# Environmental Building News™

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# Buildings on Ice
## Making the Case for Thermal Energy Storage

*by Alex Wilson*

LIKE MANY PEOPLE IN THE GREEN building world, I followed the design and construction of One Bryant Park, the high-rise office building in New York City that is being touted as the nation's greenest. The building, likely to achieve LEED Platinum, was designed by Cook + Fox Architects and houses Bank of America offices and the headquarters of co-owner The Durst Organization. One Bryant Park's wide range of green features—from rainwater harvesting and onsite wastewater treatment to optimized daylighting and a planned combined heat and power (CHP) plant—have attracted a great deal of attention.

But it was a feature hidden away in a sub-basement that I went to see recently: the building's thermal energy storage (TES) system. Along with Mark MacCracken, P.E., the CEO of Calmac Manufacturing, which created the system, I entered through the building's temporary scaffolding and slipped through a nondescript door in the lobby, leaving the building's daylit grandeur for a catacomb of hidden hallways and stairways. Escorted by assistant chief engineer Dan Monahan of The Durst Organization, we dropped three floors from street level to a sprawling mechanical room with massive chillers, pumps, color-coded pipes of all sizes, and—what we had come to see—the 44 neatly arranged tanks where ice is made each night and melted each day to help cool the 2.1 million-square-foot (195,000 $m^2$) tower.

Each of the 8'-diameter, 8½'-tall (2.4 x 2.6 m) insulated tanks holds over 1,600 gallons (6,100 l) of water and three miles (4.8 km) of plastic tubing through which 150 gallons (570 l) of glycol solution flows. When the water is frozen at night, each of these tanks holds 162 ton-hours (570 kWh) of cooling capacity, enough to provide cooling for about 10,000–12,000 $ft^2$ (930–1,100 $m^2$) of office space, according to MacCracken.


Photo: © Gunther Intelmann for Cook+Fox Architects

*Calmac IceBank tanks at One Bryant Park, one of the nation's greenest high-rise buildings. The 44 tanks provide about a quarter of the total cooling.*

Like a growing number of buildings today, One Bryant Park is using ice to allow daytime cooling loads to be shifted to nighttime, when electricity costs are lower. We'll see how this practice not only reduces cooling costs but also significantly lowers electric de-

## In This Issue



*Quote of the month:*

**"This is a huge opportunity that continues to be missed."**

– Doug Reindl, P.E., Ph.D., on thermal energy storage

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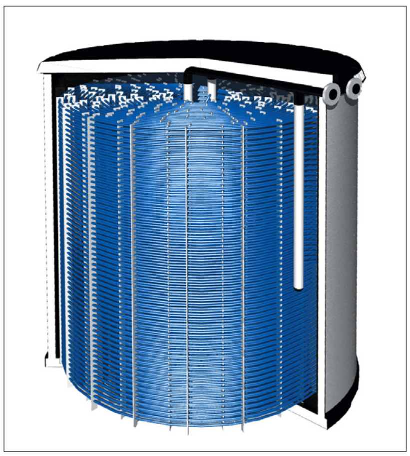
mand charges and in many places reduces both pollution emissions and primary energy consumption.

## Not Really a New Idea

Thermal energy storage for cooling has its origins with our ancestors, who cut blocks of ice from ponds in the winter months and stored it to use for cooling food (and occasionally buildings) in warmer months. In fact, the term *ton*, as used by the HVAC industry, harkens back to the days when cooling was provided by delivering blocks of ice. One *ton* is the rate of cooling that is provided by one ton (2,000 pounds or 907 kg) of ice as it melts over a 24-hour period; it is equivalent to 12,000 Btu per hour (3.5 kW). When mechanical air-conditioning systems were introduced, one ton of mechanical cooling was enough to replace the delivery of one ton of ice per day. A *ton-hour* is a *quantity* of cooling and is equivalent to 12,000 Btu (3.5 kWh).

In the 18th century, ice was shipped from northern climates (where outside temperatures were low enough to freeze water) to warmer climates; it was kept frozen during storage and shipping by packing it in sawdust or other materials. *Iceboxes* in homes were insulated cabinets into which blocks of delivered ice were placed to keep food cold. The same idea was also used occasionally to cool buildings.

