Thermal Energy Storage: The Quiet Revolution

by Ken Dragoon, Flink Energy Consulting

May 25, 2017

© Flink Energy Consulting, 2017

Thermal Energy Storage: The Quiet Revolution

Rapid rise in commercialization of thermal energy storage

by Ken Dragoon, Flink Energy Consulting

Although the need for storage is unquestioned as society moves to relying more and more on variable renewable sources of electricity, thermal energy storage (TES) remains largely overlooked by regulators, legislators, planners and utility executives. TES involves a wide range of technologies; at least one of which (ice storage) has been around for many centuries. Despite formal neglect, a recently released report estimates worldwide TES investments in 2017 at $3.67 billion, with 11% annual growth[1].

One reason thermal energy storage may be overlooked is because of the common conception of energy storage as technologies that both absorb electric power from the grid and deliver electric power back to the grid at a different time. Pumped hydro and battery technologies are great examples of that form of energy storage. However, energy storage is far more than electric power-in-power-out technologies. While TES has a role to play there as well, it really shines in other storage applications that have equal value in accommodating variable renewable resources. Understanding the importance of TES starts with understanding a wider range of energy storage categories than what most commonly comes to mind as energy storage.

Energy Storage Categories

Electric power is generated and consumed virtually simultaneously. This is an unusual property for energy delivery systems. For example, there is no imperative to consume coal, diesel, or natural gas at the moment it emerges from the ground. There is enough inherent storage in natural gas pipelines alone that production and consumption are generally matched on a daily basis—the minute-to-minute and hour-to-hour fluctuations in demand being accommodated by the large store of natural gas in the pipelines themselves. There is no equivalent in the electric power system. Having to match the production and consumption of power is a much more immediate task on power grids.

Compounding the difficulty is the fact that storing electric energy is both expensive and relatively uncommon. Batteries, pumped hydro storage, compressed air, flywheels and the host of other technologies designed to take electric power in and release it at a later time

---

[1] *Thermal Energy Storage Market by Technology (Sensible, Latent, and TCS), Storage Material (Water, Molten Salt, and PCM), Application (Power Generation, District Heating & Cooling, and Process Heating & Cooling), End-User, and Region - Global Forecast to 2022*, MarketsandMarkets, March 2017 (www.marketsandmarkets.com)

contribute an almost insignificant amount of the energy storage used to match generation with demand. The vast majority of energy storage needed to match production and consumption lies elsewhere.

Energy storage for power systems can be categorized based on where the storage occurs on the grid:

1) **Primary energy storage** stores fuels that power plants call on as needed;
2) **Grid storage** is the more familiar battery and pumped hydro storage;
3) **End user storage** involves technologies that provide a disconnect between the time of delivery of electric power and when the energy is consumed to provide end use services (heating, cooling, pumping, etc.).

The relationship of these three classes of storage to the power grid is illustrated in Figure 1. Primary energy storage provides nearly all the storage capability relied on today. It comprises the natural gas system, petroleum storage and transportation, coal piles, hydro reservoirs, and nuclear stockpiles. Primary energy storage allows power plants to selectively generate power as needed to match fluctuations in demand and, increasingly, the variable output of renewable generation.

