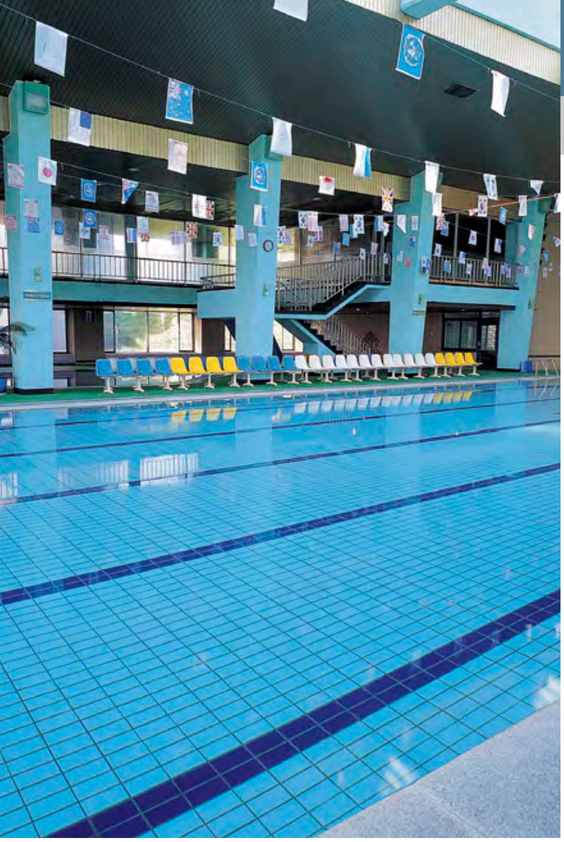


Indoor aquatic facilities can be energy-efficient and healthy environments.

Energy efficiency in indoor aquatic facilities

Thoughtful choices yield significant energy savings

by Gary Lochner, Unison Comfort Technologies

Indoor aquatic facilities are energy-intensive spaces. Pool water and surrounding air temperatures must be comfortable for swimmers. The high humidity of these spaces requires continuous dehumidification; and the presence of toxic chloramines, which are pool water disinfectant by-products, necessitates thorough air replenishment.

Indoor aquatic facilities consume energy primarily in four categories:

- Air heating and cooling (sensible loads)
- Dehumidification (latent loads)
- Air distribution (fan motor operating cost)
- Pool water heating

Through thoughtful design, indoor aquatic facilities can be healthy and energy-efficient spaces.

Table 1:
Component energy costs by percentage, indoor aquatic facility, 82 °F air / 60% RH*

Component	All Climates, Average % of total	Atlanta % of total	Chicago % of total
Fans	40	41	37
Envelope and ventilation	25	18	34
Pool water heating	20	22	19
Compressors	15	19	10

Note
* These are projected annual energy costs of an indoor aquatic facility before dehumidification system selection, using gas heat, no energy recovery, occupied 16 hrs/day, and ventilating with minimum outdoor air as defined by ASHRAE 62.

Table 1: Indoor aquatic facility energy cost baseline
This table provides a general overview of indoor aquatic facility energy costs. As climate moves from south to north more energy is used for envelope and ventilation (heating) and less is used for compressors (dehumidification and cooling). Fan energy costs are high because these environments require high volume constant air movement.

AIR HEATING AND COOLING SENSIBLE LOADS

Occupied indoor aquatic facility air temperatures usually range from 82–86 °F [28–30 °C]. This means that the pool space is in heating mode for much more of the year than a typical comfort environment.

The primary air heating and cooling sensible loads are:

- Building envelope
- Fresh air sensible heating or cooling
- Spectators (not swimmers)
- Infiltration
- Lighting and fan motors

Building envelope

Envelope loads are typically among the largest heating loads, and can be the largest cooling load if there is significant solar exposure.

BEST PRACTICE TIP

When utilizing building modeling software to calculate heating and cooling design sensible loads, be sure to use the design space temperature, which can be as high as 86 °F (30 °C), and not the normal default temperature, typically 75 °F (23.8 °C).

