Current & Alternative Cooling Technologies for Southern Nevada

The following provides an overview of the most commonly-used methods to cool buildings and industrial equipment in southern Nevada. It will also explore alternative and emerging technologies that consume less water in the cooling process.

HVAC Systems

Introduction:

Heating, Ventilation, and Cooling systems, otherwise known as HVAC systems, are an integral part of modern buildings. HVAC systems keep temperatures comfortable, humidity consistent and indoor air quality high in buildings. They also are used in industry to remove excess heat from the manufacturing process. Unfortunately, they demand a large amount of energy to operate and can sometimes consume a great amount of water.

- Evaporative Coolers (Swamp Coolers)
- Standard Air Conditioning
- Increasing Warehouse Energy Efficiency
- Chilled Water Systems
- Building Efficiency
- Alternative Cooling Technologies

Evaporative Coolers

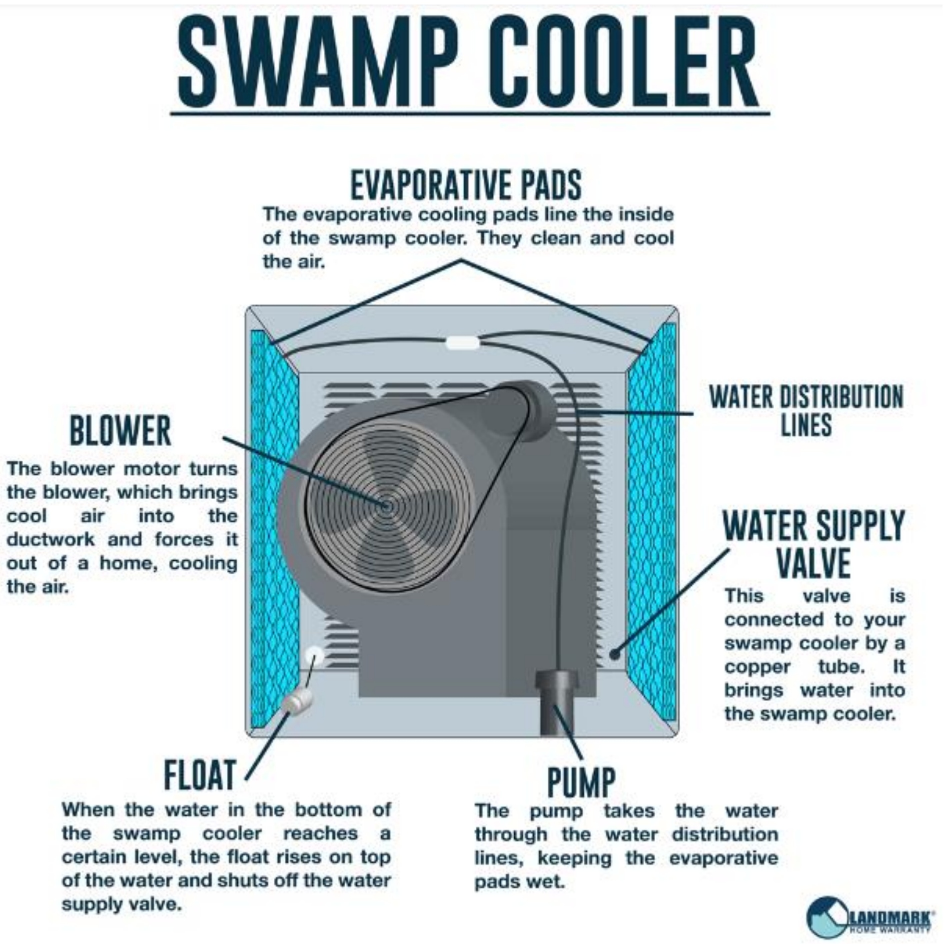
There are over 25,000 evaporative coolers, or "swamp coolers" in southern Nevada. Swamp coolers work by using a fan to blow outside air across a water-saturated pad and then into the building. As the water evaporates, the inbound air's temperature is reduced about 15-25 degrees F.

Although they cannot reduce the air temperature as much as traditional air conditioning, swamp coolers are extremely popular for large warehouses and workshops because they are a simple design and generally use less electricity than AC systems. Unfortunately, they use a lot of water to operate– typically 30-150 gallons per hour depending on the air temperature, humidity and size of the unit. Swamp coolers are also used to supply "make-up" air in restaurants that use exhaust vents in the cooking area.

Where did the name "swamp cooler" originate? It's up for debate. A common answer is that if a swamp cooler isn't regularly cleaned, it'll begin to look and smell like a swamp.

How Swamp Coolers Work:

Evaporative Coolers are very simple: Outside air is drawn into the unit and passes through a water-saturated pad (water is constantly spraying onto the pad to keep it wet). As the water evaporates, it cools the air by 10-20 degrees F. The cooler air (also more humid) is then blown into the building.



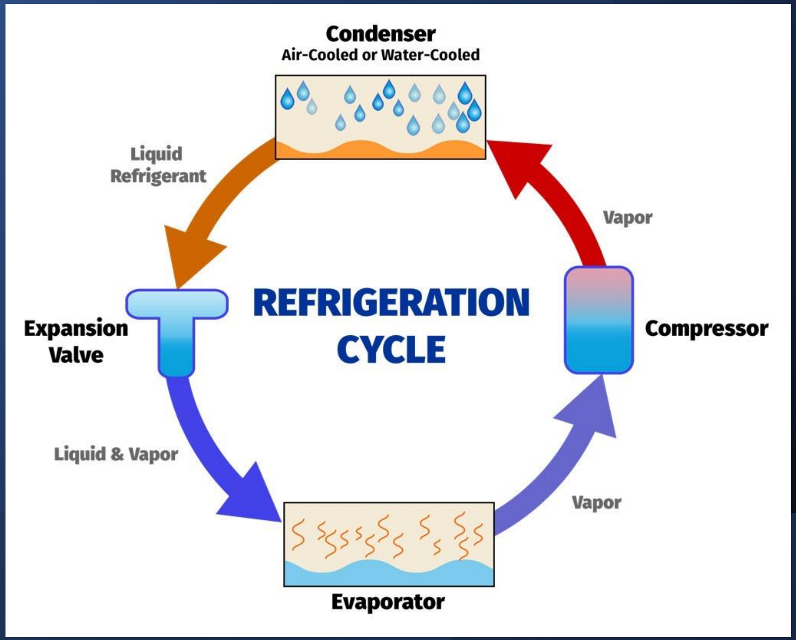
EACH swamp cooler can evaporate enough water to fill five swimming pools annually.

Best Practices for Evaporative Coolers

1. **Ensure water drain/purge line is connected to the sanitary sewer.** When the water tank is purged or overflows it often drains through a pvc line off the roof and onto the ground. This is water that can be recycled back to Lake Mead if connected to the sewer system.

2. **Only operate swamp coolers when needed.** The majority of swamp coolers in southern Nevada are turned on in May and left running until September. Each swamp cooler is evaporating water when on, so they should be shut off when possible. Consider a programable thermostat that will operate the cooling system on designated days and times.

3. **Maintain cooling pads.** Unfortunately, our water contains a lot of calcium and other minerals that cause scaling. When the pad/fill of a swamp cooler becomes clogged with scale, it hardens and becomes less efficient at cooling. Water is also wasted as it runs over the pad and purged from the system.