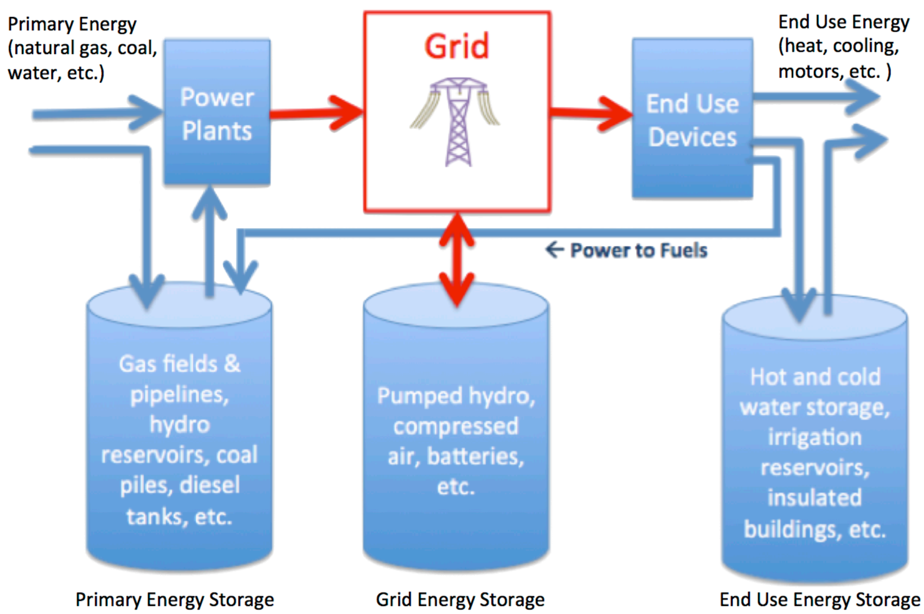

Figure 1 The three types of electric power system storage (source: *Power System Flexibility Strategic Roadmap*, Ecofys, 2015)

For matching electric supply and demand, end use storage is exactly analogous to primary energy storage. While primary energy storage allows generation to occur at a time different from the production of the fuel, end use storage allows power deliveries to occur at a different time from the use of the delivered energy. Electric vehicle charging is an obvious example, but there are many examples, such as municipal water pumping and electric water heater storage tanks. In the case of water heaters, the water coming out of the shower head may have been pumped into a reservoir and subsequently heated many hours or even days before turning on the tap.

Although grid energy storage receives the greatest attention, primary energy storage dwarfs the other two for serving electric power consumers. For example, the reservoir behind Grand Coulee Dam alone holds thousands of times as much energy as all US installed battery energy capability. The natural gas storage system, in turn, dwarfs hydro reservoir storage by orders of magnitude. As we lean more heavily on variable renewable energy sources, energy storage opportunities in all three categories deserve our attention. Thermal energy storage can contribute to all three categories, but the most prevalent and cost-effective applications are in the less familiar primary and end use storage categories.

Perhaps the most familiar application of thermal storage as primary storage is in solar thermal plants, where heat is stored in insulated tanks used to produce electric power after the sun goes down. However, burgeoning commercial applications include end use storage applications as well. The exciting world of contemporary thermal energy storage applications is explored below, highlighting applications in all three classes of energy storage: primary, grid, and end use.

Thermal Energy Storage Applications

Thermal energy storage covers a range of diverse applications in all three energy storage categories. What connects them is that they all involve the manipulation of thermally insulated reservoirs of some kind that are either above or below ambient air temperatures. Insulation is a key factor in thermal energy storage—the better the insulation, the more efficient the storage. In most cases thermal insulation is comparatively effective and inexpensive[2]. The most cost-effective applications tend to leverage existing infrastructure: generators, buildings, boilers, and water heaters. The most widespread commercial applications today are in end use energy storage.

Selected thermal storage applications are described below by category: primary, grid, and end use storage. The selection is not comprehensive, but gives a flavor of some of the many real world applications occurring today.

Primary Energy Thermal Storage Applications

Primary energy storage provides the input energy to electric power generators. Its existence allows generators to produce electric power at a time that is different from the production of the input energy itself. For example, hydro reservoirs store water until it is admitted to electric generators at such time as may be more convenient or valuable to generate power with it.

Today, perhaps the most familiar use of thermal energy is in the primary energy storage category. Specifically, in solar thermal energy plants where thermal energy storage allows

---

[2] For example, the thermal losses in modern electric water heater tanks can be as low as 15 watts, less than 5% of the average water heater usage. More impressively, liquid nitrogen (-320 F) and helium (-452 F) have long been routinely stored and transported safely and efficiently in vacuum insulated containers.

power production after the sun goes down. Another similar application is envisioned for solar thermal peaking plants, where a smaller solar collector field is used in conjunction with thermal energy storage to provide solar peaking capability.