Thoughtful window orientation and sizing can reduce solar gain, summer cooling load, winter heating load, and total air change rate. As exterior glass increases, so does the amount of warm air required at windows to reduce fogging and condensation. Skylights can be problematic because it is difficult to effectively wash their surfaces with warm supply air in high-humidity spaces, as well as to keep them maintained in what can be corrosive environments.

It is especially important in these warm, moist environments to construct walls with a high R-value and proper vapor barrier. This prevents energy loss and condensation, and protects the pool enclosure and adjacent spaces from corrosion, fascia discoloration, and undesirable organism growth. Chloramines cause pool environment air to be acidic and corrosive to stainless and carbon steel. Whenever possible use building materials, such as aluminum, that will endure in this environment.

What are chloramines?

Chlorine is the predominant disinfectant used to sanitize pool water, and treats both water-borne pathogens and contaminants introduced by swimmers. Chloramines are gases that form as a disinfectant by-product of chlorination.

Chloramines are toxic to occupants and cause corrosion.

If you notice a chlorine-type smell, the air is probably contaminated with chloramines.

Outdoor air sensible load

Transferring heat from the exhaust airstream to the entering outdoor airstream can significantly reduce the outdoor air sensible load. This can be accomplished using a heat pipe or run-around coil (both with efficiency ratings of 45-55%), or by using a flat-plate heat exchanger (65-75% efficient). See Figure 1.

Sensible heat wheels are not a good choice for this application. Aquatic facility exhaust airstreams can contain large amounts of moisture and chloramines. When moisture condenses on a sensible heat wheel during winter operation it carries condensate to the outdoor airstream where it will either freeze (which requires a defrost operation and greatly reduces energy recovery) or evaporate (which increases air heating load instead of reducing it, and can return corrosive and unhealthy-to-breathe chloramines back into the occupied space).

Demand Control Ventilation (DCV) can reduce energy consumption by modulating outdoor air intake based on occupancy. This may be acceptable in spectator areas. However, DCV is not recommended in the pool and deck areas of indoor aquatic facilities per ASHRAE Standard 62.1.[1] Note that on ASHRAE's Table 6.2.2.1 (see Table 2), there is no outdoor air exchange rate per person listed for the occupancy category “Swimming (pool & deck),” only an outdoor air exchange rate based on area, a minimum rate that is always required. So, while it may be tempting to save energy by reducing the air exchange rate when the pool is unoccupied, pools can generate corrosive chloramines whether they are occupied or not.

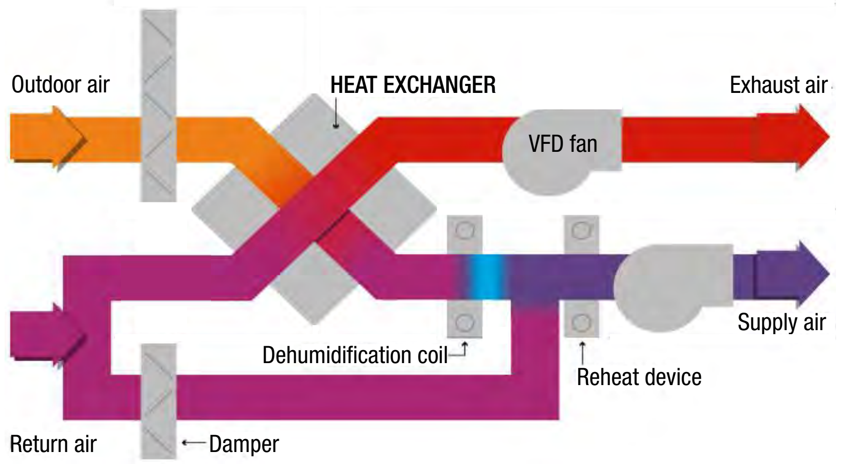


Figure 1: Exhaust air energy recovery reduces entering outdoor air sensible load
Using an air to air heat exchanger, which transfers heat from the exhaust airstream to the entering outdoor airstream, can significantly reduce energy costs. Energy efficiency varies from 45-55% for run-around coils and heat pipes to 65-75% for flat-plate heat exchangers.