In fact, the efforts of Florida physician John Gorrie to keep yellow fever patients cool led to the invention of compression-cycle ice making and refrigeration in the 1840s. Gorrie believed that cooling the air (in effect, "changing the seasons") would cure patients of this fever. Imported ice was placed in a basin suspended from the ceiling, and cool air flowed down over the patients. In an effort to eliminate the dependency on ice shipped from the north, Gorrie began experimenting with methods for producing "artificial ice" and in 1851 was granted a patent for a machine to do so by compressing gases. Gorrie is thus the father of compression-cycle refrigeration and air conditioning, though it was not until Willis Carrier developed a method to remove moisture from the chilled air over 50 years later that compression-cycle air conditioning really took off.



*Each Calmac IceBank tank contains several miles of polyethylene tubing through which a glycol-water solution flows, alternately freezing and melting the water that surrounds the tubing.* Drawing: Calmac

Compression-cycle air conditioning largely eliminated the use of ice for cooling, but TES did not disappear entirely in the early 1900s. Ice storage was used in a few applications by such companies as Baltimore Aircoil and Chester-Jensen to provide rapid cooling for milk on dairy farms and to quickly cool theaters, but these applications were rare.

With the energy crisis in the 1970s, however, companies began looking for ways to reduce energy costs, and TES emerged as an option. Calmac, founded by Calvin MacCracken in 1947, was one of the first companies to look to ice as a load-management strategy for commercial buildings, and the company has installed more than 3,500 such systems since the early 1980s.

Today when we refer to TES, we are usually referring to systems like these, which create ice or chilled water at night and deliver that energy for cooling during the day—the subject of this article. But TES is also used for heat. At least one company in the U.S. (Steffes Corporation in Dickinson, North Dakota; www.steffes.com) produces heating systems that use off-peak electricity to charge high-mass materials (bricks) at night and then deliver that heat during the day. In CHP plants in Northern Europe serving district heating systems, huge insulated water tanks store hot water that is piped into buildings. And much higher-temperature thermal storage is used in a few large, central solar-thermal power plants to store heat so that electricity can be generated when the sun isn't shining.

## Understanding Thermal Energy Storage

The basic principle of thermal energy storage for cooling is very simple. Water is chilled or ice is produced at night, when electricity is cheap, and then becomes the source of cooling energy during the day. Ice is particularly attractive because so much heat is absorbed and released during freezing and melting (referred to as the *latent heat*). Materials can store heat both as *sensible heat* and as *latent heat*. Sensible heat is stored as the temperature of a solid or liquid is changed. Latent heat is stored when there is a change in phase—in this case from liquid to solid or vice-versa.

The latent heat of ice is 144 Btu per pound (330,000 joules/kg), meaning that melting or freezing one pound of ice at 32°F (0°C) absorbs or releases 144 Btu of heat. By comparison, water stores only one Btu per pound for every degree Fahrenheit difference in temperature (4,190 joules/kg·°C), and there will usually be no more than 20°F (11°C) of temperature cycling, so a great deal more cooling energy can be stored in ice than in the same volume of chilled water.

According to the energy information company E Source, the storage density of chilled-water TES is typically between 11–21 $ft^3$/ton-hour (0.09–0.17 $m^3$/kWh), while ice storage offers a storage density of 2.4–3.3 $ft^3$/ton-hour (0.020–0.028 $m^3$/kWh). Eutectic salts (phase-change materials that can be engineered to offer different melting/freezing temperatures) are also sometimes used for thermal storage, but these systems are much less common than others. The storage density of these salts is between that of water and ice.

From a practical standpoint, this difference in thermal storage density means that chilled-water TES usually makes sense only when very large tanks are used, and these usually can't be integrated directly into buildings. Ice storage is much more compact, so it can be installed in buildings relatively easily, as in One Bryant Park. The benefit in saved space and reduced pumping energy outweighs the energy penalty of having to chill water to a lower temperature than is required for chilled water.

There are five primary types of ice-based TES systems in use today. These are described below.

### Ice harvesting

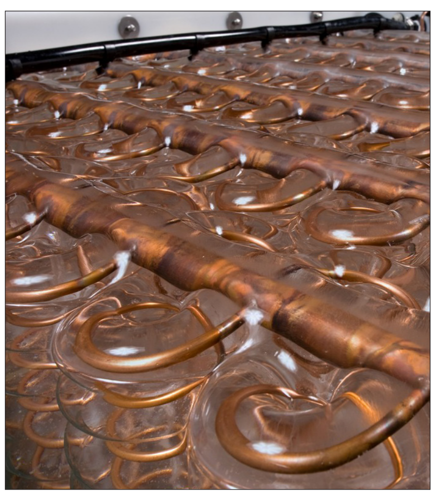
Ice harvesting uses ice produced on an evaporator surface and periodically harvested. The harvested ice is emptied into a water tank from which chilled water is pumped to meet cooling loads. These systems are rarely used today in the commercial-building market.