Air Conditioning

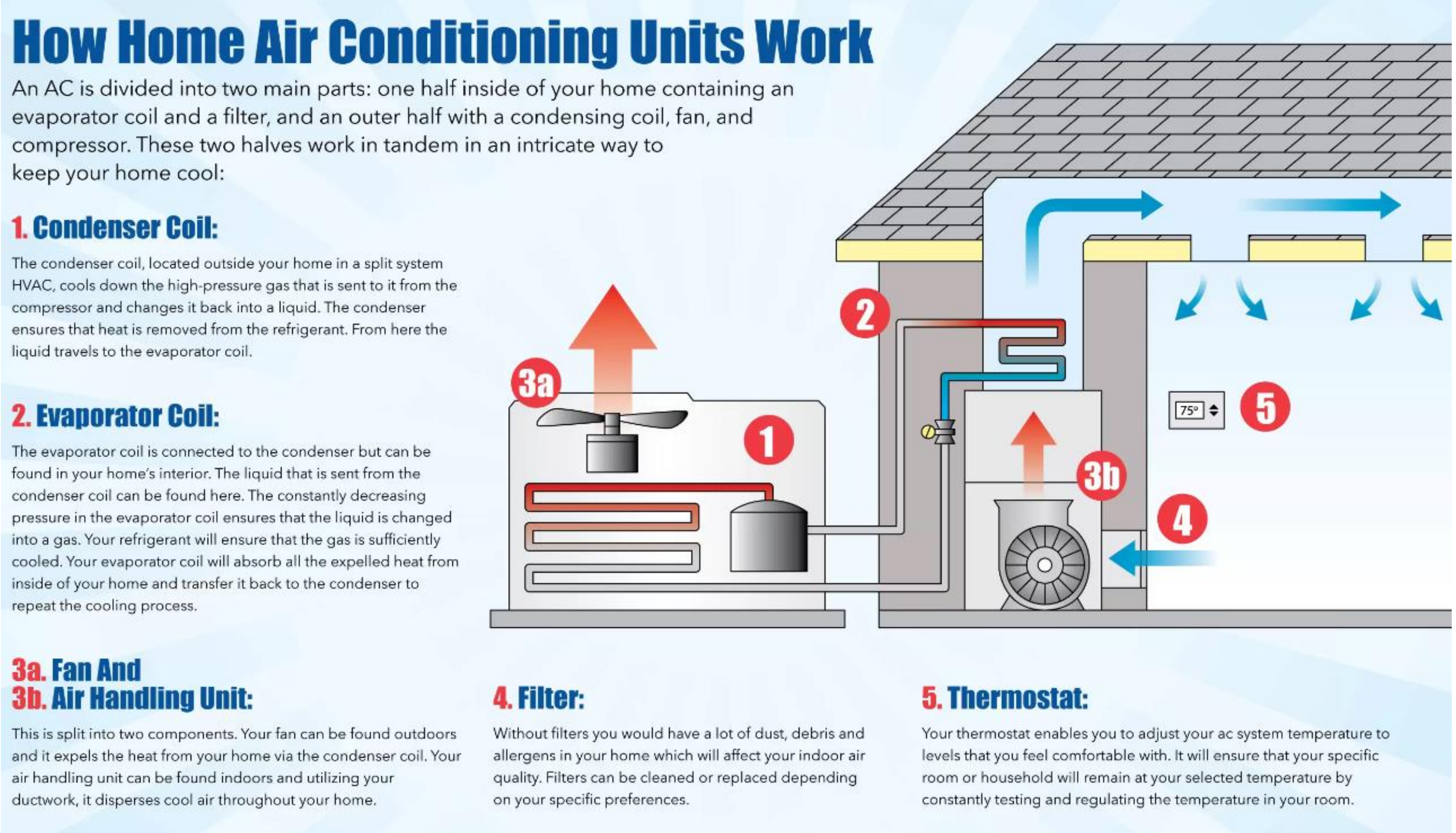
Air conditioning, often abbreviated as A/C or AC, is the process of removing heat and controlling the humidity of air in an enclosed space. Air conditioning is a member of a family of systems and techniques that provide 'heating, ventilation, and air conditioning' (HVAC). Air conditioners, which typically use vapor-compression refrigeration, range in size from small units used within vehicles or single rooms to massive units that can cool large buildings.

As international development has increased wealth across countries, global use of air conditioners has increased. By 2018, 1.6 billion air conditioning units were installed worldwide accounting for 20% of energy use in buildings globally.

Air Conditioning Basics: Air conditioning is a system used to cool down the temperature in a space by removing the existing heat and moisture from that space.

Air conditioners use refrigeration to chill indoor air, taking advantage of a remarkable physical law: When a liquid converts to a gas (in a process called phase conversion), it absorbs heat. Air conditioners exploit this feature of phase conversion by forcing a liquid refrigerant to evaporate and condense repeatedly in a closed system of coils.

Air conditioners use fans to move warm interior air over these cold, refrigerant-filled coils. When hot air flows over the cold, low-pressure evaporator coils, the refrigerant inside absorbs heat as it changes from a liquid to a gaseous state. To keep cooling efficiently, the air conditioner must convert the refrigerant gas back to a liquid again. To do that, a compressor puts the gas under high pressure, a process that creates unwanted heat. All the extra heat created by compressing the gas is then evacuated to the outdoors with the help of a second set of coils called condenser coils, and a second fan. As the gas cools, it changes back to a liquid, and the process starts all over again.



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How Air Conditioning Works:

SMALL – MEDIUM SIZED AIR CONDITIONING SYSTEMS

- **Single Split System:** A single split system is one of the most popular types of commercial air conditioning units and are used in small buildings such as a café, small retail shop, or small office. They work in unison with an outdoor unit to circulate air, which travels through the building’s ducts. Better priced than central air systems, they allow control of the temperature in each room with a control panel. Another benefit to a single split system is that if one needs repairs, the others around the building will still work because each unit is self-contained.
- **Multi Split System:** Multi Split Systems are common in larger office spaces, restaurants, doctor’s offices, and retail shops. Whereas single split systems require an outdoor unit per indoor unit, multi split systems can save space. This is because each outdoor unit can power up to nine indoor units, which can be installed onto the wall or ceiling. However, they need more piping than single split systems, so they may not be right for all buildings
- **Packaged Rooftop Unit (RTU):** RTU’s are self-contained HVAC systems, often used in smaller commercial buildings. Because all the components have been assembled and configured in a factory under optimal conditions, these systems are easy to install and work relatively efficiently. These all-in-one HVAC units connect into the ductwork of the building and provide adaptable heating and air conditioning to a specific area of the building. RTU units are commonly used for large, open spaces such as warehouses, large stores, and shopping centers. Single-story buildings are best suited since the conditioned air doesn’t have to travel very far to the space.
- **VRF System:** Variable refrigerant flow (VRF) are basically large-scale ductless systems that can perform at a high capacity and are generally found in larger mixed-use buildings such as larger office buildings or small hotels. The specific design of a VRF system varies based on application. In general, VRF systems consist of outdoor units connected to multiple indoor units via refrigerant piping to provide cooling and heating to individual zones. The outdoor units can modulate capacity based on the requirements of the individual zones, thus saving energy by not always running at 100% capacity.
- **Heat Pumps:** Heat pumps are based on the refrigeration cycle, just like air conditioners, but they offer reversible operation; when multiple heat pumps are used to serve separate areas of a commercial building, they can switch between cooling and heating modes as needed. All heat pumps in a building share a common water circuit, and they will either reject or absorb heat depending on the needs of each zone. Since the water circuit it shared, equal heating and cooling loads balance each other out.

Air Conditioning for Warehouses

Packaged AC Rooftop Unit (RTU)

Packaged rooftop units are self-contained HVAC systems, heavily used in commercial and industrial buildings in So. Nevada. Because all the components have been assembled and configured in a factory under optimal conditions, these systems are easy to install and work relatively efficiently. These all-in-one HVAC units connect into the ductwork of the building and provide adaptable heating and air conditioning to a specific area of the building. RTU units are commonly used for large, open spaces such as warehouses, large stores, and shopping centers. Single-story buildings are best suited since the conditioned air doesn't have to travel very far to the space.

