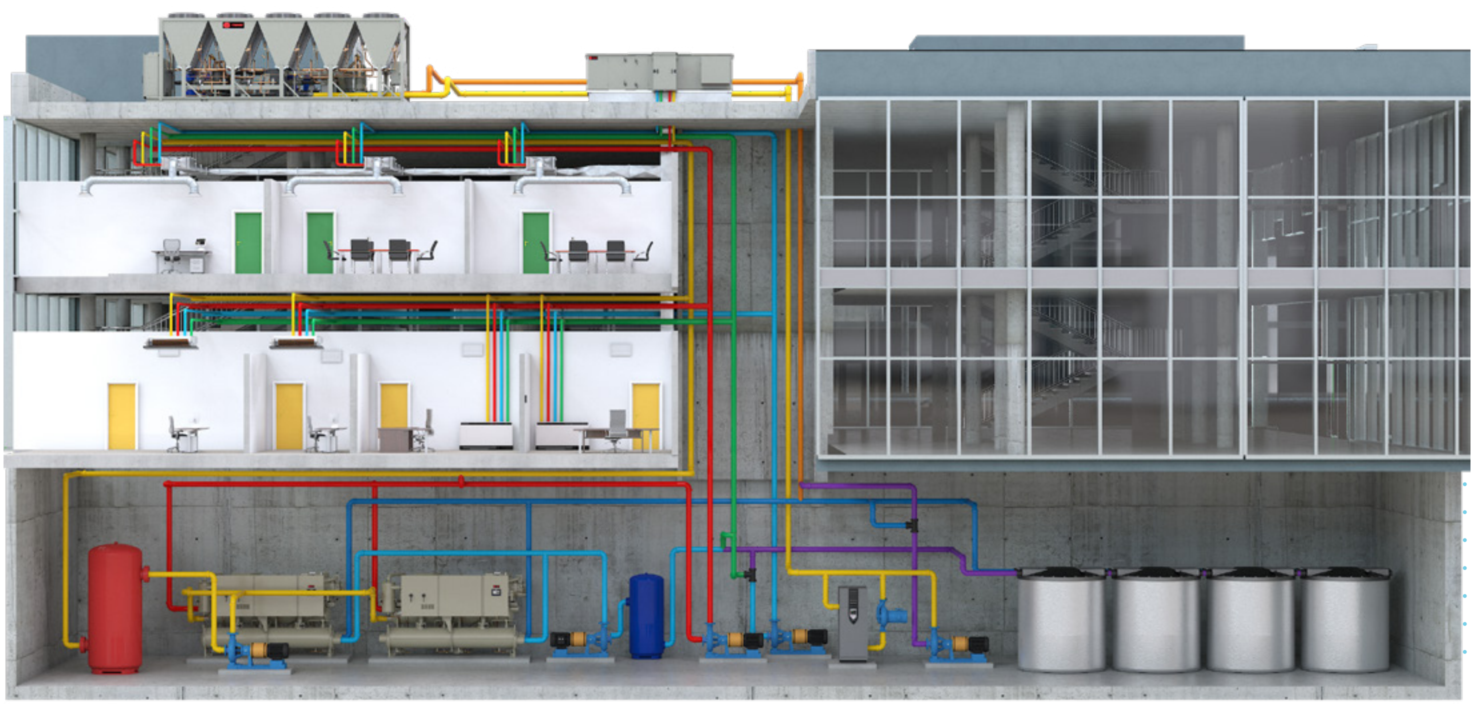
PRODUCT REVIEW

TRANE

Thermal Energy Storage Increases Heat-Pump Effectiveness

Combining water-source heat pumps and ice-based thermal storage creates a “battery” that can provide all-electric heating and cooling, even in cold climates. And it qualifies for IRA funding.

by Brent Ehrlich



Trane’s SSHP system uses thermal energy storage tanks to increase the usefulness of TES, as well as the air-to-water heat pumps.

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When we think of **the future of all-electric buildings**, two technologies tend to rise to the top: heat pumps and batteries. Heat pumps are now ubiquitous for providing heating and cooling, and lithium-ion batteries have become increasingly popular. Alone, the two technologies can work great, but each has limitations. There are challenges with heat pumps in cold climates and in dense urban areas that don't have space for them; and current battery technology is expensive, has safety concerns, and is not typically used with large HVAC systems.

There are other ways to store energy, and one of them—thermal energy storage (TES) using tanks—has been used for decades to provide cooling.

Typically, TES makes ice during non-peak hours, storing the energy used to make the ice at night so it can supply cooling during the day. **BuildingGreen** covered TES in 2011.

Adding heat pumps to this type of system allows them to be used for heating, increasing their applications, effectiveness, and efficiency. Known as packaged storage source heat pump (SSHP) systems, these heat pumps that integrate TES storage tanks have the potential to optimize both technologies, and Trane is now offering them as a package under the name Thermal Battery SSHP systems. Let's take a look at how these systems work and their potential future in **all-electric buildings**.