Infiltration sensible load

Infiltration air is outdoor air or conditioned air entering the indoor aquatic facility through its enclosure due to pressure differential. It is desirable to maintain a slight negative pressure in the pool space to keep chloramines from entering adjacent spaces. This can be accomplished in an energy efficient manner and on a real-time basis by controlling the difference between the exhaust airflow and the outdoor airflow through the pool dehumidification unit.

Table 2: Minimum Ventilation Rates in Breathing Zone[1]

						Default Values			
	People Outdoor Air Rate		**Area Outdoor Air Rate**			**Occupant Density** (see Note 4)	**Combined Outdoor Air Rate** (see Note 5)		
Occupancy Category: Sports and Entertainment	cfm/person	L/s•person	cfm/ft^2	L/s•m^2	**Notes**	#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	Air Class
Spectator areas	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Swimming (pool & deck)	—	—	0.48	2.4	C	—			2

Notes

1 From Table 6.2.2.1, *ANSI/ASHRAE Standard 62.1-2016. Ventilation for Acceptable Indoor Air Quality.*
4 Default occupant density: The default occupant density shall be used where the actual occupant density is not known.
5 Default combined outdoor air rate (per person): Rate is based on the default occupant density.
C Rate does not allow for humidity control. “Deck area” refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.
H Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

Table 2: Minimum Ventilation Rates
For swimming pool and deck areas, ASHRAE recommends a minimum air exchange rate based on area, not on occupant density. This is important to note because pools can generate corrosive chloramines when they are unoccupied.

Lighting and fan sensible loads

Typical practice regarding lighting and fan sensible heat loads is to include them in the sensible cooling load calculation and ignore them when calculating sensible heating load, to be conservative when determining the design heating capability required.

Lighting loads can be reduced by incorporating natural lighting into the envelope design and by using efficient lighting options.

Fan motor heat loads can be reduced by selecting efficient fans such as direct drive airfoil blade plenum fans. Use of forward curved fans, propeller fans, and belt drive fans should be avoided due to their low fan efficiency, sheave corrosion, belt losses, and extra maintenance costs.

LATENT LOADS

Indoor aquatic facilities have the following latent loads:

- Pool evaporation
- Outdoor air latent load (positive or negative)
- Infiltration
- Spectators (in a competition pool setting)

Pool evaporation rate

A large, heated body of water continuously evaporates moisture into the air. The evaporation rate depends on vapor pressure at the water surface, which increases when water temperature increases, and vapor pressure of the air, which decreases when the air dew point decreases. Pool activities also affect the evaporation rate. The more activity in a pool, the more evaporation.

BEST PRACTICE TIP

The pool water evaporation rate is the largest component of the space latent load, and can be controlled by making the following intelligent design choices:

1. Keep pool air temperature 2 °F (1.1 °C) above the water temperature. Pool operators often choose to lower space temperature or raise water temperature in a well-intentioned but misguided attempt to reduce energy costs or make swimmers or other occupants more comfortable. However, this practice tends to have the opposite effect. It greatly increases evaporation rate and total energy costs, and causes swimmers exiting the pool to feel cold.
2. Control the space relative humidity (RH) to 60% whenever possible (unless the amount of fresh air supplied for chloramine control causes the humidity to go below 60%). Evaporation increases 30% for every 10% drop in pool space RH (see Figure 3).

   The lower relative humidity that naturally occurs in colder months from introducing outdoor air to improve indoor air quality is often desirable because it prevents condensation on exterior surfaces without resorting to operating cooling coils for mechanical dehumidification during winter.

   To learn more, see "Choosing the best RH design set point" below.
3. Use a pool cover at night, if feasible. A pool cover nearly eliminates evaporation during unoccupied operation. It also stops pool chemical migration to the air and may allow reduction in outdoor air amounts. However, pool covers do not always match pool geometry. They also can take up space when spooled, and operators often find them cumbersome to deploy manually or expensive to deploy automatically.

A large, heated body of water continuously evaporates moisture into the air. The more activity in a pool, the more evaporation.

