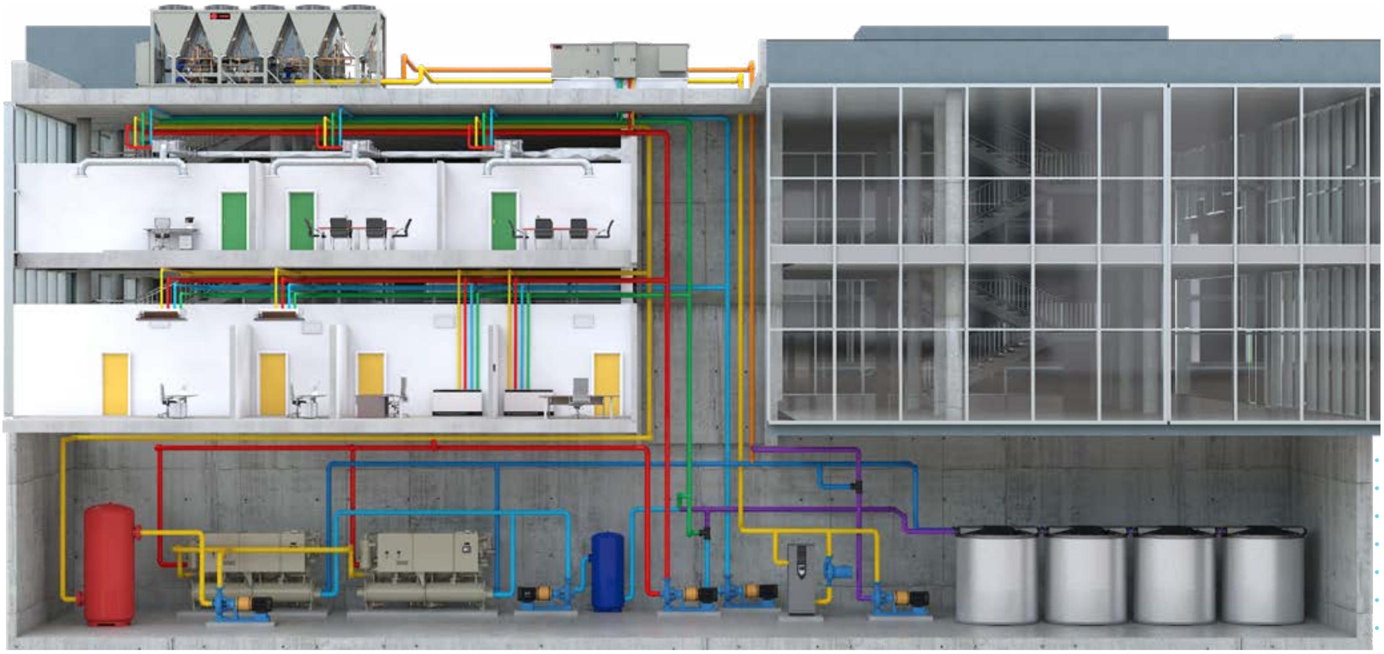


Heating with Ice

By innovating with proven thermal energy storage technology, Trane®
is making heat pump heating practical and reliable for more buildings.

In the quest to decarbonize, electric heat pumps are making their way into a growing number of commercial buildings. This proven technology has become the epicenter for innovation in electrified heating, which can be up to three times more efficient than other forms of electric heating. Compared to heat that is generated by burning fossil fuels within gas furnaces and boiler systems, moving heat with an energy-efficient electric heat pump can be the lower-carbon choice.

> Thermal Battery™ Storage-Source Heat Pump Systems collect and store today's waste energy for tomorrow's heating needs.

New Comprehensive Chiller-Heater Systems Help Fuel the Energy Transformation

Last year, Trane made it easier to specify commercial heat pump solutions for hydronic systems by introducing our Comprehensive Chiller-Heater Systems. The first system in this series, the Air-to-Water Heat Pump System, brought together an engineered combination of air-to-water heat pumps, chiller-heaters and controls. For many buildings, those three components alone can provide a reliable and efficient replacement for fossil fuel heating that helps owners achieve building electrification and avoid carbon penalties.