### External-melt ice-on-coil

With external-melt ice-on-coil TES systems, chilled glycol-water or refrigerant "working fluid" circulates through tubing in a large tank of water, and ice forms on the submerged tubing. Water then circulates through the tank, melting the ice from the outer surface inward. This chilled water is drawn off to serve cooling loads. Large external-melt systems are often used with district-cooling plants.

### Internal-melt ice-on-coil

As with external-melt systems, internal-melt ice-on-coil systems make ice by circulating the working fluid through tubing embedded in water tanks. In this case, however, the working fluid, usually a glycol solution, passes through the tubing during the daytime to deliver cooling to a building's HVAC system. As the glycol is chilled, it melts the ice from the inner surface outward. Either the chilled glycol is used directly for cooling, or it passes through a heat exchanger to transfer cooling energy to water that is circulated through the building. This is the most common type of TES system used in buildings. Internal-melt TES systems can be very large with single tanks, such as systems produced by Baltimore Aircoil and EvapCo; others are fairly small and modular, such as systems produced by Calmac and Fafco. Ice Energy makes such a system adapted to packaged air-conditioning systems.



*Ice build-up is shown on the copper coils in this Ice Bear 30.* Photo: Ice Energy

### Encapsulated ice

With this approach, hundreds or thousands of water-filled plastic containers (nodules) are placed in tanks, and the working fluid freezes and thaws the water in these containers as it flows around them. The chilled working fluid typically passes through a heat exchanger to produce chilled water for the building. The nodules are 3"–4" (80–100 mm) in diameter and made of molded, high-density polyethylene, often with specially engineered "dimples" that allow thousands of freeze-thaw cycles. These nodules are shipped from the factory filled with water and placed in the storage tank.

### Ice slurry

The final option with ice-based TES systems is ice slurry, in which water or a water-glycol solution in a tank is partially frozen into a slurry that can still be pumped directly to cool a space, or pumped through a heat exchanger (common with glycol solutions) to chill water that is used to cool the building.

## TES Compatibility With Different Cooling Systems

Until recently, ice-based TES systems were available only for large buildings with chiller-based cooling. Since the 1980s, thousands of these systems have been installed in a wide range of commercial, institutional, and industrial buildings. According to Commercial Building Energy Consumption Survey (CBECS) data published by the U.S. Department of Energy (DOE), chillers provide cooling for 72.6% of commercial-building square footage in the U.S. Chillers are also generally used for district cooling systems that provide cooling for 11.0% of U.S. commercial-building square footage—and TES supports most district cooling. But until recently, TES was not suited to the 12.5% of commercial-building square footage that is cooled using packaged, direct-expansion cooling.

This may sound like a small segment of the market, but that 12.5% of commercial building space actually includes 95% of the nation's commercial buildings. Most of these are too small to justify chillers, though the number also includes many big-box retail stores and factories that are cooled with rooftop packaged air conditioners. In 2003, the Colorado company Ice Energy made TES applicable to these smaller buildings (see *EBN* Oct. 2005). Instead of producing chilled water for cooling a building, Ice Energy's Ice Bear chills refrigerant that directly expands in the evaporator component of an air conditioner to cool the air.

## Benefits of Thermal Energy Storage

Thermal energy storage offers some important economic and environmental benefits.

### Saving money with off-peak electricity

The most obvious and most-touted benefit of TES is shifting loads from daytime hours, when most cooling loads occur, to nighttime, when electricity demand is lower and costs are often less. According to Paul Torcellini, P.E., Ph.D., of the National Renewable Energy Laboratory, most larger utility companies offer time-of-use pricing for commercial and industrial customers. For these customers, electricity costs during off-peak, nighttime hours can be significantly lower than during daytime peaks. Just how significantly off-peak electricity rates are discounted is highly dependent on the utility company, according to Doug Reindl, P.E., Ph.D., a professor of mechanical engineering a the University of Wisconsin and director of the HVAC&R Center. "The steepness of their off-peak rate discount will very much depend on the disproportionality of their on-peak vs. off-peak aggregate demand," said Reindl. Off-peak discounts are often 30%–50% and can be even greater.