System basics

Trane's Thermal Battery Storage-Source Heat Pump Systems can provide both heating and cooling using:

- Air-to-water heat pumps that transfer outdoor heat that can either be used to heat the building or incorporated with TES tanks to store energy for later use.
- A chiller-heater (non-reversible heat pump) that recovers heat from the water to provide the building's heat. It does this by "lifting" the heat energy in the water to a usable temperature. This component is available with R-513A refrigerant, which has global warming potential of 573, compared to 1,430 for R-134a.
- Calmac's (now owned by Trane) Ice Bank thermal storage tanks, which store waste heat in the form of cold water for later use (explanation below).
- The company's Tracer Controls, which "balance multiple priorities: reliability, carbon reduction, efficiency, and energy cost savings during heating, cooling, and energy storage," according to the company.

Refrigerant loop basics

Cooling systems (**including heat pumps**) typically use a vapor-compression cycle. In these systems, a refrigerant moves energy through a loop that includes heat exchangers on the hot and cold sides, a compressor, and an expansion valve. During air conditioning with an air-source heat pump, for instance:

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Thermal battery

The nuances of thermal storage using refrigeration to create ice are complicated, and thinking of TES tanks as "batteries" is in some ways counterintuitive. For standard TES systems, it's easy to think of the ice made during off-peak hours as a battery of sorts, storing that energy as ice, but it isn't the ice itself that is storing the energy: it's the phase change from water to solid and back that does it. Heat pumps can exploit that phase change for greater efficiencies. How does that work?

According to Mark MacCracken, P.E., in the ASHRAE technical feature **Electrification, Heat Pumps, and Thermal Energy Storage**, a fully burned wooden match releases about 1 Btu worth of energy and can raise the temperature of a pound of water by 1°F (say, from 32°F to 33°F). But it takes 144 matches to melt the equivalent pound of ice as it changes phase from solid to liquid at 32°F. "So as odd as it sounds, melting ice is actually absorbing, and storing, massive amounts of energy," MacCracken explains in his paper. According to Trane, each Ice Bank storage tank contains 1,655 gallons of water (13,812 pounds), so at 144 Btu/lb., each can store almost two million Btu.

How can this process be used for heating? According to Rick Heiden, HVAC systems development engineer at Trane, a simple analogy is an ice maker. You extract heat from water to make ice. If you capture that heat in a water stream, it can heat the building. When that ice melts, it can be used to cool items, including the building. “The air-to-water heat pump balances that,” he said.

In summer, standard TES systems use the energy in this process by making ice at night—rejecting the excess heat using cooling towers—to provide cooling during the day. What about winter and space heating? Large commercial buildings require cooling of the interior during most of the year to manage heat generated by people and equipment. It is counterproductive to reject “waste heat” in winter and simultaneously use fossil fuels to heat the building perimeter. Instead, Trane’s all-electric SSHP alternative incorporates the heat pump and chiller-heater to move energy back and forth from the core to the perimeter and throughout the building.

Electrification, decarbonization, and heat pumps

“Electrification of heating is one of the pillars of decarbonization,” said Heiden.

The barriers to electrification are dense urban environments (where fitting enough heat pumps can be difficult) and cold climates (where heat pumps are less effective). “The thermal energy-storage tanks shrink the size of the air-to-water heat pumps so they fit better in the urban environment,” he said. “The TES tanks are no bigger than for a cooling load, not much bigger than a chilled-water system with ice,” he added. “In cold weather, the efficiency and capacity of heat pumps starts to decrease when it gets below 40°F,” Heiden continued. “Many buildings will not be adequately heated with that.”

Adding thermal storage extends the temperature range so the system can provide 130°F water all the way down to a –30°F outdoor ambient temperature. This makes the system 1.5 to 3 times better than electric resistance, according to the company.

Options and cost

According to Heiden, basic systems can be designed for any climate zone and most building types. They are also “well suited for public and private commercial real estate, including multi-story office buildings, colleges, universities, and industrial facilities,” he claimed. They can meet building cooling loads up to 20,000 tons or more, including options for auxiliary heat and dedicated heat recovery, he said, with system design tools “available to select and size equipment to meet both thermal loads and carbon-reduction goals.“

Higher-level dual-temperature storage source systems can also be configured. “One such system uses additional chillers and cooling towers in the plant to support DOAS [dedicated outdoor-air system] units on the air-side system,” he said.

Because the size and configurations vary, costs vary as well, but owners can get up to “40% credit for the capital investment in the equipment and the system around it” through the Inflation Reduction Act, making it “one of the lowest-cost HVAC system you could consider putting in a building today,” Heiden claimed.

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