It is an amazing solution for many applications. Yet, it may not be a fit for some buildings. First, most urban buildings don't have enough roof space available to accommodate big air-to-water heat pumps—in multiple. Second, air-to-water heat pumps have diminishing capacity and lower leaving water temperatures at low outdoor ambient temperatures. And finally, defrost cycles must be accounted for when calculating air-to-water heat pump capacity.

The solution to these issues is ingenious, but the premise is as simple as a high school physics lesson: Heating with ice. Adding thermal energy storage to the Air-to-Water Heat Pump System overcomes these barriers, so more buildings can join the decarbonization movement.

> For decades, HVAC systems have used the ice in thermal energy storage tanks to shift electricity demand to reduce summertime energy costs. Avoiding utilities' peak demand charges can save thousands of dollars every year. Now, Trane's Thermal Battery™ Storage-Source Heat Pump Systems leverage thermal energy storage (or "ice batteries") to deliver even greater benefits during the winter months. New incentives make it financially appealing, too.

Physics 101: Thermodynamics of Ice Heating

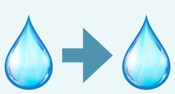
You may already know this, but let's review how ice can be used for heating.

Melting ice is the process of water absorbing and storing massive amounts of heat energy. Changing ice to water stores the thermal energy that was required to melt it.

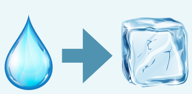
Due to the natural properties of water, a tremendous amount of heat is stored when water changes from its solid phase (ice) to liquid phase (water) at 32°F. That's why when you put ice in a glass, it can keep your beverage cold for so long. (Cheers to thermodynamics!)

Water's Phase Change

1 wood match ~ 1Btu. One British thermal unit (Btu) is the amount of heat energy that will raise the temperature of one pound of water by 1°F.



No phase change: One pound of water releases 1 Btu of energy when its temperature drops by 1°F (33°F – 32°F).



With phase change: One pound of water releases 144 Btus of energy when it changes from liquid phase (water) to solid phase (ice), but it stays at the same 32°F temperature.

Trane's most popular thermal energy storage battery holds 13,812 lbs. of water. **It can store and release two million Btus!**

(13,812 lbs. of water x 144 Btus = 2,000,000 Btus)

Each thermal battery holds Btus of heat equivalent to:

- **14 gallons** of fuel oil
- **2000 lbs.** of steam
- **20 therms** of natural gas

When the tanks are fully melted, the liquid water is a very potent heat source, surrounding a massive surface area heat exchanger. It is now a perfect energy source for a high-efficiency chiller-heater heat pump.

AS ODD AS IT SOUNDS, MELTING ICE IS ACTUALLY STORING "HEAT" ENERGY.

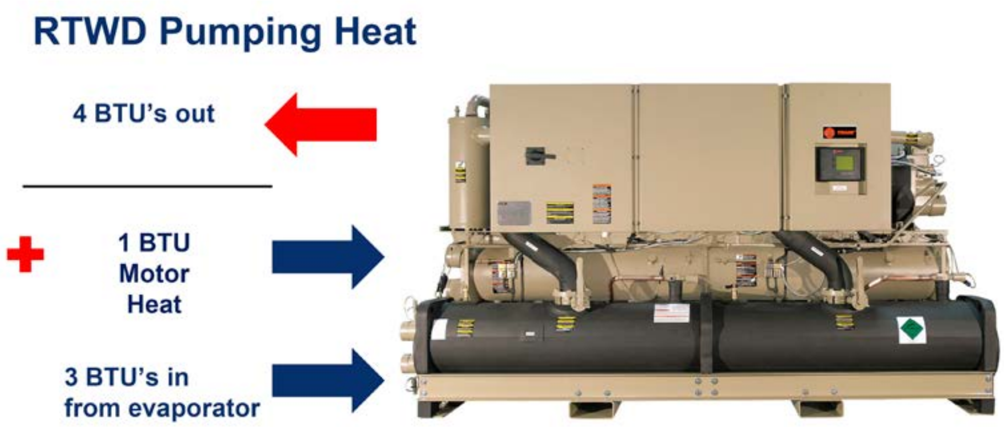
Thermal Battery™ Storage-Source Heat Pump System