Solana Thermal Solar Power Generation and Energy Storage Plant

Roughly 70 miles southwest of Phoenix stands the 280 MW Solana Solar thermal power plant. Molten salt thermal energy storage tanks absorb some of the 393° C (739° F) heat from the parabolic trough solar collectors to provide up to 6 hours of generating capacity after sunset. At 1,680 MWh of electric equivalent energy storage, Solana represents the single largest non-hydro storage facility in the US, with more than twice of all the currently operating battery storage.

Crescent Dunes Thermal Energy Storage Plant

Another example of solar thermal energy storage is SolarReserve's Crescent Dunes Solar Energy Facility, also located in Nevada. The solar power tower project began operation in 2015, generating 110 MW of power coupled with ten hours of thermal storage in molten salts for a total of 1,110 MWh of energy storage.

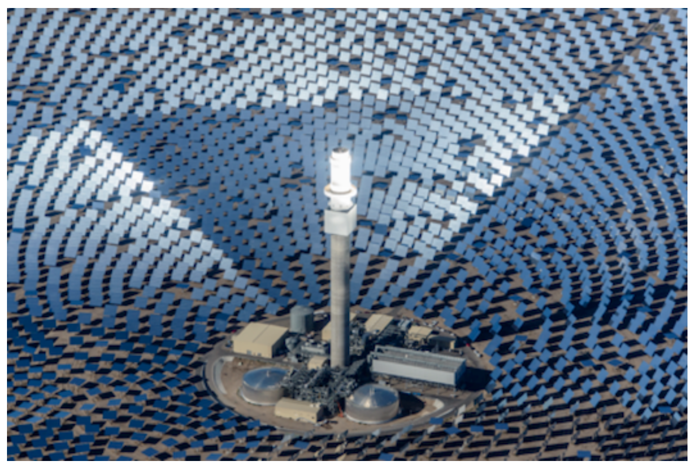

Figure 2 Crescent Dunes Power Tower. Note cylindrical molten salt thermal storage tanks at bottom center. Source: SolarReserve.

Solar thermal energy storage demonstrates the remarkable ability of thermal energy to be stored and returned with relatively low losses, even at the comparatively high temperatures needed for solar thermal power plants. The Crescent Dunes plant uses molten salts as both the heat transfer fluid and thermal energy storage medium, eliminating otherwise needed heat exchangers for higher efficiency. Although figures specific to Crescent Dunes were unavailable, other sources suggest thermal energy-in to energy-out efficiency for high temperature applications in the range of 95 to 99 percent[3].

Thermal Storage for Solar Peaking Plants

Crescent Dunes illustrates the value and practicality of solar thermal storage. The strategy there was to extend generation from solar energy past the daylight hours. Another strategy has been suggested whereby a relatively small solar thermal field is coupled with thermal

---

[3] Zhiwen, M., Glatzmaeier, G., & Kutscher, C. (2012, May 12). *Solar Today: The Thermal Energy Storage Solution*. Retrieved November 21, 2016, from Solar Today Web Site: http://solartoday.org/2012/05/thermal-energy-storage-solution/

storage to provide reliable peaking capability. The proposed advantage is to save on the capital cost of the solar thermal field, which could be further leveraged if the storage is located at the site of an existing conventional thermal plant. When power is needed to meet peak loads, or to fill in the early evening hours when photovoltaic power is rapidly falling off, steam could be generated from thermal storage. Over extended periods of cloudy days, the energy could come from natural gas, or the electric grid itself, to maintain the thermal storage capacity.

Grid Thermal Energy Storage

Thermal energy storage is far less conducive to applications where energy originates as electric power from the grid and is returned as electric power back to the grid at a later time. It would be relatively straightforward to use electric power to charge (heat) a substance that is later retrieved to produce steam to make electricity. However, the round trip efficiency would be relatively low—likely 20-30%, and the costs difficult to justify. Nevertheless, there are two applications where the economics are more promising: combustion turbine inlet cooling and leveraging storage in existing solar thermal power plants.

