COST-EFFECTIVE ENERGY EFFICIENT IMPROVEMENTS FOR MINNESOTA'S PUBLIC ICE ARENAS: OVERVIEW OF 20 OPTIONS

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OPERATION AND MAINTENANCE IMPROVEMENTS

*Increase Ice Temperature

Many arenas can substantially reduce energy costs by increasing the average ice temperature. The ice sheet constantly absorbs heat from the warmer air and building around it and the rate of heat absorption naturally decreases as the temperature of the ice sheet goes up. Because the refrigeration system must work to remove the heat that the ice sheet absorbs, its energy use also decreases whenever the ice sheet temperature can be raised even slightly. The reduced heat absorption also reduces the amount of energy needed to heat the arena and the higher average ice sheet temperature causes the refrigeration system to operate more efficiently.

Because the overriding concern of arena operators must be to maintain the ice sheet integrity, temperature controls are often set at a conservatively low value that will maintain ice sheet quality under the most adverse conditions. Because the ice sheet might be subjected to such adverse conditions for only a few hours, days, or weeks, a conservatively low temperature setpoint will keep the ice sheet colder than it really needs to be the majority of the time. Depending on an arena's schedule and refrigeration system, it may also be practical to substantially increase the ice temperature during long unoccupied periods (e.g. overnight and throughout the morning). Unless an automatic set-back control is used, adjusting ice temperatures may require daily, manual adjustments. Annual energy cost savings from increasing the average ice temperature only 1°F range from $200 to $800 for a six-month arena and from $800 to $1,600 for a year-round facility.

*Reduce Ice Sheet Thickness

Control and reduction of ice sheet thickness can reduce energy costs while also providing more consistent ice quality. While the minimum acceptable ice sheet thickness varies somewhat from arena to arena, a typical optimal thickness is one inch or less for arenas with an even concrete base; arenas with a sand base may need ice at least two to three inches thick to provide adequate support for the resurfacer. Reducing the ice sheet thickness by one-quarter inch will allow the ice surface temperature to be kept the same while the coolant or slab temperature setting is increased by two-thirds of a degree. Increasing the coolant and slab temperatures saves energy by increasing the efficiency of the refrigeration system. Typical annual energy cost savings from increasing the ice temperature one degree (one-half inch reduction in ice thickness) are approximately $145 for a six-month arena and $300 for facility that operates more than 9 months. In addition to energy savings, closely controlling ice thickness also makes the quality of ice more consistent because the ice surface temperature is closer to the rink floor and coolant temperature.

*Reduce Refrigeration System Head Pressure Controls

Energy consumption in many ice arenas can be reduced by adjusting the refrigeration system's head pressure controls. The refrigeration system keeps the ice sheet cold by recirculating refrigerant. The refrigerant absorbs heat from under the ice sheet and then dumps that heat to the

* Possible low-cost/no-cost improvement

outside air through a condenser. In order for heat to flow from the refrigerant in the condenser to the outside air, the refrigerant must be at a high temperature and pressure (referred to as the head pressure). This high temperature and pressure is generated by the compressors that pump the refrigerant through the various parts of the refrigeration system. Since the compressors are the primary energy users in the refrigeration system, reducing the head pressure will save significant amounts of energy and reduce wear on the compressors. Many direct refrigeration systems will operate properly with head pressures as low as 150 psi, while many indirect systems (those with thermostatic expansion valves) may need higher pressures of 175 psi. Typical annual energy cost savings that can be realized with only a 20 to 25 psi reduction are $400 to $1,000 for a six-month arena and $900 to $1,800 for facilities that operate 9 months or more.

The head pressure can be reduced in two ways: (1) by manual adjustment or (2) by replacing standard condenser controls with more efficient automated condenser control systems (see refrigeration system section). The refrigeration industry has traditionally encouraged maintaining a higher than necessary head pressure by turning off fans that blow outside air through the condenser and/or by using a pump that sprays water over the condenser. These approaches are very conservative in terms of ensuring adequate cooling of the ice under the most taxing conditions; however, these practices unnecessarily increase energy costs and wear on the compressors during periods of normal arena operation. This energy conservation method has already been successfully implemented in several Minnesota ice arenas.

LIGHTING IMPROVEMENTS

Efficient Lighting Fixtures for Public Spaces

A number of existing technologies can make interior and exterior lighting significantly more energy efficient. The impact any particular lighting improvement has on operating costs depends heavily on the hours of operation. Obviously, fixtures which are operated 24 hours a day will provide more savings from high efficiency improvements than similar fixtures that only operate for a fraction of each day. Maintenance costs for replacing spent fixtures must also be considered when calculating the paybacks of lighting improvements.

