Impact of Real-Time Pricing on Payback of Thermal Energy Storage Systems

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ABSTRACT

Thermal energy storage (TES) is a proven technology that is unfortunately associated with a long payback. This lengthy payback has impeded the highly anticipated installation of thermal energy storage systems across the United States. However, with the introduction of real-time pricing (RTP) available in most states all over the country, this may be about to change. Preliminary review and calculations for installation and running of TES systems on real-time pricing has shown reduction in payback period increasing the desirability of these systems altogether.

In this study, we will compare payback periods for thermal energy storage systems first with demand-based (peak/off-peak) rate structure and then with real-time pricing. A load profile will be defined and kept constant for both analyses. An actual facility will be selected and a simplified version of its load profile along with real energy bills will be used to calculate the payback for a TES. Then using past data available from PJM's website real-time rates (LMP) and complex formulas used by utility companies to calculate individual rates for each facility, a real-time pricing payback analysis will be performed. The calculations performed in this study should yield results that can be plotted almost proportionally for a bigger or smaller facility with a similar load profile. The study will be conducted under New Jersey utility rules and regulations but for the most part will be applicable to most locations in the United States.

Introduction

This study is designed to investigate the impact of real-time pricing on the payback of thermal energy storage systems as compared to that on peak/off-peak rate structure. A facility that makes use of a chiller (lacking storage capability) to meet its cooling needs was picked and used as a control for the calculations. It is important to note that the study was conducted under the hypothesis that switching to real-time pricing rate structure would help to reduce the payback of thermal energy storage, however no solid conclusion had been reached on this matter prior to this study nor were there any previously published papers on this specific topic.

Thermal Energy Storage

The idea behind a thermal energy storage system is to shift the facility's cooling load to less expensive, off-peak periods. This is done with the use of storage tanks that may store chilled water or, as in our case, ice, produced during the inexpensive off-peak periods. This ice in-turn is then used during the peak-periods to meet the cooling load without having to run energy intensive equipment such as chillers.

Some of the typical benefits of installing a thermal energy storage system include but are not limited to the following:

- ✓ Cooler night time HVAC operation is considered up to 20% more efficient than day time.
- ✓ Reduces potential blackouts and brownouts by lowering peak demand on the transmission grid.
- ✓ Economic benefit from moving cooling load from peak periods to off-peak periods.

Rate Structures

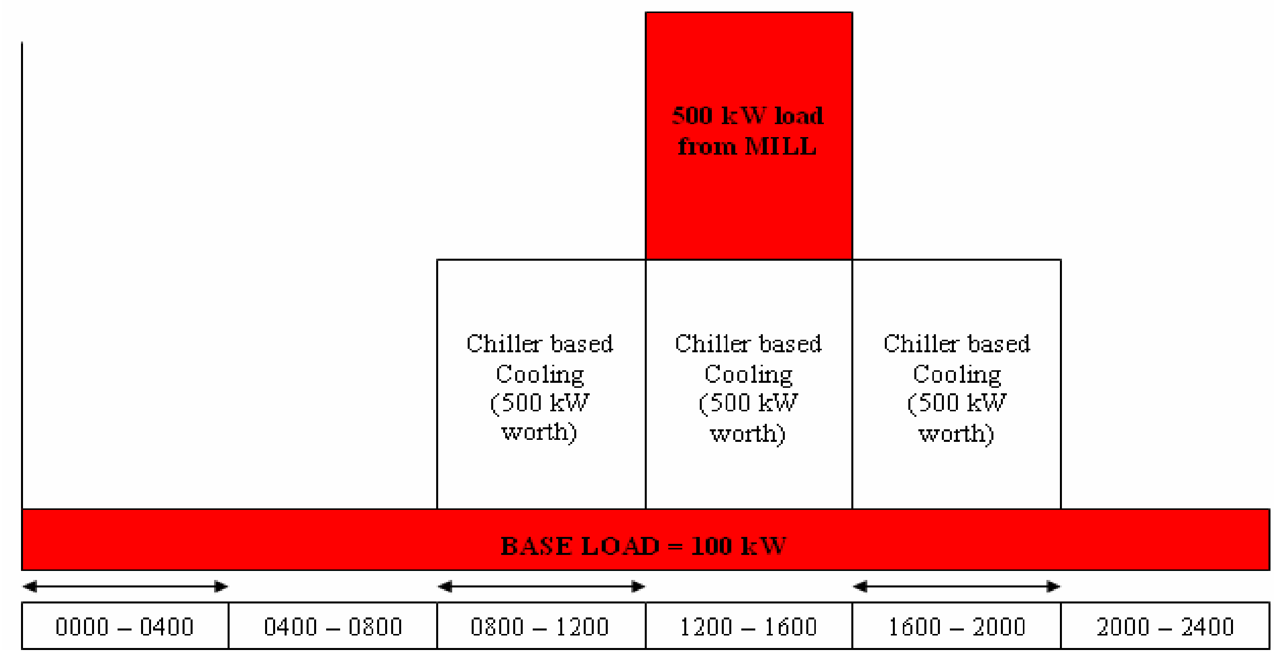
Depending on the geographical location, the utility provider, and the nature and size of business, various rate structures may be available. For this paper, we will limit ourselves to peak/off-peak and real-time pricing rate structures offered by PSE&G to businesses in Newark, New Jersey. This selection (of utility and geographical location) was made as to make our study qualitatively complete, thorough and accurate. It is important to note that not all businesses qualify for all rate structures. For example, only businesses with a monthly electricity usage of over 1,250 kW will qualify for real-time pricing. For the purpose of this study we will ignore the politics and focus on the economic affect of these what-if scenarios.