Combustion Turbine Inlet Cooling

With today's relatively low cost of natural gas, the vast majority of new conventional power plants are combustion turbines burning natural gas. Combustion turbines rely on the same technology as aircraft jet engines, in which air is taken in by a compressor, admitted to a combustion chamber where it is mixed with fuel, and the combustion gases expand through turbine blades to drive a generator. It takes energy to compress the air; and cooler, more dense air takes less energy to compress than less dense hot air. As a result, the efficiency of these units is affected by ambient air temperature—the higher the incoming temperature, the less power produced for a given amount of fuel.

It is common practice to cool the incoming air with water that cools as it evaporates. Greater cooling can be achieved (with lower water usage) using active mechanical chillers. Combining active chilling with thermal energy storage has the storage equivalent effect of grid energy storage. Additional electric power is provided to the chiller (usually at night when chilling efficiencies are greater), and power is returned to the grid through the combustion turbine itself in the form of greater peak generation and higher efficiency. Retrofitting combustion turbines with chillers and thermal energy storage can be a cost-effective way to increase capacity, while layering in energy storage capability that renders additional value to the grid.

Calpine Clear Lake Power Plant

Calpine's Clear Lake Power plant is made up of three combustion turbines that provide 316.8 MW of nominal power prior to the installation of a turbine air inlet cooling system. Chillers were added to the system in conjunction with a 1.6 million gallon insulated liquid storage tank with a 375 MWh thermal storage capacity. Mechanical chilling dropped the nominal inlet air temperature to 50° F, increasing peak output of the plant by 51 MW, while reducing the net heat rate (including added parasitic chiller loads) by 3.5%.

Riyadh Power Plant 9 (Saudi Arabia)

Cooling combustion turbine inlet temperatures has its greatest value in hot climates on systems dominated by cooling loads. A study of Riyadh Power Plant 9 in Saudi Arabia found chilling increased output in the range of 30%–more than 800 MW of additional peak load at the forty-unit plant[4]. Thermal energy storage was a key feature of the project, disconnecting production of cold fluids from the consumption with a capacity of 2.5 GWh of thermal energy storage, enabling the project to bill itself as the largest TES project in the world.

Leveraging Solar Thermal Power Plant Energy Storage

With ever-increasing levels of renewable energy generation, the incidents of curtailing renewable energy is expected to rise. The major benefit expected from the proposal to expand the California electricity market throughout the rest of the West was the expected reduction in curtailments by allowing wider dissemination of available solar generation in the middle of the day.

At some point, it makes sense to leverage thermal energy storage in existing solar thermal plants to absorb energy that would otherwise be lost. Fitting solar thermal energy storage tanks with electric resistance heating elements would be a relatively inexpensive way to absorb surplus renewable energy for use during later hours of the day, or even subsequent days.