As the utility industry modernizes with features like smart-grid technology, *real-time pricing* (in which hourly pricing is provided by an utility, usually in advance), and *dispatchable* (interruptable) loads, the ability of building owners to manage loads internally will become increasingly important. TES allows a facility manager to respond to a spike in electricity prices by shutting down chillers and cooling with stored ice.

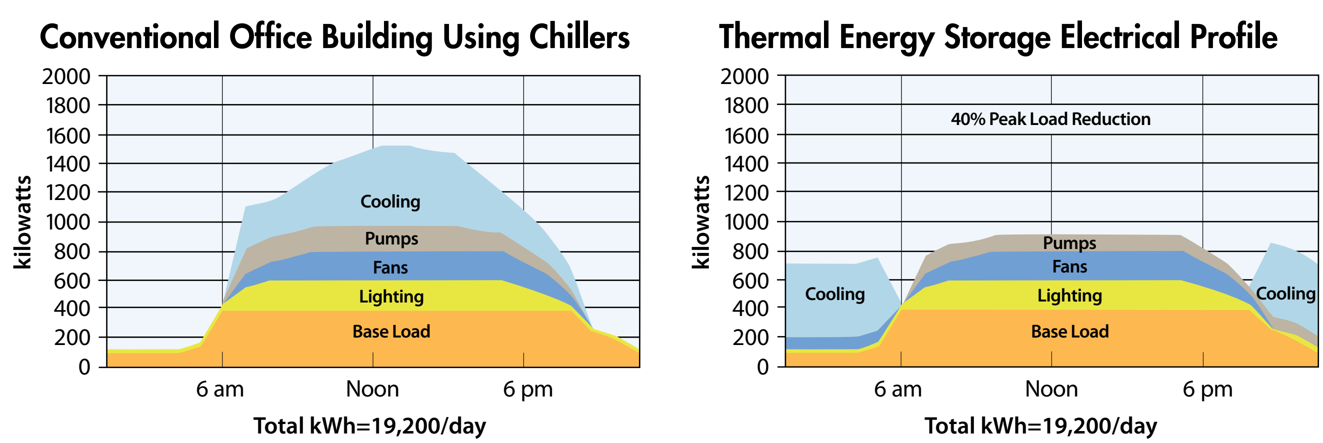
### Reduced demand charges

In most buildings, the *peak* electric loads are a lot higher than the *average* load—often referred to as a low *load factor* (the average electric usage divided by peak demand). Shifting cooling loads from daytime to nighttime can significantly increase the load factor and reduce electric *demand charges*. With commercial and industrial utility customers, demand charges are levied *in addition to* electrical consumption charges; they are based on the peak demand of the building—reasoning that the utility company has to have that amount of capacity available to the building. These demand charges are typically based on the highest electricity demand for 15 or 30 minutes over a given period of time, such as one month. Demand changes typically range from about $10–$15/kW for commercial customers, according to Reindl, to sometimes over $30/kW during peak summer cooling periods. It is typical for demand charges to account for about half of a company's monthly electric bill, according to Torcellini. For a company with a very low load factor, the demand charges can significantly exceed the electricity usage costs.

TES can significantly reduce demand charges for commercial buildings by shifting a large chunk of the daytime electricity use for cooling to nighttime hours, as shown in the figure below. The cooling can be shifted almost entirely to off-peak hours, or just a portion of the load can be shifted to off-peak hours. In either case, there will be a significant reduction in demand charges.

### First-cost savings

TES systems can reduce first costs in several ways. First, they allow




*Thermal energy storage systems shift some or all of the daytime cooling load to nighttime hours, thus reducing demand charges and allowing less-expensive off-peak electricity to be used. Pumping energy can also be reduced.*

Graphs: Adapted from Calmac

chillers or packaged air conditioners to be downsized. For example, if a building's cooling load is 100 tons, it will take as much as 100 tons of cooling to maintain comfort on summertime afternoons. With thermal storage, in addition to considering the cooling load in tons, engineers refer to *ton-hours* of cooling (as noted, this is a *quantity* of cooling, which can be stored in ice).