There are six main types of lighting improvements which are feasible in most ice arenas. Ice sheet lighting recommendations are dealt with in the next section.

1. Replacing standard incandescent lamps or “light bulbs” with more efficient fluorescent lamps will use 30 to 80 percent less electricity per lamp while producing the same light levels. In addition, maintenance costs will be reduced since fluorescent lamps last 5 to 12 times longer than standard incandescents.

2. Replacing existing four or eight foot fluorescent fixtures with high efficiency fluorescent T-8 lamps and improved electronic ballasts can provided significant cost savings.

3. Public areas such as halls, corridors, and lobbies often have more fixtures than are needed for desired light levels. Wasted light can easily be eliminated by either using lower wattage ballasts (dewatting) or disconnecting unnecessary ballasts (delamping).

4. Replacing incandescent or compact fluorescent exit signs with low power LED lamps can save from 14 to 39 watts per fixture. Since LED lamps have a life expectancy of over 20 years, maintenance costs can also be significantly reduced.

5. Exterior incandescent or quartz flood lights can be cost effectively upgraded to energy efficient high intensity discharge lamps, such as metal halide or high pressure sodium fixtures.

6. Timed switches and occupancy sensors are automatic controls which turn off lights in unoccupied areas and turn them on only when needed. Storage areas, public restrooms, hallways, offices, meeting rooms, and outdoor entrances are often cost-effective applications for these automatic controls.

All of the previous lighting recommendations have been implemented successfully in hundreds of commercial buildings in Minnesota. The payback of any lighting improvement must be calculated on an area by area basis since operating hours and other conditions may vary significantly. Many electric utilities offer lighting efficiency rebates. A few arenas that have recently upgraded public space lighting are listed below.

Arena	Contact Person	Phone
Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Farmington Civic Arena	Jim Bell	(612) 463-1851
Cottage Grove Arena	Dean Mulso	(612) 458-2846
Lily Lake (Stillwater)	Diane Deblon	(612) 430-8811
West St. Paul Arena	Dave Malay	(612) 552-4155

Ice Sheet Lighting Recommendations

Ice sheet lighting costs can be reduced by replacing or upgrading inefficient light fixtures and by varying ice sheet light levels based on activity. Common lighting fixture upgrades that are often cost-effective include changing from standard fluorescent or mercury vapor fixtures to metal halide or high pressure sodium fixtures. A relatively new option that can provide even greater energy savings is to upgrade to compact fluorescent fixtures designed specifically for athletic facilities. In addition to providing energy cost savings, the lighting fixture upgrades mentioned above also tend to result in lower maintenance costs, better quality lighting, and increased control options. Three arenas in Minnesota that are using the newer compact fluorescent fixtures over the ice sheet are listed below.

Arena	Contact Person	Phone
Cottage Grove Arena	Dean Mulso	(612) 458-2846
Vogel Arena (New Ulm)	Jim Krapf	(507) 354-8321
St. Louis Park Arena	Craig Panning	(612) 924-2545

The level of illumination required for any sports lighting installation depends upon many factors, including the general nature of the task, the speed of the action, the skill of the players, the number of spectators and their distance from the field of play. Recommended illumination levels for various ice activities from the Illuminating Engineering Society are listed below.

Recommended Ice Rink Illumination Levels

Activity	Foot-candles
Pro Hockey	100
Amateur Hockey	50
Recreational Hockey	20
Figure Skating	15
Curling	10-20
Recreational Skating	10

Because ice sheet lighting requirements vary significantly for different types of on-ice activities a lighting system which can respond to changing light level requirements will be most energy efficient. In addition to using more electricity, ice rink lighting systems which over-illuminate also cause the refrigeration system to work harder than necessary. Multi-level lighting systems provide energy savings by more closely matching the light output and energy usage to the activity on the ice. Multi-level systems are usually more cost-effective than dimming systems. Some rinks have tried to bank their lighting system to achieve similar results, but this approach tends to produce shadows and non-uniformity that can make it difficult for players and spectators to follow the puck. Many electric utilities offer lighting efficiency rebates.