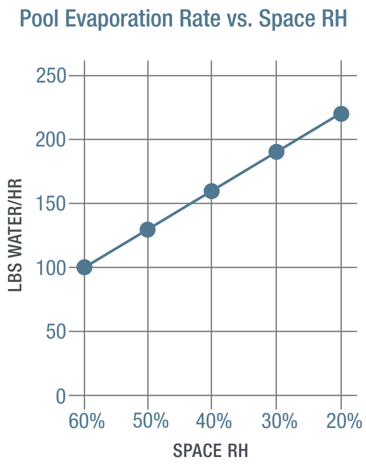


Figure 3:
Pool Evaporation Rate and RH
The pool evaporation rate is the largest component of the space latent load. This graph shows that the evaporation rate increases 30% for each 10% decrease in space relative humidity.

Choosing the best RH design set point

The higher the RH design set point the lower the dehumidification load. ASHRAE recommends maintaining RH between 40-60% to prevent undesirable organism growth, and between 50-60% RH for swimmer comfort.

BEST PRACTICE TIP

Using 60% RH as your design set point will conserve the most energy and reduce equipment first costs. Designing for 50% RH instead of 60% RH can double required cooling capacity and increase operating costs by 50% (see Figure 4).

Table 3 shows how component energy costs change when RH changes. These costs are percentages of total operating costs, which increase by a factor of 1.5 when RH decreases from 60% to 50% (Figure 4). For example (see shaded cells in Table 3), if total operating costs at 60% RH are $100,000, compressor energy cost is $15,000 (15%). However at 50% RH, total operating costs increase to $150,000, and compressor energy cost is $52,500 (35%).

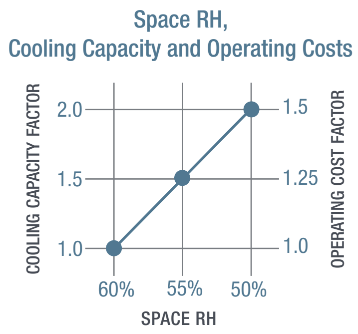


Figure 4: RH, Capacity, and Costs
Using a 60% RH design set point instead of 50% reduces first and operating costs.

Table 3:
Component energy costs by percentage, indoor aquatic facility, 82 °F air temperature*

Component	All Climates, Average % of total		Atlanta % of total		Chicago % of total	
	60% RH	50% RH	60% RH	50% RH	60% RH	50% RH
Fans	40	25	41	27	37	26
Envelope and ventilation	25	15	18	12	34	24
Pool water heating	20	20	22	19	19	18
Compressors	15	35	19	42	10	32

Note
* These are projected annual energy costs of an indoor aquatic facility before dehumidification system selection, using gas heat, no energy recovery, occupied 16 hrs/day, and ventilating with minimum outdoor air as defined by ASHRAE 62.

When space design temperature is at the higher end of the recommended range (86 °F [30 °C]) consider designing for 55% RH to have dehumidification capacity available to make the environment more comfortable when (clothed and dry) spectators are present. Also, it may be desirable to reduce to as low as 40% RH at night during cold months to prevent condensation in indoor aquatic facilities with exterior walls. This often can be achieved with the low-humidity outdoor air already being introduced to remove air contaminants.

Outdoor air latent load

Entering outdoor air has a latent load, either positive (as with moist summer air), or negative (as with dry winter air). During many months of the year the lack of humidity in outdoor air either completely cancels out the pool water evaporation load (winter) or greatly reduces it (spring and fall) resulting in

BEST PRACTICE TIP

minimal to no net dehumidification load to the space. Using outdoor air as a dehumidifying source when it is cost effective, rather than using a mechanical dehumidification system, can greatly reduce total operating costs, provide better indoor air quality, and improve system reliability.

Infiltration latent load

Infiltration air entering from an adjacent space or from outdoors will likely reduce the latent load since the pool space is generally warmer and more humid than other spaces. The (usually drier) infiltration air coming in through leaky joints and cracked or open doors will displace the moist pool area air. This infiltration can be controlled by actively controlling the pressure differential as discussed above. Refer to Chapter 25.12 in the *2013 ASHRAE Handbook: Fundamentals*[2] for more information.