Cooling is typically required in an office building for about ten hours—7 a.m. to 5 p.m. To provide that 100 tons of cooling for the full ten-hour day would require 1,000 ton-hours. In reality, the amount of cooling required during the day varies, with a lot required to lower the temperature first thing in the morning, then a gradually increasing amount through the morning and afternoon, with the peak in the late afternoon. In an office building with a 100-ton peak cooling load, the total quantity of cooling needed per day might be 750 ton-hours—a 75% *diversity factor* in engineering parlance.

If we know that the total cooling required during the day is 750 ton-hours, a TES system can be sized to satisfy either all of that cooling demand (*full-storage*) or just a portion of it (*partial storage*). With a full-storage TES system, 750 ton-hours of ice would need to be produced at night. Under ideal conditions, to produce that much ice during the 14-hour night would take a 54-ton chiller (750 ton-hours ÷ 14 hours = 53.6 tons). Therefore, by installing a TES system, the 100-ton chiller can be downsized to 54 tons—greatly reducing the first cost of the chiller.

By installing a *partial-storage* TES system, the chiller load can be reduced even further. In a partial-storage system, the chiller is often designed to operate 24 hours per day. It operates during the 14-hour night to produce ice, and operates during the 10-hour day to provide direct cooling. The net result is that the 750 ton-hours of cooling required by the building

## Sampling of TES Equipment Manufacturers

| | |
|---|---|
| Baltimore Aircoil Company<br>Jessup, Maryland<br>410-799-6200<br>www.baltimoreaircoil.com | Baltimore Aircoil Company (BAC), founded in 1938, is the nation's leading manufacturer of evaporative equipment, including cooling towers, evaporative condensers, evaporators, and large ice thermal storage systems. Thousands of the company's Ice Chiller internal-melt, ice-on-coil TES systems have been installed worldwide. |
| Calmac Manufacturing Corp.<br>Fair Lawn, New Jersey<br>201-797-1511<br>www.calmac.com | Calmac pioneered modular, internal-melt, ice-on-coil TES in the 1970s and has over 3,500 systems in operation worldwide. Cylindrical IceBank tanks are available in various sizes with capacities of 45–500 ton-hours (158–1,758 kWh) are ganged to satisfy the building load. |
| Chester-Jensen Company<br>Chester, Pennsylvania<br>800-685-3750, 610-876-6276<br>www.chester-jensen.com | Founded in 1914, Chester-Jensen was an early pioneer in ice chilling for the dairy industry. The company makes ice-harvest and external-melt ice-on-coil TES systems for a wide range of primarily agricultural applications. |
| Cristopia Energy Systems<br>Vence, France<br>+33-0-4 93 58 4000<br>www.cristopia.com | Cristopia manufactures spherical nodules for encapsulating eutectic salts used for TES. The 3.0" and 3.9" (77 and 98 mm) nodules are made of a blend of polyolefins that can provide storage temperatures between -27.4 and 80.6°F (-33 to +27°C). |
| Cryogel<br>San Diego, California<br>858-457-1837<br>www.cryogel.com | Cryogel manufactures Ice Ball water-filled spheres for encapsulated TES systems. The 4"-diameter (100 mm) polyethylene Ice Balls are dimpled to allow freeze-thaw without damage. A glycol solution circulates around the Ice Balls, freezing (or melting) the water (ice). |
| Dunham-Bush<br>Harrisonburg, Virginia<br>540-434-0711<br>www.dunham-bush.com | Dunham-Bush is a chiller manufacturer offering integrated Ice-Cel internal-melt, ice-on-coil TES. |
| Evapco<br>Taneytown, Maryland<br>410-756-2600<br>www.evapco.com | Evapco's Extra-Pak Ice Coil ice-on-coil TES systems can be configured as either internal-melt or external-melt. They typically rely on large field-constructed concrete tanks. |
| Fafco, Inc.<br>Chico, California<br>800-994-7652, 530-332-2100<br>www.fafco.com | Founded in 1969, Fafco is the largest U.S. manufacturer of solar collectors for pool heating. The company adapted its polymer heat exchanger used for solar pool heating to its IceStor internal-melt ice-on-coil TES in the 1980s and has about 2,000 of these cooling systems in place. |
| Girton Manufacturing<br>Millville, Pennsylvania<br>570-458-5521<br>www.girton.com | The company's thermomaster line of King Zeero Ice Builders external-melt, ice-on-coil TES systems was introduced in 1978. |
| Applied Thermal Technologies<br>San Marcos, California<br>800-736-5083, 442-744-5083<br>www.hydromiser.com | This company manufactures Hydro-Miser Ice Storage Chiller systems, which rely on external-melt, ice-on-coil TES systems. |
| Ice Energy<br>Windsor, Colorado<br>877-542-3232, 970-545-3630<br>www.ice-energy.com | Ice Energy's Ice Bear system is the only TES system designed to work with packaged, direct-expansion air-conditioning equipment. The Ice Bear can be coupled to a 3–5 ton air conditioner and can store up to 30 ton-hours (100 kWh) of cooling. |
| Sunwell Technologies<br>Woodbridge, Toronto, Ontario<br>905-856-0400<br>www.sunwell.com | Sunwell is the largest producer of ice-slurry systems. Most of its business is fisheries and food-processing in a related, but ice-slurry TES systems are also produced. |
| Paul Mueller Company<br>Springfield, Missouri<br>800-683-5537, 417-575-9000<br>www.muel.com | Paul Mueller manufactures the MaximICE Ice Slurry System as well as Avalanche Ice Harvester/Chiller and ice tank. Both of these TES systems can be used for cooling buildings or process-cooling needs. |