RESURFACING IMPROVEMENTS

Demineralized Flood Water Treatment

Water purity has a direct effect on the quality of ice and the amount of energy used to produce and maintain the ice surface. Ice arenas are extremely large users of water. A moderately busy ice arena with an average of 6 resurfacings a day will use approximately 1,000 gallons of water per day. The majority of this water is use to recondition the ice surface. As a general rule, heated city water is used to fill the resurfacer tank which in turn are used to flood the ice sheet. The water is heated to provide a better bond to the existing ice and to melt and fill in cracks in the ice caused by skate blades. With the use of demineralized flood water the need for heating is eliminated because pure water bonds very easily to the existing ice sheet. A reduction in the water temperature also reduces the amount of energy needed to freeze the flood water thereby reducing the work of the refrigeration system. Pure water also provides a harder ice surface that is more resistant to cuts.

Demineralized water can be achieved by two different methods. The first is an ion-exchange method that uses chemicals to remove the minerals. The second is a reverse osmosis filter that allows only pure water to pass through a filtering membrane. Both methods are extremely effective in removing the impurities in common water supplies. Installation costs for the ion-exchange demineralization and the reverse osmosis filtration systems are approximately $18,000. Operational costs for the two systems are different. The ion-exchange requires chemicals that cause the operational costs to be around $15 per 1000 gallons of processed water. Instead of requiring chemicals, the reverse osmosis systems require additional pumping power to force the water through the filtering membrane. Operational costs for the reverse osmosis systems average $3 to $5 per 1000 gallons. The paybacks on both systems typically span 6 to 10 years. The paybacks can be reduced by a change in the temperature of the ice sheet. With the use of demineralized water the temperature of the ice sheet can be raised slightly to accommodate the reduction of energy needed to freeze pure water as compared to water with dissolved solids. Several arenas that use either temporary ion-exchange tanks or a reverse osmosis flood water demineralization system are listed below.

Demineralization Type	Arena	Contact Person	Phone
Reverse Osmosis, Tanks	Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Reverse Osmosis	Hutchinson Civic Arena	Marv Haugen	(320) 234-4227
Reverse Osmosis	Cottage Grove Arena	Dean Mulso	(612) 458-2846
Reverse Osmosis	Victory (Minneapolis)	Virgil Oldre	(612) 627-2953

Electric Ice Resurfacer

Ventilation with outside air is extremely important in ice arenas where resurfacers driven by internal combustion engines are used. The airborne pollutants emitted during the combustion process must be removed from the space or diluted to a concentration level that will not harm arena occupants. A fine balance must be found to ensure that sufficient outdoor air is provided to dilute combustion contaminants, while minimizing excessive levels to reduce dehumidification and heating loads. Using electric resurfacers eliminates the need for extra outdoor air ventilation to dilute combustion products. The only remaining need for ventilation is to assure adequate occupant comfort.

Electric resurfacers have been improved with technology from the forklift industry. Electric powered forklifts have been in use for many years and have performed indoors without problems. The power requirements of an ice resurfacer are somewhat higher than a forklift, but this is easily overcome with the addition of a larger battery pack. The alternative to the battery operated machine is to plug the resurfacer into an electrical supply grid. This is accomplished with the use of a tether that is supported in the ceiling of the arena. Costs for electric resurfacers range from $72,000 for tethered machines to $75,000 for battery models. Simple paybacks for electric resurfacers can be somewhat high when only considering the incremental cost over a new propane resurfacer. A new propane powered resurfacer has a cost of $55,000 which results in an incremental cost of $20,000. The resulting payback is typically over 10 years. Paybacks are reduced when operational costs are considered. The typical propane resurfacer will use approximately $1,620/yr in propane where as an electric resurfacers performing the same number of resurfacings will use only $420/yr, resulting in a $1,200/yr savings in operational costs alone. Replacing a propane powered resurfacer will provide the immediate benefit of improved indoor air quality even though the economic payback is longer than for many other improvements.

Resurfacer	Arena	Contact Person	Phone
Battery	Victory Memorial Arena	Virgil Oldre	(612) 627-2953
Battery	Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Battery	Parade Ice Garden	Tom Herbst	(612) 370-4846
Tethered	Fogerty Arena	Mark Clasen	(612) 780-3323
Tethered	Edison Youth Hockey	John Myers	(612) 782-2123

*Automatic Flood Water Fill Shut-off Nozzle

Overfilling resurfacer flood water tanks wastes water and energy. After every resurfacing, the flood water tank is refilled so it is ready for its next use, usually every hour. When fully opened, most water hoses will fill the flood water tank in 20 - 30 minutes, but an employee must turn off the valve to avoid overflowing. In some arenas the flow rate is reduce so the flood water tank is filled in approximately an hour, or the time allotted between resurfacing. Overflowing is common in either method and results in wasting water which is expensive. It is even more costly in terms of energy consumption in arenas which use heated water for resurfacing because overflowing a tank is like pouring hot water down the drain.