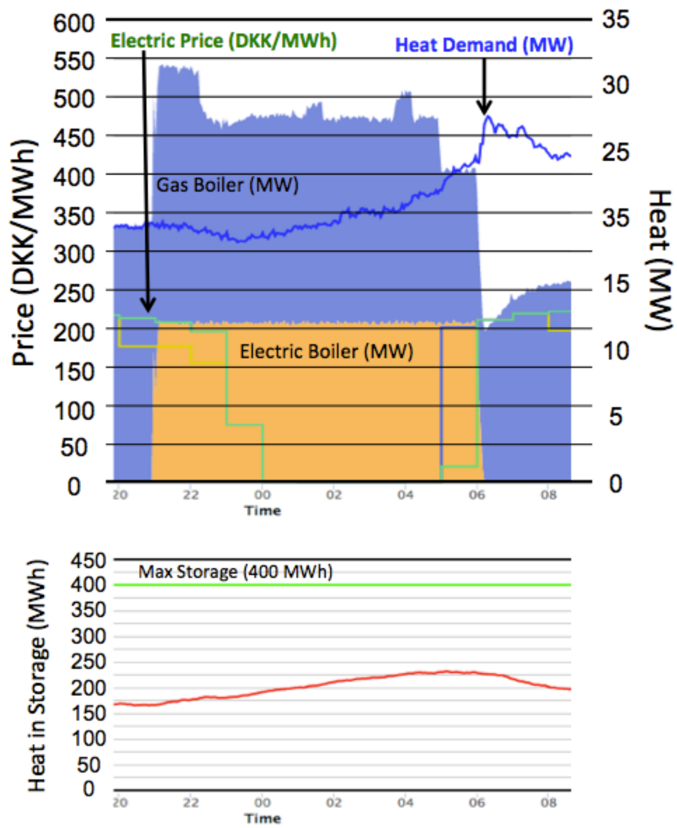

Figure 3 Denmark's Rinkøbing district energy system operation Jan 11-12, 2017. As wholesale electricity prices drop (green line in top panel), the electric boiler comes on (orange fill in top panel), storing hot water (rising red line in bottom panel) for later use. Source: http://www.emd.dk/plants/rfvv/

End Use Thermal Storage Applications

End use thermal storage opportunities arise where electric power is consumed for heating or cooling. They comprise the most ubiquitous commercial applications today, and the growth potential is huge as well. The technologies include both heat storage and cold storage. End use applications are the most widespread application, principally

[4] Al-Ibrahim, A., & Varnham, A. (2010). A Review of Inlet Air-Cooling Technologies for Enahancing the Performance of Combustion Turbines in Saudi Arabia. *Applied Thermal Engineering , 30*, 1879-1888.

because electricity is used for heating or cooling virtually everywhere.

While there are increasing examples of commercial applications in the US, understanding the importance and significance of end use thermal storage starts with looking at what is happening in Denmark.

Thermal Energy Storage in Denmark

In 2015, 42% of Denmark's electric demand was supplied by wind power, with a 2020 target of 50%. Thermal energy storage has been identified as a key part of integrating that variable and less predictable power.

Some 60% of Danish buildings are served by district heating systems. Heat from combined heat and power plants is used to supply hot water that is conveyed in insulated pipes to individual buildings where it is used to provide space heat and hot water. Because the need to produce electricity and heat are not coincident, large insulated water tanks are used to decouple the production of electricity from the district heating system demands. Typically thermal energy storage is capable of storing 8 hours of heat demand.

Figure 4 Ringkøbing district heating system hot water storage tanks (at right). The 400 MWh storage capacity system consists of a solar thermal collector system gas boilers, electric boilers, a gas turbine and an internal combustion engine. Waste heat from the turbine and engine contribute to meeting heat demand. The facility can either absorb or generate electric power and stores more than 30 hours of average heat use, or about 20 hours of peak day usage. Source: Google Maps.

While the average wind generation is 42% of average demand, there are times when the production of wind power exceeds the demand for power, as is increasingly occurring in the US. During the instances of super-production, after generation from thermal plants is minimized and power exports maximized, additional generation can be absorbed by electric boilers heating water that is stored in district heating systems' insulated water storage tanks. In that way, the energy can be stored for later use even if the thermal plants continue to remain offline[5].

Figure 3 shows an electric boiler energizing in the middle of the night to store wind power as hot water for the Rinkøbing district heating system in Denmark. The two thermal energy storage tanks have 400 MWh of storage capability, representing about 20 hours of peak day usage.

Water Heaters

District heating systems are not as common in the US, but there are an estimated 40-50 million electric water heaters that have similar storage potential. Stepping into your shower, you may appreciate that your home water heater works continuously to ensure a pleasant experience. Less obvious is the fact that although the heating elements come on within a minute or so of opening the tap, the water being heated probably won't be used for several hours—possibly not until the next day even. A typical shower uses 6-8 gallons of hot water, whereas the typical hot water storage tank holds 50 gallons of hot water and takes just 15 minutes to recover from that shower. Those 15 minutes can occur later. Smarter water heater controls can control when the water is heated, instead of doing it simultaneously with its use.

