil

For most Class Four and Class Five buildings with a reasonably constructed envelope, the primary driver of cooling energy consumption is the amount of outside air brought into the system. The introduction of more outside air than is necessary into a system, whether by holding to occupied building code for unoccupied spaces, through malfunction, or other cause, results in greater energy usage to perform work on that air. Whenever the outside air temperature is above the desired supply air temperature (usually 60°F or lower) heat must be removed. Additional heat must also be removed whenever the dew point temperature of the outside air is above the desired storage area dew point temperature (typically 45° to 50°F). In warm humid climates, the outside air needs cooling continuously, and even cool northern climates must cool outside air up to six months per year.

Most systems remove the excess moisture from outside air by a process of sub-cooling and reheating and this sub-cooling can represent a major portion of the total annual cooling energy consumption. Excess energy consumption occurs when sub-cooling is done when it is not necessary and/or when more air is sub-cooled than necessary (see C. Heating for an elaboration).

Heating (C)

The temperature set point in many storage areas is determined by the temperature that must be maintained to prevent high humidity during summer months. Maintaining this temperature in winter may require heating that could be reduced or avoided if the temperature was allowed to drift lower in winter. A very large fraction of storage area heating energy is consumed in reheating air that has been sub-cooled for dehumidification. While this process may be necessary when the dew point temperature of the outside air is above the desired dew point temperature of storage spaces, this sub-cooling and reheating is not necessary when the outside air dew point temperature falls below the desired storage space dew point. Many systems sub-cool and reheat continuously all year, even in climates where it is unnecessary for several months per year.

Some systems are designed to allow a certain adjustable fraction of the air stream to bypass the sub-cool and reheat coils, thereby reducing energy use in situations and/or seasons when conditions can be maintained without processing all of the air. Many of the systems could increase the amount of air bypassed without compromising storage climates. Careful experimentation would likely show that this quantity could be increased during portions of the year, if not all of the time.

In many northern climates, heating needs are linked to the amount of outside air brought into the system. If the quantity of outside air exceeds the amount required, excess heating energy will be consumed.

Humidifiers (D)

Humidifying typically represents a small fraction of annual energy use in storage areas and therefore offers few energy-saving opportunities. However, in northern climates where energy use for humidification is more significant, consideration should be given to the humidity set point in the space. Some facilities try to maintain 50% RH in winter, when a gradual seasonal drift from 50% in summer down to 35% in winter may not be detrimental to collections and will reduce humidification.

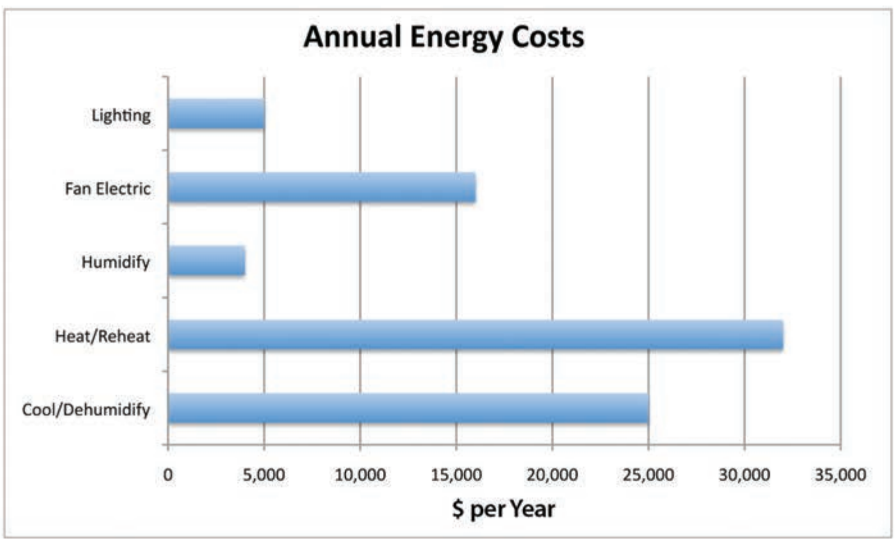
The amount of humidification required is directly related to the quantity of outside air introduced into the storage area mechanical system. Serious consideration should be given to how much outside air is brought in and when. Many systems bring in more outside air than is necessary all of the time, and most bring in more outside air than is necessary during periods when the collection storage areas are unoccupied.