Arenas can conserve water and energy by installing a simple, inexpensive device used on all gasoline pumps. An automatic shut-off nozzle can be attached to the end of the fill water hose and when the tanks are full the nozzle will automatically turn off the water. The cost for an automatic shut-off nozzle is around $30 dollars and if only one gallon of water is eliminated from spilling at every resurfacing, the payback is estimated at 6 years based on water charges alone. If the cost for heating the water is factored in, the payback decreases to only 3 years. Automatic shut-off nozzles also decrease staff time required to monitor the tank levels between resurfacing periods. Automatic shut-off nozzles are used in many Minnesota ice arenas.

REFRIGERATION SYSTEM IMPROVEMENTS

Condenser Fan Variable Speed Drive

A condenser fan variable speed drive will not only reduce the condenser energy use, but also save on compressor energy use by lowering the average head pressure. The lower and much steadier head pressure will also reduce wear on the compressors.

Energy consumption in many ice arenas can often be reduced by lowering the head pressure that is maintained by the condenser fan and/or pump controls. The refrigerant that is circulated through the refrigeration system first absorbs heat from underneath the ice sheet and then dumps that heat to the outside air through a condenser. In order for heat to flow from the refrigerant in the condenser to the outside air, the refrigerant must be at a high temperature and pressure (referred to as the head pressure). This high temperature and pressure is generated by the compressors that pump the refrigerant through the various parts of the refrigeration system. The compressors are the primary energy users in the refrigeration system, and reducing the head pressure that they must generate will dramatically reduce the arena's energy use and equipment maintenance needs. Therefore, the condenser controls should be set to provide the minimum

* Possible low-cost/no-cost improvement

head pressure needed for proper system operation whenever it is possible. Most ice rink refrigeration equipment can operate with lower head pressures during mild and cool weather because the condensers can more easily dump heat to the outside air. However, typical condenser fan and pump controls are not capable of tight, consistent head pressure control so they are set to operate the equipment well above the lower head pressure limits. Retrofitting existing equipment with a variable speed drive on the condenser fan motor is often the best way to continually keep the head pressure near its minimum operating limit.

Maximizing the cost-effectiveness of a condenser fan variable speed drive retrofit usually requires some changes to the condenser control strategy. Therefore, a new control unit for both the condenser fan and pump (for evaporative condensers) is often needed. The new control strategies used with variable speed drives virtually eliminate the short-term on and off cycling of condenser fan and pump motors and the associated head pressure fluctuations.

Although installed costs for recently completed retrofits have averaged $7,000, there has been a wide variation in cost from project to project. Typical energy cost savings are $1,200 annually. Contact information for a number of arenas that have installed a condenser fan variable speed drive control is listed in the table below.

Arena	Contact Person	Phone
West St. Paul Arena	Dave Malay	(612) 552-4155
Litchfield Civic Arena	Steve Olson	(320) 693-2679
Farmington Civic Arena	Jim Bell	(612) 463-1851
Hutchinson Civic Arena	Marv Haugen	(320) 234-4227
Cottage Grove Arena	Dean Mulso	(612) 458-2846
Victory (Minneapolis)	Virgil Oldre	(612) 627-2953

Reclaiming Waste Heat from the Refrigeration System

Waste heat generated by the ice sheet refrigeration system can often be cost-effectively captured and used to supplement an arena's heating needs, thereby reducing heating fuel use. The ice sheet refrigeration system normally takes all of the heat that the ice sheet absorbs (plus some extra heat added by the refrigeration system itself) and then dumps that heat to the outside air through an outdoor condenser. However, much of the heat that the refrigeration systems normally rejects to the outside air can instead be reclaimed to provide useful heat. The reclaimed heat can be used to heat air or water up to a temperature of 90°F or more. Typical uses of reclaimed heat include: heating the air in the arena, heating service hot water, and/or melting the snow scraped off by the resurfacer. More than half of the ice arenas in Minnesota use well-established heat reclaim technology to provide heat for one or more of these uses. Adding heat reclaim equipment costs at least several thousand dollars, but in some cases the investment will pay for itself in just a few years.