Controlling water heaters to provide energy storage has some big advantages and a few challenges. Among the advantages: there are no moving parts to wear out; the devices are widespread and solutions replicable; storage efficiency is in most cases nearly 100%;[6] the resource is year-round and its lifetime is not limited by the number or depth of the energy cycling; and the resource potential is huge. Coordinating water heaters to energize them all at once would consume three times the combined power of all currently installed US wind generation at full output.

Electricity from Water Heaters?

Although electricity comes out of batteries, not water heaters, there is virtually no difference from an interconnected grid perspective. At any moment, reducing power consumption at water heaters frees up power for other purposes. Turning off a load has the same effect as turning on a power source.

A typical high efficiency electric water heater is not only 95% efficient, but stores roughly 6 kWh of thermal energy at a cost of less than $100 per kWh of energy storage, a cost born by water heater owners for

[5] State of Green. (2016). *District Energy: Energy efficiency for urban areas.* State of Green.

[6] Water heaters do have thermal losses; a typical modern water heater may lose 10-15% of daily usage to ambient air. However, using a water heater for energy storage has little incremental effect on those losses unless the tank temperature is increased (as some control schemes do). Absent raising the tank temperature, increased energy consumption is due to introducing the control and communication equipment, making water heater storage potentially roughly 99% efficient.

an entirely different purpose— heating their hot water. According to several sources,[7] battery costs, independent of installation and power conditioning equipment, may reach $100 per kWh by 2022.

The main challenge is finding technological solutions that are inexpensive and reliable enough to deploy in large numbers of homes. The generally falling costs of electronics and the burgeoning "internet of things" is helping to address these challenges. As a result, commercialization is beginning to take off.

Mosaic Power

Founded in 2012, Maryland's Mosaic Power uses the inherent storage capability of electric water heaters to sell regulation services to the East Coast PJM wholesale electric market. As of April 2017, CEO Laurie Vaudreuil reported having 10,000 water heaters under control and connecting more of them at the rate of about 1,050 per month. Mosaic selectively energizes or interrupts water heaters to provide high-value, fast-response regulation service. Each water heater has the equivalent of about 1 kWh of energy storage, and 1,500 of them contribute about 1 MW of up- and down-regulation capability for most of the day, and about half that over the late-night and early morning hours.

Mosaic pays participating water heater owners at the rate of $100 per year, and takes special pride in their involvement in low-income housing projects that make up about a third of their network of water heaters.

Milton-Freewater City Light and Power

Tucked into the far northeast corner of the State of Oregon is a small municipal customer of the Bonneville Power Administration, Milton-Freewater City Light and Power. With roughly 4,500 customers, some 850 participate in a load control program that began in 1985 for a purpose far-removed from the need to store energy. The Municipality had undergone an outage on its wholesale provider's system. When they tried to reconnect the system, they found that their customers' water and space heating thermostats were all demanding power, overloading the system and opening the circuit breakers.

In response, the utility offered customers a rebate for allowing them to interrupt power to the devices so they could reconnect the system. Once installed, they found that they were able to repay the system in the first year or two of operation by limiting their peak demand each month—interrupting power to water heaters for a few hours to wait out the peak. Customers now receive a 2.5% discount on their bill if they allow interruption of their water heaters.

Although the utility doesn't think of their program as thermal energy storage, it is the storage capability of the water heaters that allows service interruption without adversely affecting customers' perceptions of service. Management is considering additional uses of the program that could take advantage of other storage capabilities of their existing system.

---

[7] http://www.greentechmedia.com/articles/read/How-Soon-Can-Tesla-Get-Battery-Cell-Cost-Below-100-per-Kilowatt-Hour

Hawaii

The high cost of imported diesel, the lack of adjacent power trading markets, and an abundance of both wind and solar resources have helped propel Hawaii into the forefront of managing a system that is becoming dominated by variable renewable resources. Hawaiian Electric Company (HECO) has intermittently limited net metered distributed solar and required combining battery storage with new utility scale installations. The state has a legislated goal of reaching 100% renewable energy.

