CALMAC

Frequently Asked Questions About Thermal Energy Storage

Is Thermal Energy Storage vital for the full-scale adoption of renewable energy?

Absolutely. Renewable energy is predicted by many to replace fossil fuels. However, fossil fuels are not just energy - they are forms of stored energy, ready for use when you need them. So if you are going to try and replace them with forms of pure energy (wind is moving and solar is hot) you can't ignore the "storage" characteristic of what you are trying to replace. As we learned in high school science class, there are a number of types of energy (potential, kinetic, chemical and thermal) and each can be stored. Notable forms of energy storage are pumped hydro (pumping water up a mountain at night), which is potential energy, flywheels for kinetic and lead acid batteries for chemical. All of these can be reconverted into electricity. Thermal Energy, is normally used at the point of use (a building) and committed to a specific purpose. For example, hot water storage for showers and ice storage for cooling the building.

What are the economics of implementing Energy Storage into the Smart Grid?

The cost of energy storage varies by type but most types have relatively low cost compared to the value they bring to the Grid. For instance, California has 1,000 MW of wind installed; however only 20% (200 MW) of it has typically been available when the utilities hit their peak. The installation of thermal ice storage at a building provides the ability to store energy when the wind is blowing at night and to then use the stored energy during the peak hours the following day. With storage you can get 100% of wind's output during peak hours (20% from wind and 80% from energy storage) for less than 33% of the installed cost of adding additional wind turbines. Ultimately, the peak capacity of the wind resource is increased by a factor of 5 and the cost per delivered peak kW is decreased by 1/3.

Grid-side storage is an important solution for enabling renewable energy resources. Why should people consider "building-side" or "on-site" Storage?

Economics and Energy Efficiency. The economics are clear. Thermal storage at the building is the least expensive of all the storage types. Some see a drawback in that it can't be converted back to electricity. However since the largest component of on-peak energy use is the creation of cooling, there is plenty of need for the stored cooling. As far as efficiency, again thermal storage comes out on top. Pumped hydro, as described above, uses excess nighttime electricity to creates a lake on top of a mountain and then during the day runs it down and through a turbine to re-create the electricity. The round trip "cycle efficiency" of this is about 65% to 70%. Other forms of large scale energy storage have similar numbers. Thermal storage at a building has a cycle efficiency of anywhere from 85% to 99%. So in energy terms thermal storage is a clear winner.

How does Ice Storage work?

Basically a standard chiller is run at night and cools a fluid (antifreeze coolant) which is then pumped to a coil of tubing that is submerged in an insulated tank of water. The coolant removes the heat from the water and returns to the chiller. The removal of heat from the water causes it to freeze. During the day the chiller is turned off and the coolant is used to melt the ice and then circulates to the building to cool the building. Essentially it is very similar to a conventional building's system except the storage allows the decoupling of when you create the cooling from when you need it.

What is the benefit of preparing for the Smart Grid with Energy Storage ?

A building with the ability to store energy (distributed energy) is smart grid ready. Many things that are done for demand response affect comfort or the convenience of building occupants (i.e. shutting down escalators, raising room temperatures, dimming lights, etc). In contrast, Storage is transparent to the building occupants – they have no idea how the building is being cooled, they just know that it is, and they are comfortable. The building owner is saving energy and money with no impact on the occupants, while allowing the control people to shift the largest single electric usage in the building to another time.

Provide examples of businesses using Storage today.

Literally thousands of companies around the world are using the CALMAC Ice Bank® system to cool their buildings. Installation capacity sizes range from 30 ton-hours required by a McDonald's franchise in Geneva, Switzerland to the 30,000 ton-hours needed for the JC Penney corporate headquarters in Plano, TX or the T&C Building in Kaohsiung, Taiwan, the 10th tallest building in the world. Thousands of energy conscious customers such as the Durst Organization, Credit Suisse, Rockefeller Center, Morgan Stanley, the University of Arizona, Underwriters Laboratories, Trane, Kohl's, DuPont and Nordstrom are storing their cooling at night along with many school districts, universities and medical centers.

How much of a risk am I assuming with Thermal Energy Storage?

Do you consider your water heater as risky? Each hot shower is worth about 20kW of peak demand. A busy house may have two or three showers operating at once adding 40 - 60 kW to an electric meter. To minimize investment and operating cost you install a water heater and storage tank. The water heater can make and store enough hot water using a small heater, say 10kW of demand to make a store hot water for use when you want it. The water heater reduces demand and saves money with very little risk. A partial storage ice system is very similar to the water heater. Most ice systems have a smaller chiller than the peak load requires, which will generate ice at night. The ice will be stored in tanks to be used the next along with the smaller chiller to provide enough cooling for the next day.

How complicated are Thermal Energy Storage systems?

Thermal Energy Storage is not much more complicated than conventional chilled water or the water heater in your home. TES systems require ice tanks, a diverting valve, a modulating control valve, some added control sequences, and heat transfer fluid. The ice tanks have no moving parts and no parts that can rust or corrode. The ice systems of today use standard air conditioning chillers with factory mounted ice-making controls.