Cooling System Pump Control

More closely matching the ice sheet coolant pumping rate to the exact amount of cooling that is needed saves energy. The pump that circulates coolant under the ice sheet is chosen so that it can provide the highest coolant pumping rate that will ever be needed to maintain the ice; however, a much lower coolant pumping rate will provide adequate cooling 75 to 95 percent of the time. Controls that provide multiple levels of pumping capacity greatly reduce the energy penalty from continuously operating large, high capacity coolant pumps at their maximum capacity.

The cooling system pump control options available include:

1. using a variable speed drive to adjust the speed of the pump's motor
2. cycling single or multiple pumps on and off
3. using a two-speed motor to power the pump

The first two control options have been used successfully in Minnesota ice arenas. The third control option is commonly used in industrial applications and is also appropriate for ice arenas. Two-speed motors provide a lower cost alternative that is particularly cost-effective when a pump motor needs to be replaced. The approximate costs for these options range from $1,500 to $12,000 and the payback on investment is often attractive--even for short season ice arenas. The implementation of cooling system pump control should be considered in conjunction with improving ice temperature control and implementing automatic capacity control for compressors. In Minnesota, a number of newer packaged refrigeration systems have two different sized pumps that are automatically controlled. Contact information for two arenas that have variable speed drive control of the pump motor is listed below.

Arena	Contact Person	Phone
Litchfield Civic Arena	Steve Olson	(320) 693-2679
Lily Lake (Stillwater)	Kevin Shields	(612) 430-1234

Improve Ice Temperature Control

Improvements to ice temperature controls can often provide better ice quality and reduce energy costs by consistently maintaining the ice surface at the highest acceptable temperature level. The ice sheet absorbs heat from the warmer air and building which surround it. As the temperature of the ice sheet increases, less heat is absorbed thus reducing the amount of energy needed for the refrigeration system. The reduced heat absorption into the ice sheet not only reduces the refrigeration system energy use, but also reduces the amount of energy needed to heat the arena.

The ice surface temperature can often be increased by using two control technologies:

1. infrared ice temperature sensors
2. overnight setback of ice temperature

Infrared sensors can be mounted above the ice sheet to measure the ice temperature by sensing the amount of infrared light radiated by the ice sheet. Although this promising technology has not yet been applied in Minnesota, it has been successfully used in a number of arenas in the United States and Canada. Overnight setback of ice temperature (e.g. from a normal setpoint of 20°F to 24°F) provides another opportunity to reduce refrigeration system energy use. This technology allows the ice sheet to warm during non-use and then automatically cools the ice sheet before skaters return to the ice arena (without affecting ice quality).

Making energy saving improvements to an ice temperature control system can sometimes cost as little as $1,000, but significant upgrades usually cost at least $9,000, with a resulting energy savings payback period that is typically several years long or longer. The implementation of improved ice temperature control should be considered in conjunction with implementing automatic capacity control for compressors and installing cooling system pump controls. Arenas that have infrared ice temperature control and/or ice temperature setback are listed below.

Arena	Contact Person	Phone
Litchfield Civic Arena	Steve Olson	(320) 693-2679
Farmington Civic Arena	Jim Bell	(612) 463-1851
Cottage Grove Arena	Dean Mulso	(612) 458-2846
Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842

Automatic Capacity Control of Compressors

The compressors in ice arena refrigeration systems are sized large enough to be able to handle the initial freezing of the ice sheet. During lower cooling load periods, such as overnight and in winter, the compressors are oversized and waste energy. Many control systems simply cycle an arena's compressors on and off—even when the potential to vary compressor capacity is built into the system. Automatic capacity control of the compressors can provide more efficient operation of the compressors by supplying a more consistent feed of refrigerant at a slightly higher average temperature. The higher temperature allows the refrigeration system to operate more efficiently and use less energy.

Additional savings can also be realized by a reduction in an arena's monthly electric demand charge. The electric utility bases an arena's demand charge on the highest power draw over a fifteen minute interval during a given month. The power draw for compressors with a simple on-off cycling control is high because the compressors operate near their maximum capacity whenever they are on. In contrast, automatic capacity control allows the compressors to operate at significantly reduced power draws most of the time. The reduction in monthly demand charges (kilowatt or kW) can be significant, amounting to more than the savings associated with total monthly electric use charges (kilowatt hours or kWh).

Automatic capacity control of compressors has long been used by a number of ice arenas in Minnesota. The cost to upgrade an existing refrigeration system with a new control system using automatic capacity control is usually several thousand dollars or more, which typically leads to a long energy cost savings payback time period. However, the most important benefit of automatic capacity control is often the reduction in the personnel time and expertise necessary for day-to-day operation of the refrigeration system. This is because the simple on-off control systems used in many ice arenas often demand significant arena staff time to frequently check on the system and make manual adjustments. The implementation of automatic capacity control of compressors should be considered in conjunction with the decisions to implement improved ice temperature control and/or cooling system pump control. Two arenas that have recently added automatic capacity control are listed below.