The simplicity of the installation of these air conditioning units as well as the relatively low capital and operating cost makes this application effective for many industrial warehouse-type buildings.

RTU's are available in sizes ranging from 1 to more than 100-tons of AC capacity. RTU's also come in with different levels of energy efficient ratios (EER). An ERR is the ration of the rate of cooling (in BTU per hour) to the power (in watts) at full-load conditions. The higher the EER, the more energy efficient, and therefore less energy consumption per hour.

PROS:

- All-in-one "package" air-conditioning solution
- No water consumption
- Low maintenance
- High cooling capacity and reduces humidity

CONS:

- Higher initial capital cost
- Slightly higher energy consumption/cost
- May require increase in building's electrical capacity
- May require additional insulation to meet IECC standard

Air-Turnover/Air Rotation System

Air-rotation systems are an alternative to conventional rooftop AC units. Air-rotation units address the air stratification in warehouses by continuously circulating the air in the space. It picks up air at the floor, removing the coldest air layer supporting the thermal barrier. The air is heated or cooled, and returned quietly through a screened discharge plenum to create a uniform temperature and a comfortable, more cost-effective conditioned space.

This system eliminates the need for duct work that can interfere with overhead space. Any single zone space of at least 10,000 square feet with ceiling height of 25 feet or greater, is a candidate. One air-rotation unit can handle 50,000-100,000 square feet of floor space. Proprietary air foil axial fans minimize horsepower and noise.

Also, ground level mounting eliminates roof penetrations, reduces structural costs, allows ground level service and maintenance, and reduces installation expense over roof mounted systems. DX cooling is achieved with Daikin condensing units. Chilled water and ammonia cool are also available. Heating can be electric, gas, oil, steam or hot water. Outside air management including economizer are optional.

PROS:

- Reduces electrical costs
- No rooftop penetrations
- No additional rooftop support
- No ductwork
- Indoor or outdoor mounted
- Faster installation/easier maintenance
- Portability

CONS:

- Higher initial product costs
- Only suitable for large open areas

Photo: Johnson Controls Air-Rotation System

Increasing Warehouse Energy Efficiency

Passive and/or Low-cost Techniques to Increase Air Conditioning Performance and Reduce Energy Demand

- **Insulated and reflective roofing:** The roof of a building, especially one with a large surface area, receives a high amount of heat gain since it is very susceptible to solar radiation and environmental changes. By installing a roof insulated with polyurethane as well as simply painting the roof white can reduce the cooling load significantly.
- **Wall insulation:** The building's walls are one of the important parts of the building envelope. The wall thermal insulation value is important as the building's energy consumption is heavily affected by it. The installation of polystyrene to insulate the building can result over a 20% reduction in yearly space cooling load.
- **Targeted Ducting and Ventilation:** Metal or fabric ducting can be used to distribute and direct a/c air down to employees and work areas, targeting the people/equipment that needs it the most. Both metal and fabric ducting can be used in conjunction with air conditioners, dust collectors and blowers, or simply be used with a fan. Tube length, hole size, and hole spacing are calculated so that the area along the entire length of the tube receives smooth, consistent air movement.
- **HVLS (High Volume Low Speed) Ceiling Fans:** These large fans can reduce cooling costs by adding an evaporative cooling affect, air circulation, thus creating a uniformly comfortable temperature to the work environment. When ceiling circulator fans are used along with air conditioning, tests from ASHRAE have shown that a thermostat setting can be raised without loss of employee comfort when ceiling fans are running. The breezes created by these fans provide an evaporative cooling affect that lowers skin temperature by up to 7 degrees.
- **Improve electrical efficiency:** Install energy-efficient lighting, office equipment, and appliances. The heat load from lighting and electronics can be more than 50% of the total for commercial buildings. Installing LED lighting and energy-efficient electrical equipment is vital to reducing cooling loads.
- **Shade the AC unit if outdoors:** Condensers and compressors located in direct sunlight need to work harder and fail more often. Shading is relatively inexpensive and effective.
- **Insulate AC cooling ducts:** Having the ducts properly insulated will preserve the cool air in the ducts and reduce loss to other parts of the building.

Wall Insulation

Insulating the walls of a warehouse can reduce costs related to heating and cooling as well as reduce sound levels.

Insulation is rated by its “R-Value” which is the material’s ability to control heat transfer. Insulation types include fiberglass, spray foam, cellulose, aerogel, bubble and Prodex.

Warehouse insulation can be installed during construction or as a retrofit.

HVLS Ceiling Fans

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Circulating Fans can also eliminate cold areas and dead air pockets by stirring the stale or stagnant surrounding atmosphere. Cooled air is continuously recycled.

Thermostats stay at their desired temperatures for a longer period, reducing the air conditioning system's load and its operating expense. Ceiling fans running continuously can also help to reduce the build-up of ceiling heat, which helps to prevent the air conditioning thermostat to shut off sooner during the cooler times of the day.

The air movement rating for these fans range from 7,000 CFM to 100,000 + CFM.

Targeted Ducting and Ventilation

Metal or fabric ducting can be used to distribute and direct a/c air down to employees and work areas, targeting the people/equipment that needs it the most. Both metal and fabric ducting can be used in conjunction with air conditioners, dust collectors and blowers, or simply be used with a fan.

Tube length, hole size, and hole spacing are calculated so that the area along the entire length of the tube receives smooth, consistent air movement.

Heat Rejection Coatings

Ceramic reflective coatings reduce the surface temperature of applied surfaces to within 5-8 degrees of the ambient temperature. This can be a reduction of 10-40 degrees, resulting in equipment cycling less frequently and cooler air being delivered to the occupied space. Studies have shown a 10-15 percent reduction in energy consumption.

Coated coils have demonstrated reduced energy consumption by returning performance back towards original design specifications.

Photo: Protecall HVAC Coatings

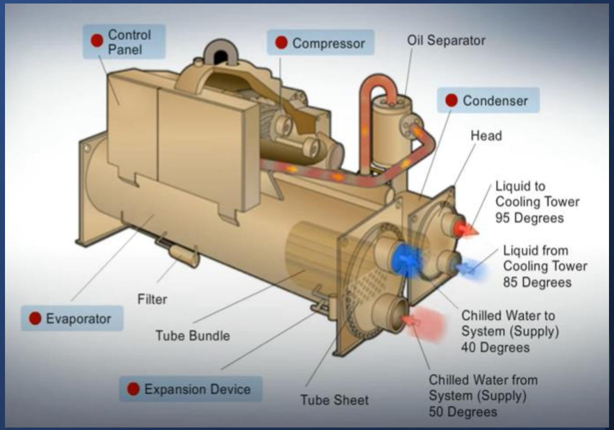
Radiative Cooling

This new technology utilizes specially treated panels that reflect infrared light back into the atmosphere and eventually into Space. The reflective wavelengths are in the infrared spectrum that absorb and then emit radiation. The panels can radiate away enough heat to consistently stay a few degrees cooler than surrounding air; up to 10 °C in hot, dry places.

The system uses no water, minimal energy and produces no noise. So far, theoretical estimates of how much electrical power can be saved have been based on data from small samples tested over short times, but additional pilot projects are currently underway.

- Ideal for reducing the energy and water consumption from a commercial refrigeration/freezer unit.