- **Real-Time Pricing** - The instantaneous pricing of electricity based on the cost of the electricity available for use at the time the electricity is demanded by the customer.
- **Peak/Off-Peak –** Where a 24 hour day is broken into two periods for billing purposes i.e. peak and off-peak period. For our case study, and based on PSE&G regulations, peak period is between 0800 – 2000 hours and off-peak period is between 2001 – 0759 hours. PSE&G regulations stipulate a minimum of 10 off-peak hours. In addition, two separate demand charges are applied i.e. annual demand which is all year round and summer demand charged during the four summer months in addition to annual demand.

Case Study

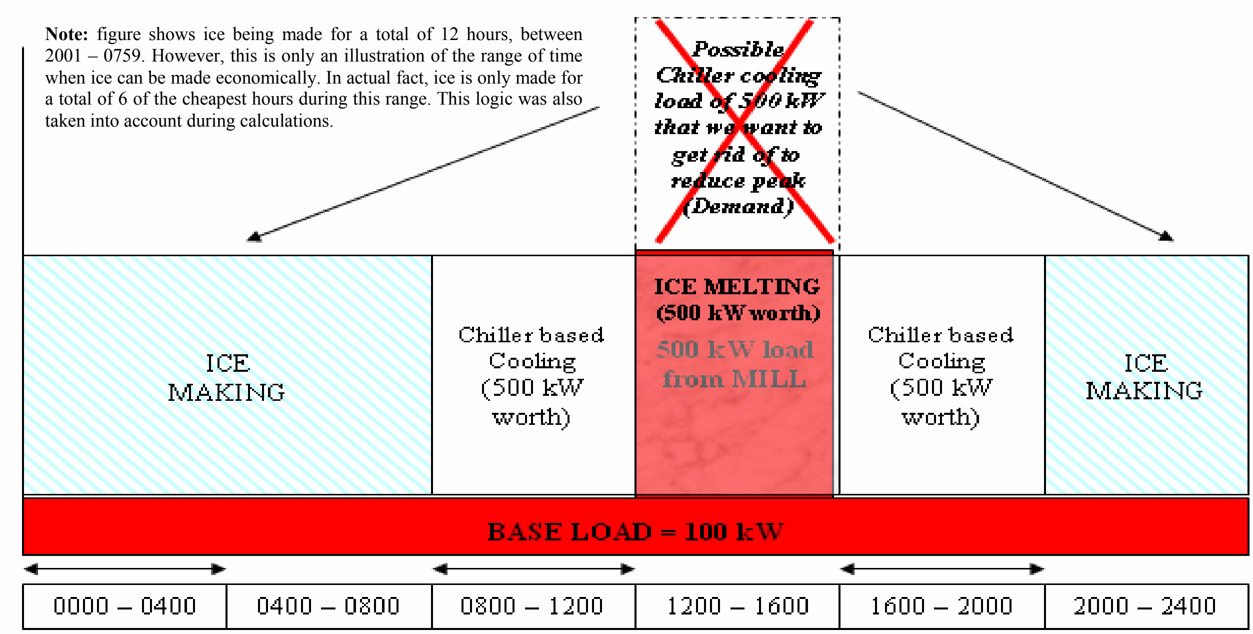
A business located in Newark, NJ was picked for the study. The load profile of the facility was then simplified to focus specifically on the cooling load and therefore more clearly show the economic affect of installing a thermal energy storage system and then running it on the two different rate structures i.e. peak/off-peak and real-time pricing.