Arena	Contact Person	Phone
Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Cottage Grove Arena	Dean Mulso	(612) 458-2846

HEATING, DEHUMIDIFICATION AND VENTILATION IMPROVEMENTS

Low Emissivity Reflective Ceiling

Reducing the amount of heat that the ice sheet absorbs will result in lower energy bills and improved ice quality. One of the main sources for heat in an ice arena is infrared radiation. Infrared radiation can account for more than 35 percent of the total cooling load of an ice sheet. Although it can not be seen or felt, heat from the ceiling and lights radiates down on the ice sheet and increases the load on the refrigeration system. The amount the refrigeration system has to work varies from day-to-day depending on the outside temperature, arena air temperature, ice temperature, and direct sunlight on the roof. The infrared radiation load also varies from site to site due to the amount of roof insulation, the ceiling height, and the ceiling's ability to transmit energy.

Installation of a barrier between the ceiling and ice sheet can effectively stop the infrared radiation. There are typically two types of barriers used in ice arenas: low emissivity paint applied directly to the ceiling, and low emissivity fabric suspended just below the ceiling. Both products reduce the amount of heat that is radiated down to the ice sheet. The installation cost of the low emissivity paint ranges from $20,000 to $100,000 depending on the roof structure and amount of prep work needed. Paybacks for low emissivity paints are typically from 2.5 to 12 years with a functional life span of four to five years. The low emissivity fabric ceilings can be installed for $23,000 to $28,000 and generate a payback of approximately 2 years in arenas which operate 11 months a year. The useful life of low emissivity fabric is over 20 years. Both low emissivity paints and fabrics have been used in Minnesota arenas with proven success. A number of sites with low emissivity fabric are listed below.

Arena	Contact Person	Phone
Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Hutchinson Civic Arena	Marv Haugen	(320) 234-4227
Farmington Civic Arena	Jim Bell	(612) 463-1851
Cottage Grove Arena	Dean Mulso	(612) 458-2846
Victory (Minneapolis)	Virgil Oldre	(612) 627-2953

CO_2 and CO Ventilation Control

Typically ice arenas are over-ventilated to assure that occupants are not harmed from the exhaust gases from ice resurfacers. The gases carbon dioxide (CO_2) and carbon monoxide (CO) are by-products of the internal combustion engines that power some types of resurfacers. CO_2 is also released when skaters and spectators exhale. Ventilating the arena removes the potential harmful gases by replacing polluted air with fresh air. Ventilation also assures that the arena will pass the required weekly air quality check that is required by the Minnesota Department of Health. If the rate of outside air introduced into an arena is not controlled properly the arena will be either under- or over-ventilated. If it is under-ventilated the arena will fail its air quality checks and possibly cause health problems for the occupants. Over ventilation increases energy consumption in two ways. First, during winter heated air is vented outside and make-up air taken from outside is brought into the building. The heating system works harder because the fresh air must be heated to the desired indoor temperature. Second, the introduction of warm moisture air during the summer into the cool arena causes moisture problems in the form of fog and condensation on the building which significantly increases the refrigeration system's energy consumption.

The installation of sensors that measure CO_2 and CO along with an exhaust fan control system provide active and accurate control of the amount of fresh air brought into an arena. A minimum air flow will typically be called for during periods of limited use (i.e. ice skating lessons) or non-occupancy. The level of outdoor air is automatically increased during higher occupancy and reduced during low occupancy periods. The system is programmed to ventilate at its maximum capacity during the time the resurfacer is in operation and then to monitor for CO and adjust the ventilation rates as the concentration of CO decreases. Thus, ventilation levels are optimized for sufficient indoor air quality while energy costs are minimized. Installation costs vary depending on the number of exhaust fans and the type of control system that is currently in use. Typically these costs will be between $2,000 and $5,000 with a payback ranging from 1 to 5 years. This type of ventilation control has been implemented in several arenas around Minnesota.