Helping meet that goal are a fleet of 499 electric water heaters on Oahu capable of responding to signals sent from HECO's energy management system. The water heater storage technology provided by the Steffes Corporation stores one to two days of hot water supply, offering the same storage operational flexibility as a 10-15 kWh battery in a single water heater. The water heaters can selectively energize when solar output is high or contribute flexibility to rapidly changing conditions on the grid.

Space Heating

Thermal energy storage for space heating is not a new phenomenon. Long before planners concerned themselves with the super-abundance of mid-day solar energy, utility operators confronted what to do with surpluses of coal-fired energy during the nighttime hours. A solution dating from the 1940s is to use electricity to heat bricks in insulated boxes at night, when power is produced more cheaply. In the 1980s, the UK developed the so-called "Economy7" tariff that spawned millions of units deployed to take advantage of the lower night time rate. This technology is alive today, with at least two commercial units available in North America: Dimplex and Steffes. The most widespread applications of the technology in the US appear to be located in the Midwest, where coal generation still dominates.

East Central Energy

Minnesota's East Central Energy (ECE) is an electric cooperative serving 59,000 members with power purchased from Great River Energy, a generation and transmission cooperative. About 70% of Great River Energy's generation resources come from coal and 20% from hydro and wind renewable resources. As a result, finding strategic loads for nighttime generation is a priority. ECE is able to pass on lower nighttime power costs from Great River Energy in a special rate available to owners of thermal energy storage systems, predominantly composed of Steffes Corporation units.

ECE offers its members (customers) zero interest financing over three years for installing the Steffes storage units, along with a roughly 60% discounted rate for the power they consume. Some 2 MW of electric storage heating load has been added over the last three years, and ECE looks forward to adding another megawatt in the coming year. They have deployed 2,300 space heat storage units and 8,000 water heater storage units, for penetration rates of 3.8% and 13.6% respectively. The units are radio-controlled by Great River Energy, separately metered, and receive the discounted rate while charging between 11 pm and 7 am.

According to Energy Services Supervisor Justin Jahnz, a result of this strategic load growth is that their peak winter load occurs at midnight. Jahnz says he has yet to meet a member dissatisfied with their storage heating system's performance. He pointed out that the flexibility of the technology is greater than they make use of today, but expects the value of flexible, controllable loads will only increase over time.

Space Cooling

Seasonal cold storage in insulated icehouses is described as far back as 1780 BC[8]. Until refrigeration became widespread early in the twentieth century, seasonal cold storage in the US was commonplace through much of the 19th century. Legacies of that era include the 7-Eleven chain of convenience stores that began by selling dairy products from ice-houses in the south[9] and the use of "tons" (of ice) as a unit for measuring the cooling capacity of modern air conditioning units.

Although mechanical refrigeration technology ended the era of seasonal ice house storage, cold storage is enjoying a comeback. Refrigeration equipment works more efficiently at night when ambient air temperatures are lower and the cost of producing power is also lower at night. The combination of higher efficiency and lower nighttime prices make cold storage attractive for providing air conditioning loads. Cooling is required year round in most commercial buildings due to internal lighting, office machines, people and solar heat admitted through windows. That cooling load is a significant contributor to power system afternoon peak demand periods.

Ice Energy and Calmac

Calmac and Ice Energy are two active ice storage manufacturers. Calmac specializes in central chillers for large buildings and industrial applications. Ice Energy sells the Ice Bear ice battery additions to rooftop air conditioning units that are common on commercial buildings. They also sell a residential version, as complete replacements for the conventional home AC unit. Where Calmac focuses on energy savings to building owners from operating chillers at night with lower prices and higher chiller efficiencies, Ice Energy works directly with utilities desiring to mitigate peak load demands.

Figure 5 University of California Irvine chilled water storage, provides 65% of air conditioning (~74 MWh) load from power consumed at night. Source: Steve Zylius, UCI.