*Ice Energy's IceBear works with a packaged air conditioner, while most TES systems require a chiller.* Photo: Ice Energy

can be spread over 24 hours, so the chillers can be downsized to just 32 tons (750 ton-hours ÷ 24 hours = 31.25 tons). In reality, various other factors come into play, so the chillers can't be downsized quite this much, but 35%–50% reductions are common, according to MacCracken. Smaller chillers save money, and the smaller TES system (compared with the full-storage option) is also less expensive.

Further first-cost savings are often realized by decreasing the size of ducts, pumps, fans, cooling towers, and power-supply infrastructure. The smaller ducting is possible in part because ice-based TES systems typically deliver cooler air. In some cases, these reduced duct sizes can reduce floor-to-floor height. The *Cool Storage Technology Guide*, published in 2000 by the Electric Power Research Institute (EPRI), suggests that "the floor-to-floor height can be reduced by 4" (100 mm) when the supply air temperature is reduced from 55°F (13°C) to 45°F (7°C)," as is typical with ice-based TES systems. By reducing structural and envelope costs, this height reduction can cut total construction costs by 3%, according to EPRI.

In new construction, it is not uncommon for the first-cost savings in chillers and other equipment to entirely pay for the TES system, according to MacCracken, so that the operating cost savings are achieved at very little—or even zero—additional upfront cost. In retrofit applications, costs of TES are higher, but the payback of that additional investment will still be relatively short—three to seven years, according to MacCracken.

## Higher efficiency?

One might expect lower efficiency from TES systems. Anytime you're storing electrical energy in a different form (ice in this case), there will be conversion efficiency losses, and there should be a penalty by forcing a chiller to work harder to cool the storage medium to below freezing temperatures. However, those losses are offset (at least partially) by gains in efficiency elsewhere. By operating chillers or packaged air conditioners at a constant output level, cycling losses are eliminated. Most air-conditioning systems operate at peak efficiency only about 25% of the time, according to Calmac. During ice making, the chillers or air conditioners operate at peak efficiency throughout their operation.

Operating at night when outside air temperatures are cooler also improves chiller or air-conditioner efficiency. Ice Energy, the Colorado-based manufacturer of the Ice Bear TES system for smaller, packaged rooftop and split A/C systems, claims that in climates with large diurnal temperature swings, such as the western high-desert states, the efficiency of the compressor operating at night will more than compensate for losses in system efficiency, so that the total efficiency of the air conditioner with TES can actually be higher than if the air conditioners were working during the daytime without TES.

Even when an ice storage system increases kilowatt-hours of electricity used by the building, the shift to off-peak electricity may improve the *source-energy* efficiency. This could happen, for example, if more-efficient baseload power is used at night, while less-efficient peaking plants are used to meet daytime peaks. This potential benefit of TES is highly specific to the source-energy mix of the utility company whose power is used. In California the 1996 report *Source Energy and Environmental Impacts of Thermal Energy Storage* by the California Energy Commission (CEC) found that a shift to off-peak electricity saves a significant amount of source energy. Depending on how the savings are measured, the report found 8%–30% savings in the Pacific Gas & Electric territory and 12%–43% in the Southern California Edison territory.