Arena	Contact Person	Phone
Mankato Civic Center	Marshal Madsen	(507) 389-3000

*Time-of-Day Heating and Ventilation System Control

Implementation of time-of-day controls for heating and ventilation systems can significantly reduce the operating expense of ice arenas. Manual operation of heating and ventilation systems is only efficient if ice arena employees adjust controls whenever heating or ventilation needs change. For example, when an internal combustion, engine-driven resurfacer is operating, employees must manually activate exhaust fans to provide adequate ventilation for the arena. If these fans are left on too long after resurfacing the arena will be over-ventilated which can cause moisture problems, added heating and cooling costs, and added refrigeration loads. The efficiency of manual controls is dependent on how well the arena staff understands the heating and ventilation systems and how often energy conserving practices are followed. Automatic operation of the heating and ventilation systems based on time-of-day and occupancy can result in optimum control of an arena's indoor conditions and minimal energy use. Some of the measures that can be installed to provide energy savings include:

1. Night setback of heating setpoints to allow arena temperature to drop at times of non-use.

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2. Automatically cutting back on the amount of ventilation during unoccupied periods.
3. Automatically controlling exhaust fans during and after resurfacing.

Each of these measures has the benefit of being automatically activated at prescribed times of the day. Once a time of use schedule is developed for each piece of equipment, there is no need to worry about making manual adjustments to operate that system. Installation costs for each of the above measures are typically $1,000 to $2,000 a piece. Paybacks are typically less than 12 months but also depend on the current operation of the arena. Regardless of energy savings, properly programmed time-of-day controls provide optimal space heating and ventilation under a variety of conditions. Night setback thermostats, automatic ventilation systems, and automatic exhaust fans have all been used successfully in Minnesota arenas. Some examples are listed below.

Application	Arena	Contact Person	Phone
Setback thermostat	Cottage Grove Arena	Dean Mulso	(612) 458-2846
Ventilation while resurfacing	VFW (E. Grand Forks)	Dale Skyberg	(218) 773-1181
Ventilation while resurfacing	Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842

Spectator Radiant Heating

Ice arenas have unique heating requirements because only certain areas of the building such as spectator seating and players benches need to be heated. Heating ice arenas with traditional forced air furnaces can result in high energy costs and overheating of areas that do not require heat. Forced air furnaces draw air from a central location and pass it through a heater exchanger were the air is heated. The air is then distributed throughout the arena to maintain a desired temperature. The air movement around the arena causes a disturbance in the stratification of air over the ice sheet. Air currents over the ice increase the convective heat loss on the ice sheet and force the refrigeration system to work harder to maintain the ice sheet's temperature. The warm air supplied by the forced air furnace also tends to accumulate at the ceiling were it will add to the infrared heat gain to the ice surface by maintaining the ceiling at a higher temperature than what is needed.

Heating with low intensity infrared heaters solves this problem by only heating surfaces such as walls, floors, and people. These surfaces, in turn, act as heat reservoirs and release heat to the surrounding air. Infrared heaters are positioned over spectator areas and players boxes were the heat is needed. The heaters are also directed away from the ice sheet so that they will not emit any heat towards the ice. The air over the ice is not disturbed so the refrigeration system doesn't have to work as hard as it would with a forced air system. Infrared heating has the added benefit of being a negative pressure system so that the noxious combustion gases are expelled outside and do not cause indoor air quality problems. Low-intensity infrared heating has been used in a wide variety of Minnesota arenas with great success. Installation of infrared heating systems cost approximately $15,000 to $20,000. Paybacks have to be analyzed on an arena by arena basis. Some of the arenas in Minnesota that use infrared heaters are listed below.

Arena	Contact Person	Phone
Hoyt Lakes	Tom Ferris	(218) 225-2226
Hodgins Berardo (Coleraine)	Pat Guyer	(218) 245-3525
West St. Paul	Dave Malay	(612) 552-4155
Farmington Civic Arena	Jim Bell	(612) 463-1851
Bud King (Winona)	Bob Monstrose	(507) 454-7775
Cottage Grove Arena	Dean Mulso	(612) 458-2846

Desiccant Dehumidification

Elevated relative humidity in ice arenas negatively affects skaters, spectators, and building components. High humidity is typically uncomfortable for skaters and spectators and can result in the formation of fog over the ice which restricts visibility. The humid air also condenses on the cooler building structural components which can cause deterioration of the building and dripping onto the ice surface. Condensation causes steel components to prematurely rust and results in high building maintenance costs through added repairs and repainting. Wet building components also provide growth sites for mold and bacteria. High relative humidity also wastes energy by causing increased condensation on the ice sheet. Extra condensation forces the refrigeration system to work harder to maintain the ice sheet temperature. Without proper ice maintenance, the thickness of the ice sheet will also increase which also increases the refrigeration system's workload.