Chilled Water Systems



Once a building or industrial process reaches a certain size it becomes cost-effective to use a centralized HVAC system. Centralized systems utilize “chillers” to facilitate the heat transfer between the inside and outside of a building or industrial process. Chilled water systems have become an essential HVAC component for a wide variety of larger commercial facilities, including hotels, hospitals, shopping malls, sporting arenas, airports, and manufacturing plants.

Chillers: Chillers generate chilled, or cold, water which is pumped around a building to provide air conditioning by collecting unwanted heat. There are two main types of vapor-compression chillers, air cooled and water cooled. The term “air” or “water” cooled refers to how the chiller’s condenser is rejecting heat from the building or industrial process.

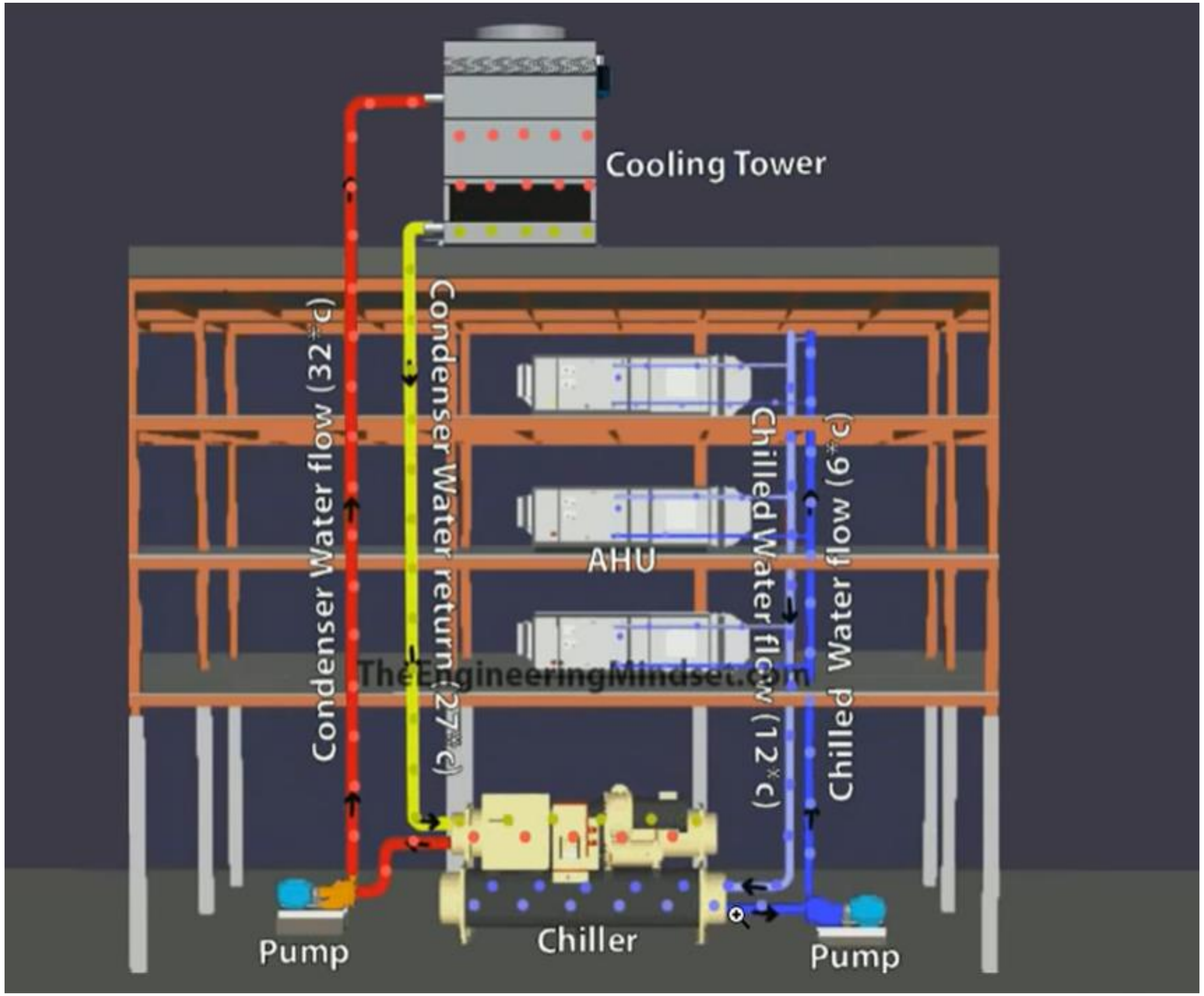
Air-Cooled Chillers: Air cooled chillers are very common in southern Nevada, especially in medium to larger size commercial buildings. They are usually located outside, either up on the roof or at ground level. These chillers produce cold water which is pumped around the building (in a loop) to the many Air Handling Units (AHU's) and Fan Coil Units (FCU's) which remove the unwanted heat from the building and transfer it into the chilled water loop. The chilled water will enter the AHU's/FCU's at around 43°F and by the time it leaves the heat exchanger within the AHU/FCU it will have risen to around 54°F and will then make its way back to the chiller to transfer this heat outside before repeating the cycle.

As opposed to open cooling towers that use evaporation, closed loop systems are only able to bring the water temperature down to the ambient temperature. This can be a problem when it's extremely hot. Because water is a much better heat exchanger, dry cooling is not as efficient as wet cooling. It is also more energy intensive due to the greater number of units and motorized fans required.

Above: Air cooled chiller

Water-Cooled Chillers: The working principle for both air-cooled and water-cooled chillers is the same. A compressor pushes a refrigerant round the inside of the chiller between the condenser, expansion valve, evaporator and back to the compressor. And, like air-cooled chillers, water-cooled chillers collect unwanted heat, which is extracted from the air, and collects it in the chilled water loop. This loop circulates back to the chiller and once it reaches the evaporator, the unwanted heat will be transferred over to the chiller's condenser via a refrigerant loop. However, in water-cooled chillers, the condenser absorbs this heat and then transfers it into a secondary loop called the "condenser water loop" which runs between the chiller's condenser and a "cooling tower".

Above: Water-cooled chiller and associated rooftop cooling tower.

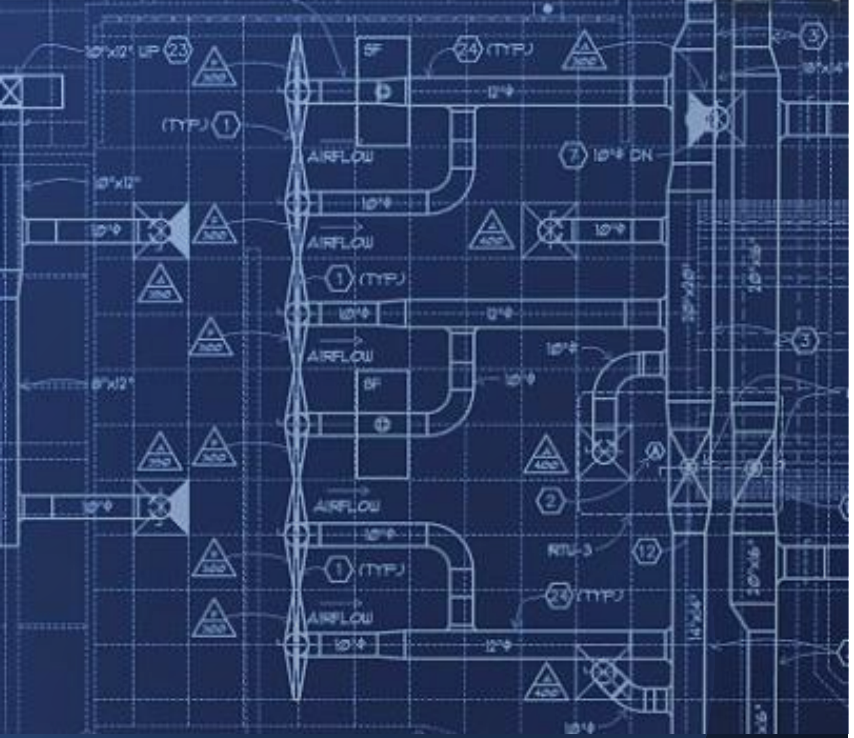


Left: This schematic shows a water-cooled chiller in the basement, the risers of the chilled water loop feeding the air handling units (AHUs) on each floor and the risers of the condenser water loop which goes to and from a cooling tower, located on the roof.