It is important to make a distinction between displacement of water vapor by air movement through gaps such as doors and cracks (infiltration) and moisture diffusion through the building materials of the enclosure due to vapor pressure gradients (exfiltration). If an intact vapor barrier is not provided, moisture will migrate from the high vapor pressure of the pool through the walls to the lower pressures of outdoor ambient air or the adjacent space, regardless of the pool air pressure differential to surrounding spaces or outdoor ambient air.

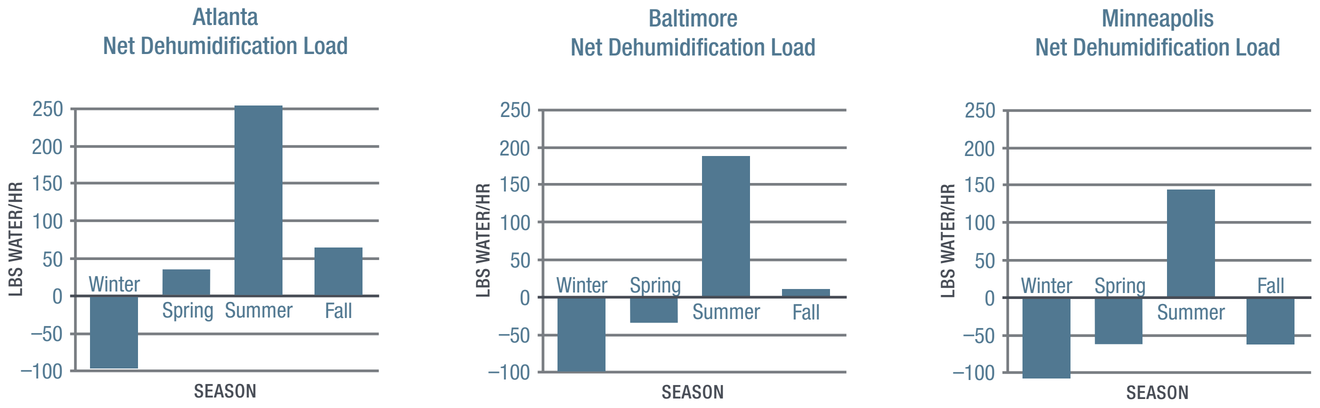
Spectator latent load

Spectators observing events add to the space dehumidification load. Using ASHRAE guidelines for people seated at an event, and modifying for the temperature and humidity of a pool space, the spectator latent load can be estimated at 0.16 lbs/hr (0.07 kg/h) per spectator.

Two strategies for dehumidifying aquatic facilities

Mechanical pool dehumidification systems use cooling coils year round to extract moisture from indoor air.

Outdoor air dehumidification systems replace moist indoor air with dry outdoor air for most of the year, and use cooling coils when outdoor air moisture content is high in summer.



Data based on minimum 25% outdoor air, occupied mode

Figure 5: Net Dehumidification Load Profiles by Season and City When Dehumidifying with Minimum 25% Outdoor Air

In an indoor aquatic facility, the net dehumidification load varies by season and climate and derives primarily from the outdoor air latent load (positive or negative) and pool evaporation rate.

Using outdoor air as a dehumidifying source when it is cost effective, rather than using a mechanical dehumidification system, can greatly reduce year round operating costs, provide better indoor air quality, and improve system reliability.

Net dehumidification load profile

The sum of the latent loads is greatly influenced on a seasonal basis by the outdoor air load and the pool evaporation rate. It is not an even load over the course of the year; in fact, the only time the seasonal averaged loads exceed 25% of the design load is during summer. See Figure 5.