Trane's Thermal Battery Storage-Source Heat Pump System is a four-pipe hydronic cooling and heating system that provides conditioned fluid to coils or other loads within a building. Generally, systems of this type are used in medium- to large-sized buildings. It uses conventionally designed, variable-flow cooling and heating distribution loops. Like any heat pump system, it benefits greatly from an optimized hot water supply temperature in the range of 95°F to 110°F, although higher temperatures are achievable.

The system has four main components with thermal energy storage being the unique differentiator. As a single-source solution, Trane maintains control over equipment quality and takes responsibility for maximizing the system's operational benefits.

Chiller-Heater

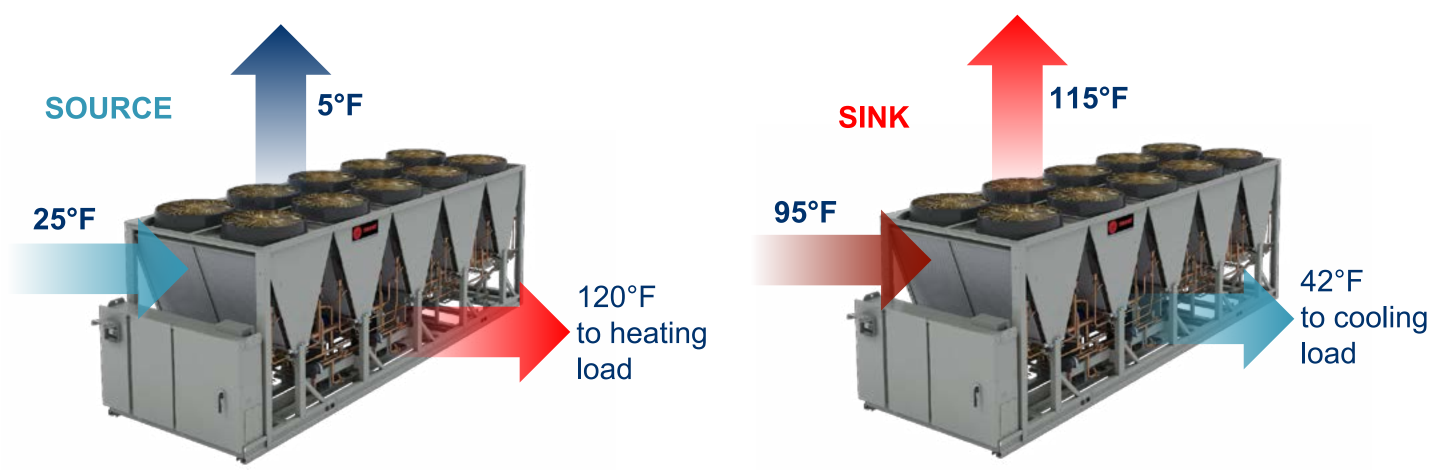
Chillers are a type of water-to-water heat pump. They can only move heat in one direction. A chiller recovers heat from zones within the building that have accumulated excess heat. During the winter, it reuses that extra heat by moving it into zones that need warming (perimeter spaces). If there is excess heat that is not needed in the building at that time, it can be stored and used for the next morning's warm-up, instead of being expelled as waste heat. This heat recovery is possible whenever there is thermal storage in the system.



Trane® RTWD chiller-heater.