Source: EngineeringMindset.com

Cooling Towers: Every water-cooled chiller requires a cooling tower. Cooling towers are a type of heat exchanger that uses water and evaporation to remove unwanted heat. This contrasts with air-cooled chillers which use fans and the outside air to remove heat. In a water-cooled system, water that has been warmed by collecting heat from inside a building or from an industrial process, flows through the cooling tower where it's recirculated and exposed to air. Some heat leaves the water through evaporation. The "cooler" water (reduced about 10-12 degrees F) then reenters the air conditioning equipment to cool that equipment down, and the cooling cycle repeats. The cooling tower's role is to cool down the water so it can return to the chiller to pick up more heat. The lower the temperature of the water returned to the chiller, the more efficient the chiller is at removing heat from a building. In simpler terms, cooling towers efficiently relieve some of the pressure on the rest of the HVAC system, which lessens the chance of a breakdown and improves reliability.

Cooling towers evaporate about 1.5 gallons per ton-hour of cooling (EPA). Therefore, a 1,000-ton cooling tower will evaporate approximately 1,500 gallons per hour.



ALTERNATIVE COOLING TECHNOLOGIES

There are several alternative strategies to conventional wet cooling towers, however, a few technologies have been identified by the Pacific Northwest National Lab (PNNL) and Alliance for Water Efficiency (AWE) that were deemed as having the most suitability and potential to reduce evaporative water loss in the extreme climate and operating conditions of southern Nevada. These alternatives a were required to meet specific criteria, including that they are commercially available, have verified water savings performance, and have published capital costs. The alternative technologies identified were:

- **Thermosyphon Hybrid Cooling**
- **Hygroscopic Cooling**
- **Adiabatic Cooling**

In addition to the cooling tower alternatives recommended by PNNL and AWE, the Southern Nevada Water Authority has been evaluating other cooling and water-saving technologies that may be less familiar and/or do not have an extensive track record of operation in the field. They include:

- **Heat Pump Air-cooled Chiller**
- **Waste Heat Recovery**
- **Effluent Heat Exchange**
- **Thermal Storage (Ice/Chilled Water)**
- **Geothermal Heat Pumps**
- **Evaporative Plume Abatement**
- **Radiative Cooling**

Thermosyphon Hybrid Cooling

This type of technology is a hybrid heat-rejection system, which optimizes the use of two cooling technologies—one wet (an open cooling tower) and one dry (a thermosyphon cooler unit)—in a single, integrated operating system. The system precools heated water through a passive heat exchanger based on natural convection. As shown in schematic, the refrigerant liquid sinks to the bottom of the system and the refrigerant vapor "floats" to the top, whereby natural convection moves the warmer vapors up ("heat rises"). This process allows the refrigerant to cool as it circulates naturally between the unit's evaporator and condenser without the need for any compressors or pumps.

The TSC fans automatically modulate to use the most efficient combination of water and air-cooled systems in response to utility rates, ambient and system temperatures, and system loads. This allows the TSC to operate in a highly efficient manner across a vast range of weather and load conditions. The system's modular design is highly scalable, with the ability to incrementally add multiple units in parallel to handle the largest cooling requirements, therefore appropriate for many applications. The TSC can also be used as an efficient dry water-side economizer in combination with a traditional cooling tower or deployed as a stand-alone dry cooler.

PROS
- Uses "dry cooling" until demands rise and "wet cooling" is required
- Significantly less water consumption than cooling tower system
- High cooling capacity per unit

CONS
- More initial capital costs due to the integration of technologies
- Still requires water treatment due to cooling tower use
- Potential growth of bacteria with cooling towers, but less so

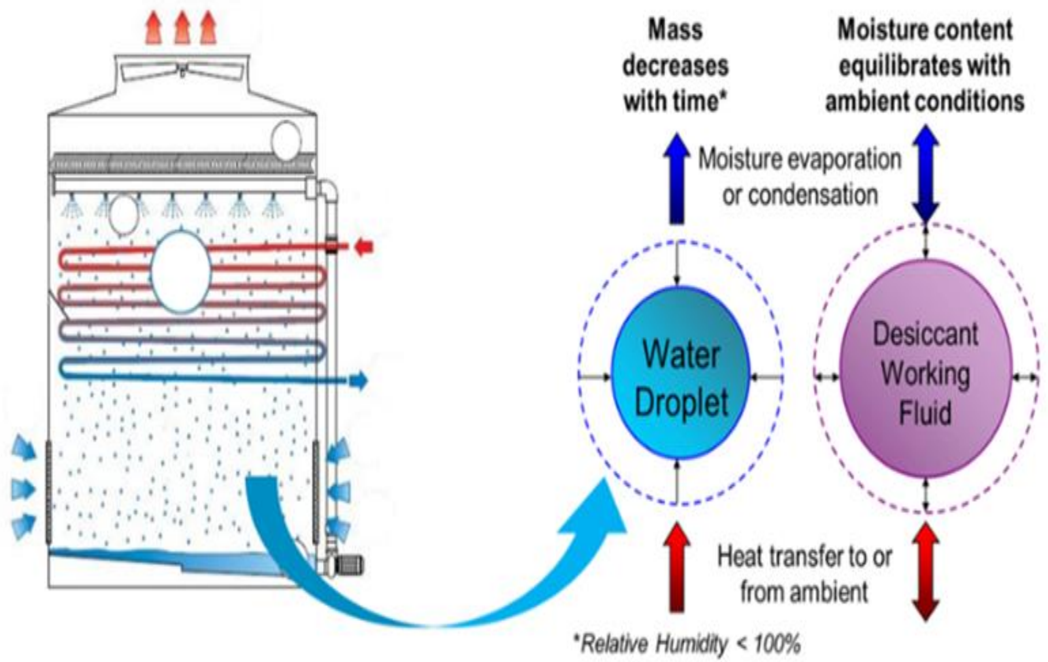
Hygroscopic Cooling

A hygroscopic cooling (HSC) works similarly to a traditional cooling tower, but instead of pure water as the cooling fluid, a hygroscopic liquid desiccant fluid is used, such as calcium chloride (CaCl2) mixed with water. In a traditional cooling tower, most of the heat is transferred through evaporation. Hygroscopic coolers however transfer more heat through convection rather than evaporation when the outdoor air is cooler than the temperature set point of the system. When outdoor air temperature exceeds this threshold, the system switches to evaporative cooling. The system can be controlled to optimize this process, thereby reducing water use by reducing the amount of evaporation. HSC systems also save water through the elimination of blowdown. Unlike traditional cooling towers, hygroscopic coolers remove dissolved solids by precipitating and then filtering the solids out of the fluid for reuse.

These systems were found to be most appropriate in applications that require operation when the ambient air temperatures drop below system's set point. In other words, the application requires cooling even when the outdoor temperature is cooler than the set point. This is typically caused by internal loads in the building, called “latent loads”, such as people and equipment that produce heat. If cooling it typically only required during peak outside temperatures, these systems will have lower water savings potential.