Dehumidification technologies and strategies

The choice of dehumidification technology has a major effect on energy usage. There are three common strategies for dehumidifying air:

- **Chemical dehumidification.** These systems dehumidify with desiccants, typically requiring post cooling. However, chemical dehumidification systems are generally not economical at the high dew points of pool spaces, and desiccants deteriorate when exposed to chlorine.
- **Mechanical dehumidification.** These systems use cooling coils, typically with reheat, to extract moisture from indoor air. Complex options include multiple condensers and pumped glycol overlays to recapture energy from compressor operation.
- **Outdoor air dehumidification.** These systems replace moist indoor air with dry outdoor air. Note that systems using only outdoor air cannot provide humidity control on humid summer days in most climates.

  Introducing low humidity outdoor air to humid indoor aquatic facilities, even when that air needs to be heated, can be the most economical way to dehumidify these spaces, especially since fresh air is already being delivered to dilute the above-average level of indoor air contaminants (see Figure 6).

  When outdoor air cannot meet the dehumidification load economically, typically in summer, hybrid systems use mechanical dehumidification, often a cooling coil with reheat, to meet the dehumidification load.

Dehumidification load recommendations

BEST PRACTICE TIP

There are several ways to reduce an indoor aquatic facility's dehumidification load:

- Designing for 60% RH rather than 50% RH can reduce energy consumption by 50% and required cooling capacity by 100%.
- Keeping pool air temperature 2 °F (1.1 °C) above the water temperature will reduce the pool water evaporation rate.
- Using outdoor air whenever possible, rather than mechanical dehumidification, to lower indoor humidity levels.

AIR DISTRIBUTION

Proper air distribution in an indoor aquatic facility:

- Prevents condensation
- Prevents corrosion
- Prevents temperature and humidity stratification
- Removes airborne disinfectant by-products such as chloramines
- Provides effective mixing throughout the space
- Delivers fresh, outdoor air to the swimmers' breathing zone (right above the water), to people on the deck, and to spectators.

A fairly high rate of total air movement is needed to meet these requirements.

Because of these specialized requirements, VAV control strategies to reduce fan costs should not be applied during occupied operation. Whether occupied or not, the air distribution system must continuously prevent condensation, corrosion, and stratification, which requires that diffusers throw air effectively.

How much can you save?

A 6,300 square foot competition pool in a 300,000 cubic feet indoor aquatic facility maintained at 82 °F (28 °C) and 60% RH can have the following operational cost reductions when using outdoor air dehumidification for most of the year instead of using year round mechanical dehumidification:

- 50% in Denver (ASHRAE Climate Zone 7)
- 40% in Minneapolis, Portland and Boston (ASHRAE Climate Zones 4, 5 & 6)
- 30% in Washington DC and Kansas City (ASHRAE Climate Zone 4)
- 25% in Los Angeles (ASHRAE Climate Zone 3)
- 20% in Atlanta, shown in graph at right (ASHRAE Climate Zone 3)
- 15% in Dallas (ASHRAE Climate Zone 3)

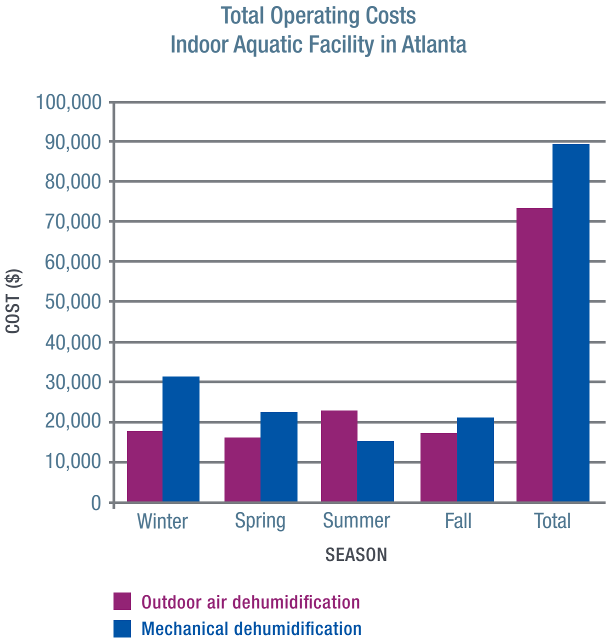


Figure 6: Total Operating Costs, Indoor Aquatic Facilities, in Climate Zones 3–7
The chart above describes the total operating costs of an indoor aquatic facility located in Atlanta, GA, and includes costs for air heating, pool water heating, dehumidification, and fan motors. The text above describes total operating costs for the same aquatic facility when located in Climate Zones 3 through 7.