Air-to-Water Heat Pump

Generally located on building rooftops, these units can move heat in two directions, depending on the season. They can absorb "warmth" from outdoor air for heating use or reject excess heat from the building into the outdoor air to cool interior spaces. Capturing heat from outdoors is counterintuitive. However, while it may not feel warm outdoors in Minneapolis in January, there is still plenty of heat in that very low temperature air. The air-to-water heat pump extracts that heat and raises it to a usable temperature level for immediate building heating. If the building is already warm enough, the thermal energy storage tanks can absorb the heat by melting ice. That energy is now captured and stored for later use, generally in the morning before interior heat has accumulated.



Trane Ascend® Air-to-Water Heat Pump, Model ACX. A heat pump with a reversing valve allows the evaporator and condenser to switch roles by reversing the flow of refrigerant within the circuit.

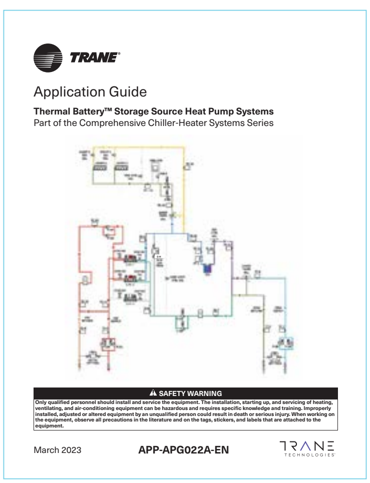
Thermal Energy Storage

Also known as ice tanks or thermal batteries, thermal energy storage interacts with the chiller-heater and heat pump to capture and release stored heat energy. Each tank is filled with water (which never leaves the tank) plus three miles of plastic tubing containing a glycol/water solution that carries and moves the heat. The chiller-heater moves the heat into and out of the storage tank.

The water in the Ice Bank® energy storage tank simply changes from its "low energy" ice phase, to its "high energy" water phase.

Controls

Trane programs the control sequences which coordinate interactions between system components and the building environment to optimize comfort and energy efficiency year-round. Programming establishes operational rules for coordinating the system's three heating sources: heat that is reclaimed from the building, heat that is collected from the outdoor air and heat that is released from the thermal battery.


TRANE

Application Guide

Thermal Battery™ Storage Source Heat Pump Systems
Part of the Comprehensive Chiller-Heater Systems Series

SAFETY WARNING

Only qualified personnel should install and service the equipment. The installation, starting up, and servicing of heating, ventilating, and air-conditioning equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. When working on the equipment, observe all precautions in the literature and on the tags, stickers, and labels that are attached to the equipment.

March 2023 **APP-APG022A-EN** TRANE TECHNOLOGIES

Easy to specify and implement

Guidance on equipment sizing, system configurations, operating modes and control sequences for reliable operation help meet your application requirements.

Overcoming Six Heat Pump Challenges

The Trane Thermal Battery™ Storage-Source Heat Pump System solves many heat pump application challenges. As a result, this innovation is opening more doors to decarbonization by removing market barriers, improving performance, and adding flexibility that maximizes the environmental benefits.

Challenge 1: Thermal Balancing During the Heating Months

Heating loads in buildings usually peak in the early morning, whereas cooling peaks generally occur in the afternoon. So, there is a mismatch between when extra thermal energy exists and when it is needed.

Adding thermal energy storage to the system helps solve this disparity. In conventional HVAC system designs, if a building has zones that overheat in the winter, cool outside air is brought in and the hot inside air is rejected outdoors. This is a familiar process known as "free cooling." In a way, this is an intentional waste of heat since fossil fuel heating is still being used at other times that same day. With thermal energy storage, instead of wasting that heat (via free cooling), the ice tank can cool the space in the afternoon, just as it would during the summertime. But now the goal is to have as much water in the tanks at the end of the day as possible. The tanks store the reclaimed heat energy in the cold water. Whenever there is a call for heating in the building, the chiller-heater removes the energy from the water (making ice) and pumps it to adjust for the required temperature to heat the building.

So, by using thermal energy storage, the system collects today's reclaimable energy for tomorrow's heating.