PROS:
- Less evaporative loss of water due to use of convection vs evaporation
- No blowdown of water so little to no make-up water demand

CONS:
- More initial capital costs due to the integration of technologies
- Still requires use of evaporative cooling during warmer days
- Potential growth of bacteria, but less so



Adiabatic Cooling

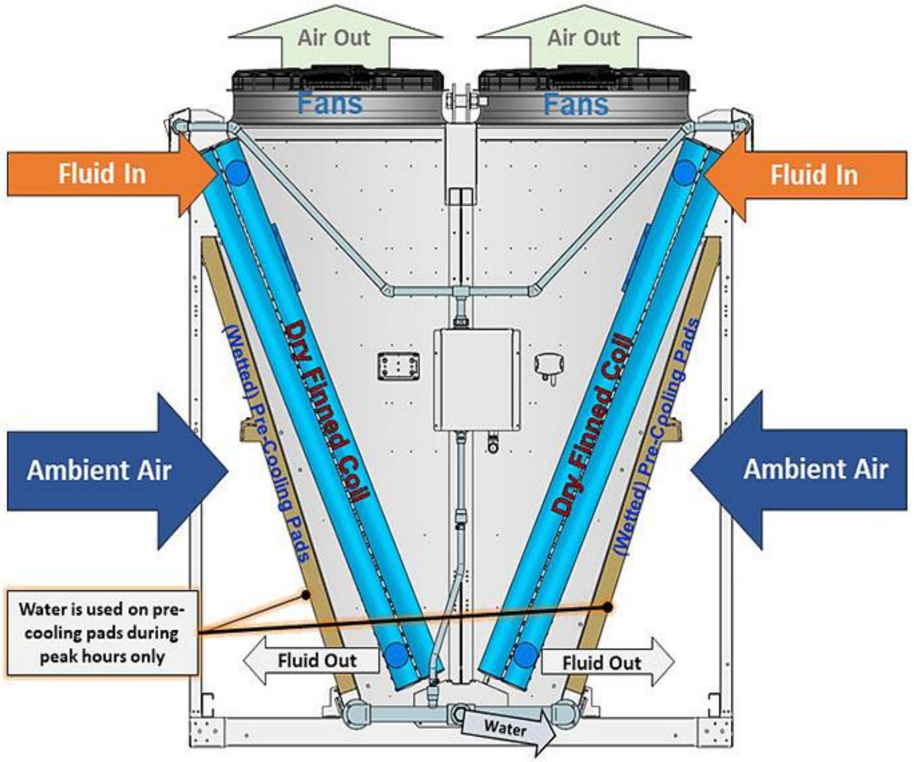
Adiabatic cooling systems work by using water to pre-cool the air flowing through a closed loop coil. Adiabatic coolers run in two modes: wet (or "pre-cooler") operation and dry operation. Wet operation is only activated during peak demand conditions (e.g., times of high outdoor temperatures and/or during high internal cooling loads conditions). A fan draws outside air through the unit where water is sprayed into the air. When the water encounters the warm air, water evaporates, and heat is dissipated. When outdoor temperatures are low and cooling loads are minimal, the system operates in dry mode, operating like a conventional finned dry cooler. Adiabatic cooling systems have a wide range of water savings because water use is heavily influenced on the operating conditions and how the system is controlled. These systems do not circulate water, which has the added benefit of no water treatment reducing operation costs.

PROS:

- Less water consumption than tradition cooling tower system
- No to minimal water treatment required
- Low risk of legionella

CONS:

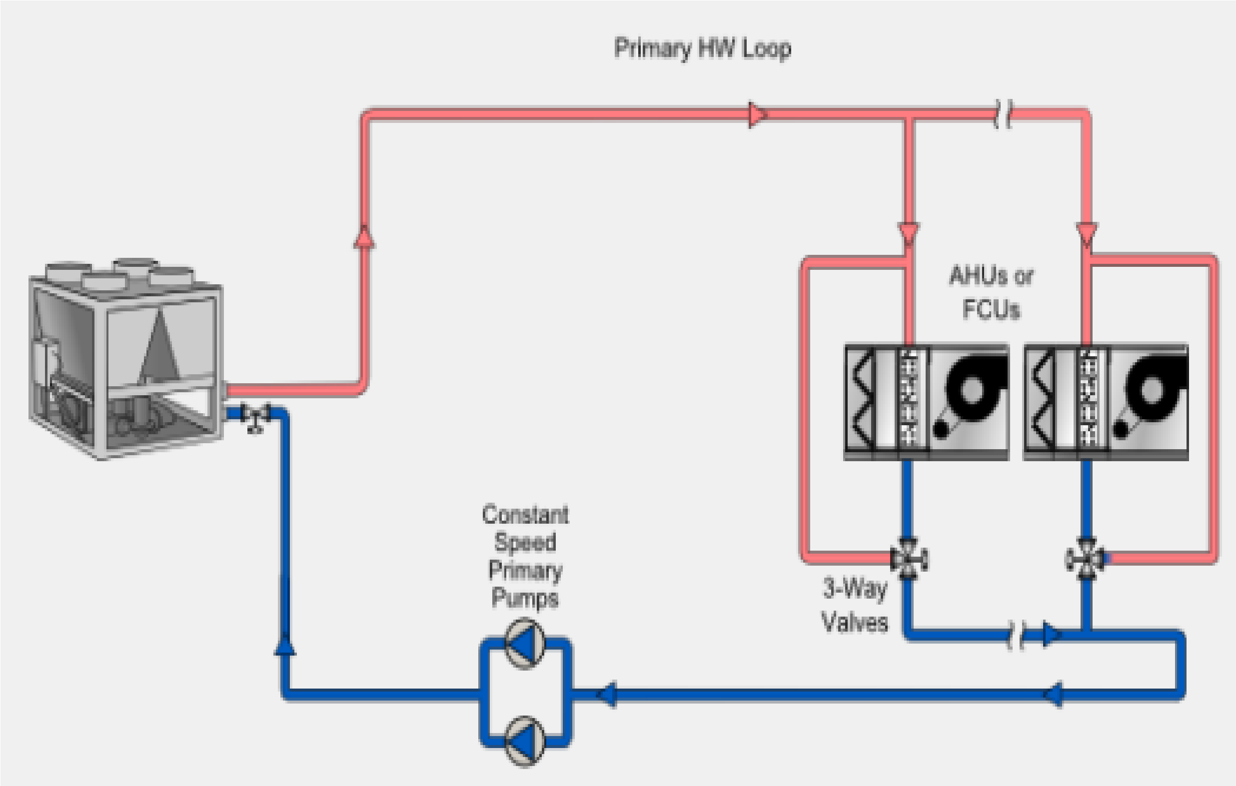
- Higher initial capital costs compared to a cooling tower
- More energy required for same cooling load
- Limited capacity per unit. More space is often needed



Above: Mechanism of an adiabatic cooling system. Water is used to pre-cool the ambient air before its blown onto the condenser coils. Pre-cooling can add 25% more cooling capacity to a dry cooling unit and lower operating (electricity) costs.

Air Cooled Inverter Scrolled Heat Pump Chiller

This system reduces operational costs in the proposed building, while providing more reliable heat in colder regions. The system's advanced rapid start feature enables the compressors to turn on faster to meet startup load. Without a cooling tower, condenser pump, and other parts, an air-cooled chiller requires less maintenance than other systems with a more complex component structure. By removing the cooling tower and hot water boiler, it is possible to save energy in an air-cooled heat pump chiller. In addition, the inverter technology can provide better cooling and heating performance regardless of cooling and heating demand without a separate cooling tower and hot water boiler.