How complicated is Thermal Energy Storage equipment?

Technology has evolved, changed and matured in the last 15 years. The TES market started over 20 years ago with over 30 manufacturers with all types of technologies. Today the number of manufacturers is down to a handful of companies with products that the market accepts because they work, are easy to apply, and they are simple. Gone, for the most part are the expensive liquid overfeed systems and the harvester systems. Today's systems use standard commercial chillers and factory assembled ice tanks. There is also a wealth of information to help the designer, contractor, and operator design, install, operate, and maintain TES systems.

How difficult is it to design and install Thermal Energy Storage?

Technology and the tools available to help design, install, and operate TES systems have changed dramatically over the years allowing TES to be reliably and affordably applied and simple to operate. Partial Storage TES systems can save up to 40% of comfort cooling costs. Those costs can be up to half of the entire electric bill! Plus, TES has environmental benefits beyond the meter and utility benefits that can help you negotiate better rates with your utility, like an improved electric load factor.

What are the installed costs of Thermal Energy Storage?

Installation of partial ice storage is very affordable. The chiller size can be reduced saving money. Electrical component sizes are reduced saving money. Cooling towers and pumps can also save money from small capacities.

For example:

Non-Storage System:	1000 ton Chiller x $650/ton = $ 650,000
Partial Storage System:	500 ton Chiller x $750/ton = $ 375,000
	3000 ton-hr of ice storage x $100/ton-hr = $ 300,000
	$ 675,000

In this example the cost of the storage system is essentially the same as conventional. Lower Electrical costs are not included and the design does not take advantage of cold air distribution potential savings.

Can redundancy be designed into Thermal Energy Storage systems?

Look at an example comparison of conventional cooling with two fifty-ton chillers for a 100-ton building and partial ice storage. The TES system for this example might be two 30-ton chillers and one Calmac 1320 ice tank. If only one chiller works on the conventional system, 50 tons of the 100-ton peak cooling load can be met. If only one chiller works on the partial ice storage system, 50-tons of the 100-ton peak cooling load can be met too. Thirty tons come from one chiller and 20 or maybe even 25 tons come from the ice generated at night by the operating chiller. The systems have similar capabilities should one machine be inoperable. The risk of a component down is the same for each system. Comparing like systems is very important for an economic evaluation. If the level of redundancy is similar for conventional cooling and TES, the value of partial ice storage can be proven. Lets examine a 100-ton building. A redundant conventional design is (2) 100-ton chillers. The partial storage design with redundancy for comparison would be (2) 60-ton chillers and one Calmac 1320 ice tank. If a component fails in either system the facility can still be cooled. The value of this TES redundant design is in place because the chillers and associated equipment is downsized helping to offset the system first cost while minimizing demand to save operating costs.

How much space do you need for IceBank™ tanks?

You don't need much space at all. It is easy to relate the space needed for partial ice storage to the water heater in your home. A typical 1700 sq. ft. home has a 4 sq.ft. water heater. The water heater uses (4 sq. ft. / 1700 sq. ft.) only 0.23% of the floor space. A Calmac tank can cool, at a peak rate over an 8-hour period, about 20 tons. If you use the 500 sq. ft. per ton rule, a 70 sq. ft. tank will cool about 10,000 sq.ft. and use about 0.70% of the floor space for FULL STORAGE. Most thermal energy storage systems are partial storage systems where storage accounts for about 30% of the total cooling required reducing the floor space needed to about ¼ of 1% of the conditioned space. Just like your water heater!

What types of electric rates are needed to justify Thermal Energy Storage Systems?

You don't need time of day rates for the economics of thermal energy storage to work. Most of the operating costs savings come from on peak demand charge avoidance. Partial Storage systems typically pay back in less than two years if they can avoid $9.00 demand charges. Many mature markets typically can install partial storage system for the same cost as conventional cooling.

Can facilities with a flat electric rate justify Thermal Energy Storage?

Flat electric rates are, in most all cases, determined by the electric load factor. Most flat rates are available in deregulated markets where negotiating rates is part of the process. A peaking electric load profile is more expensive to service than a flat load profile so if changes to the load profile can be made better rates can be negotiated. Thermal energy storage is an effective way to change an electrical load profile. Cooling is typically 40% of peak demand shifting a portion of the load to off peak can improve the load factor and the flat rate charged by the utility.

Can Thermal Energy Storage be applied to facilities with a night-time cooling load?

Many of our projects have nighttime cooling. A rule of thumb to start with says that if the cooling load is less than 20% of the daytime peak a system can be designed to cool the nighttime load with the ice making system. If that nighttime load is greater than 20% a more effective design may be to install a separate chiller. Many systems have two or more chillers. A large system for a skyscraper might have a very efficient non-glycol chiller for base and nighttime loading. A separate ice system can generate thermal energy storage and/or enhance the daytime cooling.

How different is designing an Thermal Energy Storage System from a conventional chilled water system?