Controlling moisture is essential for arenas which operate for 10 to 11 months a year. The use of conventional direct expansion air conditioning equipment can handle the moisture load for the majority of summer months but at an extremely high energy cost. The use of desiccant dehumidification equipment is ideally suited for high moisture load applications. Desiccant dehumidification systems work by absorbing moisture. These systems primarily use natural gas which can be purchased at a reduced cost in off-peak summer months when they are needed. Installation costs for desiccant dehumidification systems can be high ($150,000 to $300,000) but the addition of the dehumidification systems can result in an extension of the operating season from 7 months to year round operation. Paybacks on dehumidification systems are difficult to determine due to the change in the operating season and must be calculated on an arena by arena basis. Desiccant dehumidification systems are only appropriate for arenas which operate during the summer months. Several arenas in Minnesota that have added desiccant dehumidification systems to extend their operating season are listed below.

Arena	Contact Person	Phone
Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Cottage Grove Arena	Dean Mulso	(612) 458-2846
Blake	Tom Donahue	(612) 988-3825
West St. Paul	Dave Malay	(612) 552-4155
Hutchinson Civic Arena	Marv Haugen	(320) 234-4227

MISCELLANEOUS IMPROVEMENTS

Power Factor Correction

By eliminating a power factor correction penalty, electric bills in many ice arenas can be reduced without changing the amount of electric used by the arena. Often when older electric motors are used to operate equipment they have low power factors. The power factor is the ratio of actual power being used in a circuit (in kilowatts) to the power which is apparently being drawn from the line (in kilovolt-ampere). The actual power is the "real" power that performs useful work such as causing a motor to rotate or creating heat in a resistive element. Apparent power is the power required to establish an electrical field for the motor. The apparent power is used by the motor and returned back into the electrical system to establish a circuit. The apparent power level is used by the utility to size all system components from generation capacity and distribution lines to transformers at the building site. Electric utilities penalize customers for low power factors because they have to have generate more electric than what is required by their customers.

Low power factors can usually be corrected by installing capacitor banks at the point where the supply of electricity enters the building. Capacitor banks act as storage devices that store current needed by the electric motor and release the current to the motor at the correct time thereby improving the overall power factor of the building. Power factor correction is typically performed if utility bills indicate that the overall power factor for the site is below 90 - 95 percent, depending on the utility. Not all utilities charge power factor penalties. Power factor correction equipment can be installed by most electricians and ranges in price based on the voltage supplied to the building, amount of capacity needed to correct the problem, and the total electrical load of the building. Typical paybacks are less than 5 years for a building with a power factor of 80 percent or lower.

High Efficiency Motor Replacement

About half of the world's electricity is used by motors. The electric bill for America's motor driven systems is about $90 billion per year. Given the significant amount of energy and money devoted to motor-driven systems, even modest improvements in their efficiency hold the promise of huge savings.

The electric motors currently being used in arenas for refrigeration systems, pumps, and exhaust fans have a large impact on total arena electrical consumption. Electric motors are relatively cheap to purchase and extremely expensive to operate. The cost of electricity to run a typical commercial or industrial sector motor with a duty factor of at least 4,000 hours per year is equivalent to ten times its capital cost. The replacement of an older standard efficiency motor with a new high efficiency motor may result in double savings. First, savings will occur by significantly reducing energy consumption. High efficiency motors will use less energy than an older motor with the same horsepower rating and load. Second, if an arena is charged a power factor correction penalty by their electric utility, this penalty will likely be eliminated by replacing older motors. Older motors have power factors in the range of 70 to 80%. New high efficiency motors have power factors of better than 95%, which do not incur power factor penalties.

Motor replacement is not always recommended in every situation. The hours of operation, motor load, and the ability to downsize the new motor all have to be considered during the evaluation of a potential motor replacement. In many applications replacing a relatively new standard efficiency motor with a high efficiency motor will produce a payback within a year. Capital costs for high efficiency motors are based on the size and type of motor but are typically 30% to 50% higher than standard motor replacements. Over the life of a typical industrial motor, a one-percentage-point efficiency gain will pay for the incremental cost of the more efficient motor several times over, and may even save as much as the entire capital cost of the motor. Many electric utilities offer rebate programs for replacing inefficient motors. Three arenas that have carried out high efficiency motor replacements are listed below.

Arena	Contact Person	Phone
Farmington Civic Arena	Jim Bell	(612) 463-1851
Bloomington Ice Gardens	Andy Baltgalvis	(612) 948-8842
Cottage Grove Arena	Dean Mulso	(612) 458-2846