PROS:

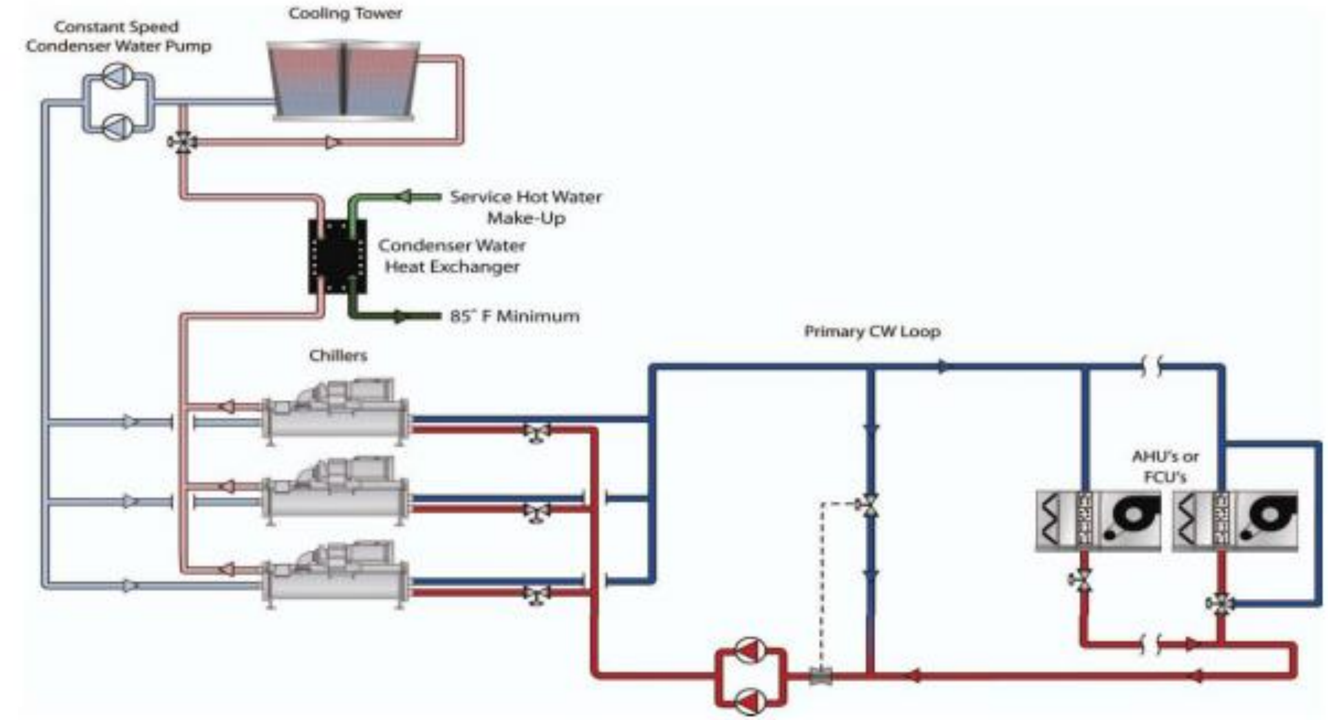
- Energy efficient
- No evaporative water loss
- Excellent for replacing existing heat pumps with cooling tower
- Can be scaled up

CONS:

- Higher initial capital costs

Waste Heat Recovery

Waste heat recovery systems are increasingly used in mixed-use buildings to move waste heat from hospitals, data centers, large hotels, or industrial activities to provide beneficial heating in other parts of the building. Recovering waste heat becomes an attractive option for facilities working to achieve low energy use (such as net zero energy or high-performance buildings) and to reduce emissions. These systems also can save water by reducing the heat load sent to an open cooling tower.



PROS:
- Can reduce energy consumption
- Can reduce water consumption
- Can reduce carbon emissions
- Can reduce total utility costs

CONS:
- Best suited for new construction
- Some higher upfront costs

Effluent Cooling

Condenser water that would typically go to a cooling tower would instead be piped into a heat transfer box filled with the property's effluent (liquid waste/sewage). The water and effluent never mix, but some heat is absorbed by the relatively cooler effluent surrounding the condenser fluid. Before the raw effluent enters the heat transfer box, it is first macerated by the unit to ensure normal flow.

PROS:
- Can replace the use of a small cooling tower
- Can reduce heat load sent to any cooling tower
- Can tap into existing wastewater pipe on property
- Can reduce energy consumption.

CONS:
- Significant re-plumbing can be required.
- Sewage composition is complex and can cause scaling of heat exchanger.

Thermal Storage

In the typical full thermal storage system, the refrigeration system (chillers) generates ice at night when electrical utility rates are typically lowest (off-peak). During the day, when utility rates are higher (on-peak), the ice melts to provide cooling to the building.

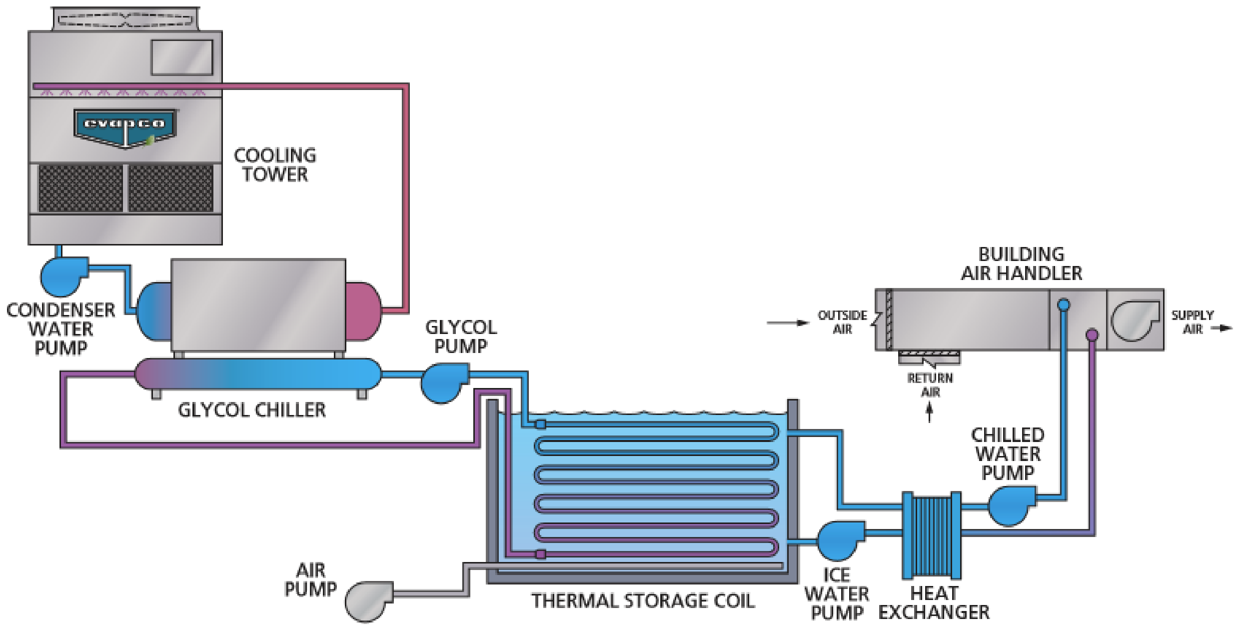
In the partial thermal storage system, a reduced size chiller or refrigeration system operates in conjunction with the ice storage to meet the peak cooling loads. There are several types of partial storage systems whose application is dependent on building loads, system equipment and energy costs. However, many partial storage systems are used to “shave off” peak energy demands to reduce operating costs.