Storage Area Lighting (E)

The operation of any storage area lighting fixture when there is no one nearby requiring illumination can be considered a waste of electrical energy – both at the light fixture and at the cooling system that must remove the heat generated by this fixture. The occupancy of most storage spaces is very intermittent and an organized and sustained effort to prevent the unnecessary operation of storage area lighting fixtures will reduce energy consumption. The quantity of lighting in some storage areas is excessive, also, in which case consideration should be given to removing some fixtures.

Summary of Class Five and Six Building Energy Savings Opportunities

The paragraphs above describe how each energy-consuming component of a storage area “system” can use more energy than is necessary to maintain the desired climate conditions. They demonstrate that excess energy use does not announce itself and show that energy use reductions will probably result if each energy-consuming component is carefully examined to see if the way it actually operates coincides with the way it needs to operate to maintain the desired storage climate.



Typical Operation	Optimal Operation
$ 5,000	$ 4,000
$ 16,000	$ 12,000
$ 4,000	$ 4,000
$ 32,000	$ 22,000
$ 25,000	$ 17,000
$ 82,000	**$ 59,000**

The Annual Energy Costs figure on p.77 shows the potential energy cost reduction that could result from such a careful examination. The “typical operation” annual cost is based upon the actual measured performance of an example storage area mechanical system. The “optimal operation” annual cost shows the savings that would result from eliminating unnecessary energy use. Based on analysis of collected data, the preservation quality of the storage climate would be unaffected by the change from typical to optimal, while the annual energy cost would be reduced by 28%.

In institutions with multiple mechanical systems there are many energy-saving opportunities and strategies. Some require engineering expertise and capital improvements, however, there are usually significant opportunities that can be identified by existing staff and which require little or no capital investment. These operational savings can be realized by looking for and correcting “sub-optimal operation.”

9C Operational Energy Saving Opportunities to be Investigated

Experience with monitoring the ways storage area mechanical systems actually operate and the findings indicated in the paragraphs above suggest that research by members of the Environmental Management Team in the following two areas may identify significant energy savings opportunities.

Quantity of Outside Air

As you read in Section 9B, the amount of humidifying, reheating, cooling, and sub-cooling are all largely affected by the amount of outside air allowed to enter the system. The quantity of outside air entering most systems is fixed and does not change with occupancy or season of the year.

The quantity of outside air is based on assumptions about how many people will occupy the space, and how much outside air is required per person. Consideration is also given to the possibility that the materials stored may give off contaminants, the concentration of which will be diluted to acceptable levels by a continuous flow of outside air.

Because the energy cost incurred in conditioning the outside air is considerable and rising, it is appropriate to investigate the assumptions behind the need for outside air to determine if reductions are possible all of the time, during unoccupied periods, and/or seasonally. Define whether your space is “occupied” or “unoccupied” by code, and only bring in the minimum amount of outside air necessary. For many environments, for both preservation and sustainability, less is better. Systems with updated direct digital controls may be able to program the opening and closing of outside air dampers for occupied and unoccupied hours.

Any time outside air is restricted from the system the amount of work that the system has to perform is reduced. If the system is equipped with a variable speed drive, experiment to see how far the fan speed can be reduced (thereby moving air through the system more slowly) while still maintaining the desired environmental conditions.

System Time of Operation

Years of monitoring mechanical system operation and storage climates have resulted in data recorded during periods of system failures and both intended and unintended system shutdown for various durations. These observations demonstrated that some storage climates are unaffected by short-term system shutdowns and suggest that some systems could be shut off for certain portions of the day (unoccupied hours) for some portion of the year without reducing preservation quality.