8 *Mari and Karana: Two Old Babylonian Cities*., Stephanie Dalley, Gorgias Press LLC, 2002.

9 Per 7-Eleven Inc. history web page accessed April 20, 2017: http://corp.7-eleven.com/corp-BAK/history

Each Ice Bear for commercial buildings provides 30 ton-hours of cooling (42 kWh). Ice Energy has deployed more than a thousand units across forty service territories in North America, and have signed contracts to install many times that number in the coming months. Ice Energy units are able to take a variable load, usher it into nighttime hours, and smooth it out—the perfect complement to variable renewable energy resources.

University of California Irvine

The University of California at Irvine developed a micro-grid system that integrates heating, cooling, and power generating facilities. Among the components is a chilled water storage facility that allows 65% of the daytime chilling to be supplied by power (steam and/or electric) that is delivered at night

The heart of the storage system is a 100 foot tall, 90 foot diameter, 4.5 million gallon insulated water tank. Chillers supply 39° F water primarily at night, when electricity prices are lower and temperatures are cooler. Full of cold water, the system can supply 53,000 ton hours of cooling to the campus, or approximately 74 MWh of electric energy. It would take $30 million of battery storage (at $400/kWh) to provide the same level of storage.

Energy Storage Policy

As utilities increasingly rely on variable renewable resources, there is a growing awareness of the value of energy storage to maximize the value of those resources. A Utility Dive survey of utilities found about three-fourths of all utilities expect grid scale and distributed energy storage to increase moderately or significantly[10]. The importance of energy storage is also underscored by rising incidents of very low (even negative) wholesale electric market prices that have already occurred in many parts of the US and Europe.

Energy storage is a means of absorbing surplus energy when it occurs, and releasing it back at times when the energy is more valuable. As a consequence, several states offer incentives for new energy storage projects. However, the policies don't always recognize thermal energy storage opportunities and can result in higher overall energy storage costs.

There is naturally a lot of excitement around new energy storage technologies under development—especially various forms of battery storage. Many battery technologies are showing rapidly improving performance and cost characteristics that attract interest from investors, researchers and utilities. The most widespread low-cost thermal energy storage opportunities are in end use storage applications, which are often unconsidered or explicitly omitted in state energy storage policies.

States that currently have energy storage incentives include New York, New Jersey, Massachusetts, California, Oregon, Florida, and Hawaii. Of these, California, Massachusetts, New York, and California policies include incentives for thermal energy storage. New Jersey explicitly excludes end use thermal energy storage. Hawaii is engaged in water heater energy storage demonstration projects. Oregon's policy did not exclude end use storage, but the utility commission decided it would not currently consider "demand response" storage as

---

[10] Utility Dive Webinar, *Utilities in the Age of Trump: the electric power sector in 2017*, presented April 20, 2017.

qualifying. Florida's program is strictly battery storage for grid resiliency on solar systems.

Cities and utilities are also engaged in or considering policies for acquiring or providing incentives for energy storage. Allowing some participation of end use (and other) thermal storage in these programs will help keep energy storage costs low. Often rate structures do not encourage energy storage, ore even actively discourage it. For example raising demand at night to take advantage of low energy prices or to absorb surplus renewable generation exposes many customers to high demand charges. Policies need to ensure commensurate incentives and eliminate counter-productive rate structures.

Conclusion

Thermal energy storage often flies under the radar because it does not generate electric power. Nevertheless, its effect on the grid is very similar to the more obvious forms of grid storage, and virtually identical to hydro reservoir storage. Because end use thermal energy storage makes use of existing infrastructure built for other purposes, it can have significant cost advantages over batteries, pumped hydro, and other "green field" energy storage technologies. Despite its low profile, the economic advantages of thermal energy storage have brought it into increasingly common usage. Policy changes to encourage, or at least cease discouraging thermal energy storage would hasten deployment of this diverse set of technologies to meet the increasing need for energy storage to accommodate variable renewable energy resources.