PROS:

- Reduction in energy costs
- Increase in reliability
- Can reduce water consumption
- Can be used with an air-cooled chiller

CONS:

- Higher initial capital cost
- Needs space for tank



Thermal Storage System Schematic

Geothermal Heat Pumps

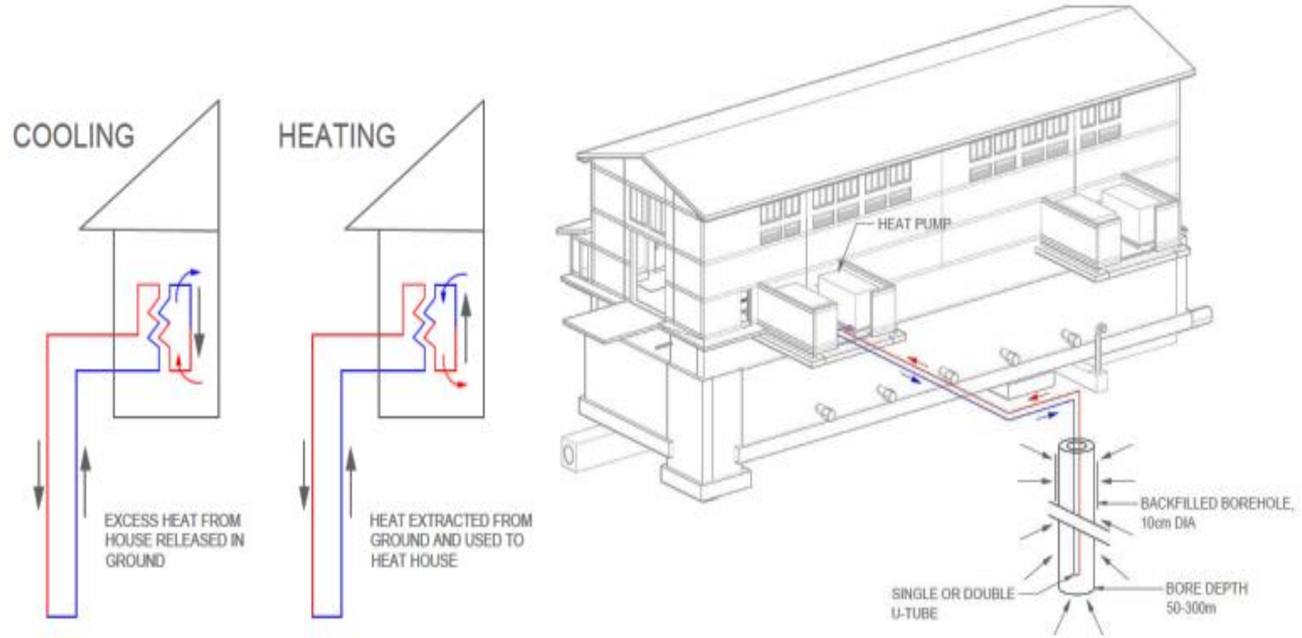
Ground source heat pumps utilize the ground as a heat exchanger to extract or dissipate heat. For this application horizontal trenches or vertical boreholes are required for the installation of the closed loop piping system

PROS:

- Reducing in heating and cooling costs
- Reduction in condenser water heat load via ground heat exchange

CONS:

- Higher initial capital cost
- May require significant changes to landscape



Evaporative Plume Abatement

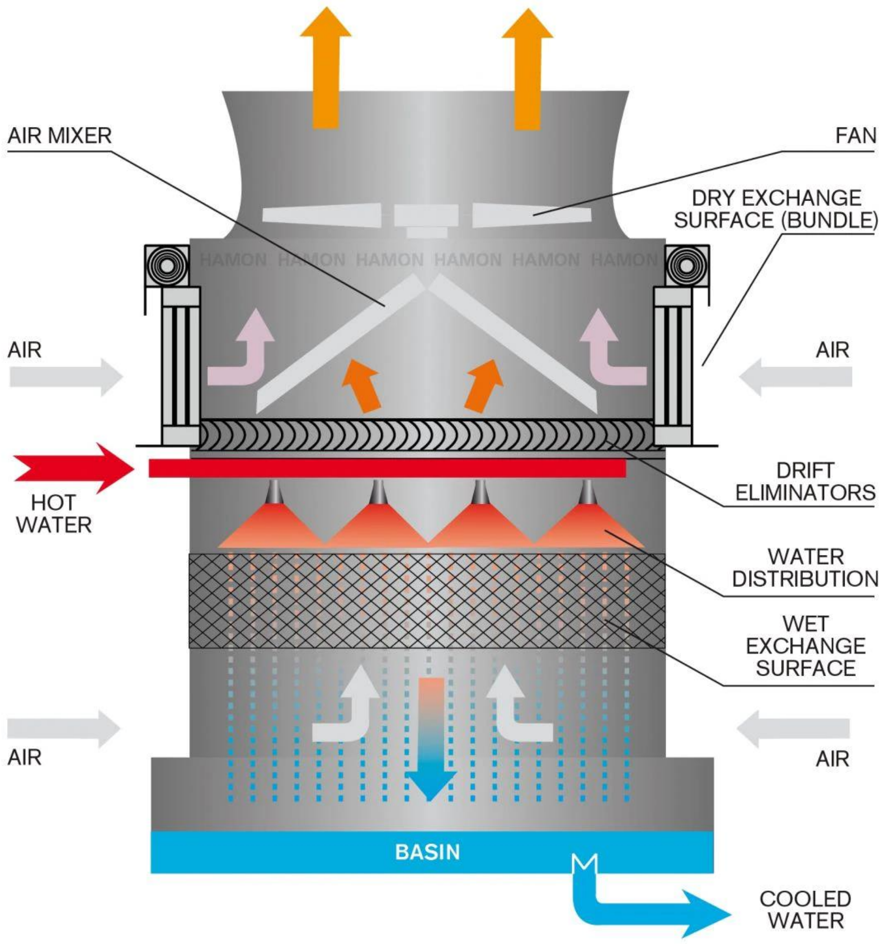
Plume abatement is a technology that captures water vapor from a cooling tower's plume. A plume is formed when the relative humidity of the air leaving the tower is greater than 100%. The excess water vapor condenses into fine droplets that are suspended in the air to form fog, otherwise known as a visible plume. Evaporation from cooling towers is a predominant cause of plume formation. Plume abatement technology cools the plume through an air-to-air heat exchanger to condense the water vapor to liquid water, which is then collected in the tower's basin. An auxiliary fan introduces cooler ambient air across the cooling tower to cool and condense the plume.

PROS:

- Reduces evaporative water consumption from cooling towers
- Infrastructure can be added to existing cooling towers in most cases

CONS:

- Reduces evaporative loss by less than 20% in most cases
- Limited amount of data confirming technology



Radiative Cooling

This technology utilizes specially treated panels that reflect infrared light back into the atmosphere and eventually into Space. The reflective wavelengths are in the infrared spectrum that absorb and then emit radiation. The panels can radiate away enough heat to consistently stay a few degrees cooler than surrounding air; up to 10 °C in hot, dry places.

The system uses no water, minimal energy and produces no noise. So far, theoretical estimates of how much electrical power can be saved have been based on data from small samples tested over short times (there are only three full-size actual installations to date). There are also doubts about the materials' ability to work in a wide variety of climates and places. The cooling effect works best in dry climates and with clear skies.

Ideal for reducing the energy and water consumption from a commercial refrigeration/freezer unit.

PROS:

- Cools process water down using minimal energy and no water
- Requires no water treatment
- No risk of bacteria growth or legionella

CONS:

- Early stages of development; few real-world installations
- Unclear if the technology can be scaled up