Understanding Carbon-Free Heat Sources

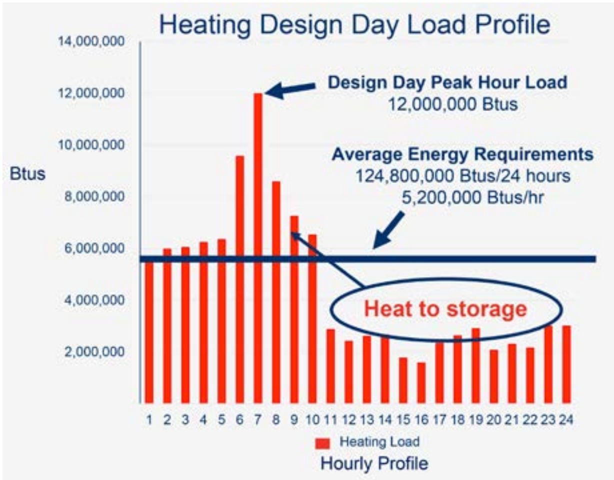
If the HVAC system doesn't have a way to generate its own heat (such as a boiler system), how can it possibly keep spaces evenly warm in all temperatures? Well, occupied buildings naturally generate a lot of their own heat during daytime hours. Those internal heat gains come from a number of sources including metabolic heat generated by the activity of occupants, thermal heat gains generated by computers and lighting and heat from waste, exhaust air, or domestic hot water piping. In perimeter zones, glass curtain walls essentially become huge solar collectors during the day in the winter. All these energy sources can be captured and reclaimed to charge the thermal battery.

Challenge 2: Urban Scaling for Outdoor Heat Pumps

Lack of rooftop space is one of the biggest barriers to using heat pump systems in urban settings with high building density. Heat pumps are big, and large buildings require multiple units. Many buildings have rooftop space and weight limitations. Using thermal energy storage with heat pumps reduces the space requirements. That's because adding storage may provide flexibility in design to reduce the air-to-water heat pump capacity size. Rather than having to design the heat pump to meet the peak hour load of the coldest day of the year, the energy load requirements can be spread out over a 24-hour period.

The peak heating hour requires 12,000,000 Btus. It would take 10 air-to-water heat pumps to meet this load demand. However, considering a 24-hour total design day load, the energy could be collected from the outdoor air with only 5.2 million Btus worth of air-source heat pumps.

In other words, by storing heat in thermal energy storage tanks, the number of air-to-water heat pumps can be cut in half, thereby reducing the rooftop space requirement.



Challenge 3: Maintaining Performance in Colder Climates

Air-to-water heat pump efficiency and capacity drop substantially as ambient temperatures drop, approaching the equipment's operational limit at around 0°F. Using chiller-heaters, thermal energy storage and air-to-water heat pumps together can provide a substantially broader operating map. If the outdoor ambient temperature is below the operational limits, the system can draw from the stored heat. Waiting until it is warmer outside to collect heat from outdoor air also helps to gain better efficiency and more capacity from the air-to-water heat pump.

Thermal energy storage provides flexibility to optimize the system design. Whether storage is used to avoid running the heat pump during extreme cold temperatures, or to collect energy when the grid produces less expensive electricity (or low-carbon energy) the building owner's priorities can be optimized. This flexibility of load is exactly what the Department of Energy's new Grid-Interactive Efficient Building Program (GEB) states is key to a low-carbon future.[1]

1. Grid-Interactive Efficient Buildings, Office of Energy Efficiency & Renewable Energy. (ENERGY.GOV)

Challenge 4: Managing Peak Electrical Demand During Winter

Heat pump heating alone is possible in many places, but the cost of electricity to run it can get expensive, especially during on-peak demand times. Adding thermal energy storage provides the flexibility to avoid running air-to-water heat pumps when the cost of electricity is highest, which means building owners may help to lower their overall operating costs.

Challenge 5: Comparing Costs vs. Gas Boilers

System designers generally recognize that, in new construction, the cost of a cooling-only applied system with thermal energy storage can be nearly the same as the cost of a conventional system without thermal storage. Why? Because thermal storage may reduce the number of required chillers. Money that would have been spent to purchase more or larger chillers may help to offset the installation costs of thermal energy storage.