TES designs need different equipment and control specifications. Those different specifications need to be developed and do have real costs. Other than that TES design is not much different from conventional chilled water design. A designers first few jobs may cost more than conventional cooling in order to develop procedures and TES specifications. Most all of the experienced TES designers say after a few projects that their TES designs cost the same as conventional cooling. There may be state and federal energy grants or rebates to help offset these costs. Some designer's look at these added job costs as an investment in marketing to develop a niche that provides them with a competitive advantage a marketplace. Some designers will compete for a client with scope and a conventional scope; then provide a cost add for a TES design. The additional costs can be repaid with shared energy savings.

My tenants pay for utilities so why should I Invest In Thermal Energy Storage?

Thermal energy storage reduces your tenants' cost and makes your facility more competitive. TES may allow you to negotiate better utility rates further reducing your tenants costs and increasing your competitiveness in the marketplace The environmental benefits beyond the meter of TES will allow your company to be viewed as a good corporate citizen.

How does Thermal Storage Make Sense for my building (hotel, hospital, school, residence)?

Though some facilities have 24 hour operation TES may be a good life cycle value. Hotels have offices, ballrooms, and meeting rooms with intermittent use that can add to the electrical demand peaks. TES can minimize the demand penalty associated with those events. Hospitals have surgical suites and out patient centers that have daytime only use. TES can minimize the demand penalty with those facilities as well. Schools are a perfect application for TES because the cooling loads are so variable and TES minimizes the demand charges simply.

While the electric power industry is in turmoil, should I wait until it shakes out before making any big investments?

There will always be some sort of turmoil in a deregulated industry. In turmoil there is opportunity. Risk Management is a common practice that businesses are now applying to energy to manage costs and risks associated with an open energy market. Making informed choices and having consumption information can save energy costs and minimize risk. TES allows fuel choices for cooling that conventional cooling systems don't allow. The time to implement a TES strategy is in the beginning of the HVAC design or replacement process. Chillers can be downsized to reduce mechanical and electrical equipments costs if done up front. Design strategies can be used to decrease pipes, pumps, fans, motors, and air ducts on new construction projects further reducing installed costs.

What if my design better fits or is a unitary or rooftop system?

For existing unitary projects or any existing project for that matter, adding ice storage for the sake of ice storage will not provide a good economic analysis or life cycle value. For existing facilities the time to consider ice storage is when changes to the HVAC system are being considered for some other reason. The existing system may be expensive to operate and repair, or it may be unreliable. If contemplating changes for some other reason, an economic comparison with TES as one of the system choices can be made. Otherwise the TES option is compared to doing nothing.

If unitary rooftop units are being replaced at an existing facility, another alternative to evaluate may be Calmac's Roofberg application. This application converts the existing rooftop to a glycol rooftop air handler. The condensing section is disconnected and the refrigerant coil is converted to or replaced with a glycol coil. The converted rooftops are connected to a partial ice storage chiller plant nearby. Opening up the roof or disturbing asbestos insulation is eliminated minimizing the disruption of the occupants. Diversity of cooling loads can be used to size the partial ice storage system minimizing the installed capacity. Demand costs can be reduced up to 50% and maintenance costs are less because of less equipment.

How efficient is Thermal Energy Storage?

Two locations must be reviewed for energy consumption: energy consumption at the site and at the source of generation. Energy consumption at the site may or may not occur; in most cases thermal energy storage will save energy at the site. Source energy savings will always occur.

Site Energy Consumption:
The buildings electric meter measures site energy consumption. Energy can be saved at the site using thermal energy storage because chillers are fully loaded, most of the time, operating at their most efficient condition. Chillers in partial storage strategies are operating upstream of ice storage. The chillers cool the upper half of the delta T so they don't have to work as hard making operation more efficient on peak. Larger cooling loop delta T's can be used because of the series architecture of chiller and the partial ice storage reducing flow and pumping energy. Colder air temperatures can be distributed into the space with partial ice as well reducing the volume of air and fan energy requirements. Most designs today have oversized chillers. Oversized chillers never get to operate at their most efficient point. Larger chillers need larger pumps and cooling towers, which also operate at part load conditions. Up to 14% savings of site energy has been documented using thermal energy storage compared to conventional cooling. Thermal energy storage varies TIME to match capacity. Inefficient unloading is not necessary.

Source Energy Consumption:
Load Factors for North American power plants have been decreasing as more and more facilities become air-conditioned. Load factors have been declining from 1960 when the load factor was about 64% to around 50% today. Heat rates of power plants, the amount of BTU's used to make a kWh, change with load factor. Just like a chiller it is more efficient fully loaded. Power plants used at night are the large efficient base load plants with better heat rates. A typical California power plant, for example has a heat rate of 11, 744 btu/kWh at 30% load and 7,900 btu/kWh when fully load. Heat rates are also better at night because of lower temperatures. A typical Southern California Edison Marginal Plant had a 31% improvement in heat rates during off peak times. Electricity is also 3 to 7% easier to transmit during the nighttime hours.

Source Energy Savings Summary:

- 20 - 43% savings for shifting On-Peak to Off Peak kWh generation for the Incremental Energy Cost Method
- 8 - 24% savings for shifting On-Peak to Off Peak kWh generation for the Marginal Plant Method
- 3 to 7% lower transmission line losses

California Energy Commission