Determining factors include the amount of exposure the storage spaces have to weather (quantity of exterior walls or roof), the construction of the storage space envelope, control of lighting in the storage spaces, and the configuration and control of the HVAC system.

IPI and Herzog/Wheeler & Associates are engaged in a four-year project to conduct controlled experiments in five research libraries located around the U.S. to document the potential for reducing energy consumption without compromising storage climate through the periodic shutdown of storage area HVAC systems. Funded by IMLS, this project will conclude in November 2013. IPI is also conducting research funded by NEH on the effect of temperature and humidity set backs on collection preservation and energy use. This project concludes in April 2013.

Case Studies

IPI is working with an Environmental Management Team at each of the five research libraries involved in the IMLS-funded Energy Saving Opportunities project mentioned above. Team members selected the most appropriate candidate spaces, identified the proper channels to work through to make adjustments to mechanical system controls, and finalized the work plan for data gathering and analysis. It was determined that each institution would experiment with seven to ten hours of total shutdown time for each 24-hour period, generally conducted overnight. The time selected provided the greatest potential for energy savings, and the nighttime hours lessened the possibility of human comfort concerns. In addition, shutdowns during typically cooler evening and night hours would lessen potential swings in environmental conditions. One institution chose to experiment with scheduling four hours of the shutdown during the middle of the day to take advantage of energy savings potential during peak electrical rate periods. Data from one-month shutdown test periods were reviewed before the full 12+ month experimental period began.

Early results show less than 33°F in temperature fluctuation during the average nightly shutdown, with no cumulative gain in temperature over time. The shutdown period is having little to no impact on the preservation quality of the space, and energy is being saved during each shutdown period. Relative humidity fluctuation during the shutdown period is minimal, with fluctuations of 2% to 5% observed. Data indicates that the systems recover their set point, or at least return to the condition they were previously providing, when they turn back on. Due to the rate of moisture equilibration for most collection materials this small amount of relative humidity change in the air should have little effect on the overall preservation quality of the environment.

Based on observations to date, carefully managed shutdowns of mechanical systems that serve collection storage areas have potential benefits for both preservation and energy savings. For most systems these savings come from reduced electrical consumption at fans or electrical heating, water consumption at the cooling coil, and steam or hot water at the heating coil.

A publication and associated web-resource focused on the optimal management of temporary HVAC shutdowns will be available at the close of this project.

A similar energy saving research project that IPI is conducting with a major library has focused on a storage facility with two large air handling units, one for the north and one for the south end of the building. The large book storage area selected for the shutdown experiment is surrounded by tempered space, has no added sources of heat or moisture, and is unoccupied at night. The project team chose to shut down one AHU for eight hours every night, seven days a week (1/3 of the normal AHU operation).

The effect of the shut down on collections was measured using IPI's Preservation Metrics™. Energy usage was measured based on:

- Measured air volumes that are moved, heated and cooled
- Measured fan amps
- Calculated BTUs of heating and cooling, related to dollar costs provided by the facility administrators

Based on these calculations the annual energy saving potential of a nightly shutdown of one or both AHUs serving the space was significant:

Constant Operation	**One Unit**	**X 2 = Two Units**
Cooling Costs	$110,000	$220,000
Heating Costs	$98,000	$196,000
Fan Operation Costs	$25,650	$51,300
TOTAL ANNUAL COST	$233,650	$467,300
One-third savings based on nightly shutdown	$77,883	$155,766

During the period of this experiment environmental data from the storage space showed no changes in relative humidity, and a maximum temperature increase of 2°F, summer or winter. We concluded that the risk-managed shutdowns had little or no effect on the preservation quality of the storage space, and that further tweaking could result in better environments and larger annual savings.

Keep in mind that these are risk-managed experiments in locations specifically selected for this research project. Any operational change in the mechanical system must be balanced by the maintenance of an acceptable environment for preservation.