Similarly, thermal energy storage reduces the number of required heat pumps. Combined, heat pumps and thermal energy storage can replace boilers. And remember, while the installed cost of gas-fueled heating systems may be less per energy unit, they need to have twice the capacity. Plus, thermal storage tanks now get double the mileage: the same tanks can be used to gain energy cost savings for summertime cooling and wintertime heating.

Eligible for new tax incentives. Up to a 40% tax credit through the Inflation Reduction Act is now available that could make payback on thermal energy storage projects instantaneous. Learn more in our recent article "The Trane Thermal Battery™ System: What It Is, Why You'd Want It and How the Inflation Reduction Act Can Help Pay For It"

Challenge 6: Maximizing Electrification Benefits

Carbon is the deciding factor. Even with the sizing difference, fossil fuel combustion heating systems may still be less expensive to install. However, that shouldn't be the only consideration. Remember, Storage-Source Heat Pump Systems provide dramatic carbon advantages that can never be achieved by buildings that continue to burn fossil fuels.

Unfortunately, heat pumps still meet only around 10 percent of the global heating need in buildings.[2] To get to net zero emissions by 2050, heat pump stock will need to almost triple by 2030 to cover at least 20 percent of global energy needs.[3] Innovation like ice heating will be key to meeting these targets.

Key Takeaways

To sum it all up, many more buildings will be able to achieve decarbonization goals due to the practicality of the overall Thermal Battery Storage-Source Heat Pump System.

All-electric cold climate heating. Unlike conventional heat pump systems, Thermal Battery™ Storage-Source Heat Pump Systems provide added operational flexibility for cold climates. With proper system control, we can heat effectively, efficiently, and affordably under a wide range of conditions. Thermal energy storage gives buildings the flexibility to collect and store reclaimable waste heat and utilize the lower cost, lowest carbon energy from the grid.

Zero-carbon future. A building that continues to burn fossil fuels for heating can never be carbon free. However, as the grid increases its use of renewable carbon-free energy sources, buildings that electrify heating will have a lower-carbon future. Thermal energy storage allows more buildings to use carbon-free electricity from the grid for cost-efficient heating that reduces emissions coming directly from the building itself. For buildings with solar panels, thermal energy storage can use electricity directly from the onsite renewable energy source.

Reliability. Thermal energy storage can back up air-to-water heat pumps. Depending on the system and building, they may provide 12 to 24 hours of stored energy that can be used for heating or cooling, depending on the season.

Versatility. Storage-Source Heat Pump Systems eliminate the need for separate heating and cooling systems. The same equipment is used to deliver energy-efficient, electrified cooling and heating—with the year-round advantages of grid responsiveness to avoid peak demand charges.

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2. Heat Pumps, iea, (Web)
3. Installation of about 60 million heat pumps covering 20% of buildings' heating needs required by 2030, IEA Technology Report, September 2022. (Web)

It’s All Easier Than You Think

Before long, engineers may find it’s no more difficult to specify a Thermal Battery Storage-Source Heat Pump System than the other applied systems more commonly used today. Engineering support is currently available within Trane Design Assist™. Financial factors will almost always weigh on decision making, and your Trane Account Manager can provide detailed cost comparisons against various system types using our Trane® First Pass analysis tool. We can provide data on first costs, utility savings and carbon savings to help you and your customers make the best decisions for long-term benefits.

Change is easy when innovation provides so many advantages. Decarbonization regulations have inspired an innovative solution that provides dramatically lower carbon intensive HVAC systems by reclaiming “free heat.” By repurposing existing thermal energy, a building can capture and reuse all its waste heat. We’ve been using ice-based thermal energy storage in HVAC systems for cooling for decades. Now, we’re using the basic principles of thermodynamics to use the same ice tanks for heating.

Learn more at **trane.com/sshp**

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