Air movement during unoccupied operation may be reduced if a pool cover is used to eliminate the transfer of chloramines to the air and if an owner is vigilant in monitoring the effectiveness of reduced airflow with regard to corrosion, condensation, and stratification. Note that most owners find pool covers inconvenient to use and partially ineffective for nonstandard-shaped pools; and there also can be a surge of chloramines into the air when a pool cover is removed.

Consider first and total operating costs when choosing a pool heating technology. A simple, dedicated system may have lower overall costs than a more complex system using energy recovery.

POOL WATER HEATING

Pool water heating is required to bring pools up to temperature after being filled, to heat make-up water during operation, and to replace heat lost through pool water evaporation.

For each pound of water evaporated approximately 1050 Btu leave the pool, cooling the water. The cooling effect of evaporation accounts for over 90% of pool water heating costs. See the “Pool evaporation rate” section above for tips on how to reduce the evaporation rate.

Pool heating technologies

An operational aquatic facility requires a pool heater that can always meet the pool heating load. Technologies that meet this requirement include high efficiency gas heaters, electric heaters, and boiler water loops.

Supplemental pool heating technologies can reduce annual energy costs but are not able to consistently meet the pool heating load. These include solar water heating, condenser water loops, exhaust air heat pumps, and refrigerant condensers.

Consider first and total pool heating operating costs

Energy costs to heat pools can be high, but when choosing a pool heating technology it is important to consider first and total operating costs as well as energy costs. For example, it may be more cost-effective to use a simple dedicated pool heating system rather than one that provides pool water heating, dehumidification, and temperature control with the same refrigeration system. These systems are complex, requiring additional

condensers, pumps, valves, and piping, and may force unnecessary compressor operation to provide pool water heating.

SUMMARY

Indoor aquatic facilities can be energy-efficient and healthy environments. Increasing the amount of entering outdoor air has two main benefits. First, it flushes toxic chloramines from the space, making it healthy for swimmers and spectators. Second, outdoor air is dryer than pool air for most of the year and becomes a natural and efficient way to dehumidify these spaces that have high latent loads. Only in summer, when outdoor dew points are high, is there a need for more expensive mechanical dehumidification. In winter, efficient exhaust air heat recovery warms up entering outdoor air, reducing operating costs.

A design process that uses outdoor air to dehumidify, integrated with simple and efficient energy recovery, thoughtful choice of space conditions and water temperature, effective air distribution, energy efficient enclosure design, and enough outdoor air to ensure healthy indoor air, will create a cost- and energy-efficient indoor aquatic facility.

About the author

Gary Lochner is Vice President of Business Development at Unison Comfort Technologies. He holds a Mechanical Engineering Degree with heat transfer emphasis from the University of Minnesota. His background includes technical and leadership positions at a major HVAC manufacturer and a succession of roles at Heatex and Innovent. For nearly twenty-five years Gary has helped design over 1000 HVAC units serving indoor aquatic facilities, ranging from high school pools to community rec centers to major water parks. Gary has spoken on design considerations for these spaces at many ASHRAE chapter meetings. This broad experience has uniquely equipped him with a deep understanding of the many complex factors at play in natatoriums.

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Design Guide

Ventilation and air distribution in indoor aquatic facilities. Gary Lochner.

Chloramines & Pool Operation

Website from The Centers for Disease Control and Prevention

www.cdc.gov/healthywater/swimming/aquatics-professionals/chloramines.html

ASHRAE

"Places of Assembly: Natatoriums" *2015 ASHRAE Handbook: Fundamentals.*

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1	*ANSI/ASHRAE Standard 62.1-2016. Ventilation for Acceptable Indoor Air Quality.* ASHRAE.
2	"Heat, Air, and Moisture Control in Building Assemblies" *2015 ASHRAE Handbook: Fundamentals.* ASHRAE.

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