## Reduced pollution emissions

Off-peak electricity generation is cleaner than peak energy, at least in some areas. The same CEC report quoted above argues that peaking power plants that have to be fired up during the day are dirtier than baseload power generation systems that operate 24 hours per day. A 2005 report conducted in the Sacramento Management Utility District (SMUD) by $E^3$ Ventures of Golden, Colorado, for Ice Energy, examined nitrous oxide (NOx) emissions during peak-demand hours (11 a.m. – 7 p.m.) with NOx emissions during off-peak hours (10 p.m. – 6 a.m.). They found that emissions drop from 0.603 lbs/MWh (0.27 kg/kWh) during peak hours to 0.264 lb/MWh (0.12 kg/kWh) off-peak, a 56% reduction.

Where peaking power is provided with relatively new gas turbines or hydropower from reservoirs (where the flow can be controlled) and coal-fired power plants provide baseload power, shifting loads to off-peak hours might not reduce emissions. "I would think that the best profile for the utility would be a perfectly constant load so that they could optimize for energy and emissions. This will take significant storage," Torcellini told *EBN*.

Another factor in the environmental benefits of TES is the conversion of pollution emissions into smog. NOx emissions from a given fossil-fuel-fired power plant will result in less smog at night than during the day, because smog production is a photoreactive process—catalyzed by sunlight.

According to Reindl, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has been working with the U.S. Environmental Protection Agency (EPA), several DOE national laboratories, and other partners to develop tools for more accurately estimating $CO_2$ and other emissions from utility companies. He hopes that this information will become more available to decision-makers.

### TES is a way to store renewable energy

One of the biggest challenges with wind and some other renewable energy sources is the mismatch between electricity availability and demand. This isn't a problem if renewables are producing only a small percentage of the power, but it will become a big issue if, for example, wind share grows to 20% or more. TES allows renewable electricity produced at night to be used for cooling loads that will happen later—when wind may not be available.

"We've got to be able to store renewable energy," said MacCracken. Ice thermal storage is a very low-cost way to do that. Compared to other options (lead-acid and lithium-ion batteries, pumped-hydro storage, flywheels, etc.), thermal storage offers by far the best combination of high efficiency and low cost, according to MacCracken. "If the energy that is stored will be used to run a compressor and cool something, it is much more cost-effective and energy-efficient to store the thermal energy at the site," MacCracken told *EBN*.

## TES and LEED

TES should become a key tool for greening buildings. Currently LEED for New Construction does an adequate job of rewarding use of TES because these systems reduce energy *expenditures*, and that's the metric by which energy points are earned. However, the energy credits in LEED for Existing Buildings: Operations & Maintenance (LEED-EBOM) are based on Energy Star, which considers only kWh consumption at the site times an average heat rate to arrive at source energy. "Energy demand and energy costs are completely ignored [in LEED-EBOM]," according to MacCracken.

A big issue in discussion today is how to measure reductions in carbon emissions in LEED and other rating systems. According to MacCracken, the general direction of measurement is toward average grid carbon emissions, with no accounting for day and night differences. If LEED were to switch to a simple carbon metric, rather than source-energy consumption or energy cost, electricity demand would be completely ignored. "$CO_2$ is the right way to go [as a metric of building performance]," says MacCracken, "but we have to get it right and not oversimplify. A building's peak demand is a metric that cannot be ignored."

## Final Thoughts

Ice-based thermal energy storage systems are playing an increasingly important role in leveling electricity demand by shifting cooling-energy use to off-peak periods. This offers significant cost savings to building owners as well as $CO_2$ emission reductions and environmental benefits in some areas. TES will also make it feasible to significantly increase reliance on wind power and other renewable-energy sources—by providing an affordable mechanism for storing electricity during off-peak periods. As the nation's utility grid is modernized and a "smart grid" emerges, TES will become even more important.

Given the significant benefits of TES, it is indeed surprising that the practice is not more widely used. "This is a huge opportunity that continues to be missed," says Reindl. He notes that tremendous investments are being made in electric energy-storage technologies—especially batteries. "Storing megawatt-hours of electric energy is very, very expensive." He argues that the idea of storing electricity as thermal energy has been largely lost in the shuffle. "Of course you can't run your TV or computer on a thermal storage system, but it can shift what is often the most electric-intensive load in buildings: the refrigeration system."

### For more information:

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