Facility Energy Profile Without Thermal Energy Storage:

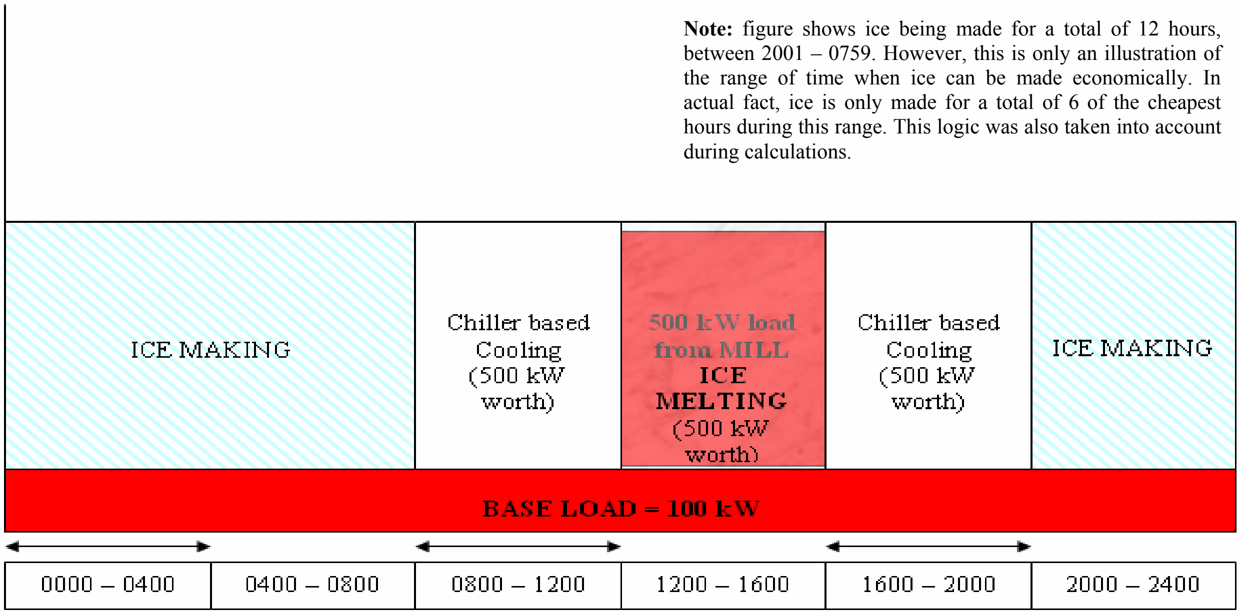


The business is a manufacturing facility located in Newark, NJ. A simplified version of the energy load profile is shown above. A 152 ton chiller with a power consumption of 500 kW is used to meet the cooling load between 0800 – 2000 hrs. During 1200 – 1600 hrs, a "MILL" (energy intensive equipment used in manufacturing) is turned on. The "MILL" has an energy drain of 500 kW. In addition, there is a constant base load of 100 kW 24hrs / 7days a week. To simplify our model further, we will assume that this configuration is repeated everyday including weekends (24/7) regardless of climatic conditions (the chiller is switched on during specified hours).

Switching to a thermal energy storage system, the load profile would look as follows:



And finally, ***Facility Profile with Possible Thermal Energy Storage:***



A partial-thermal energy storage system has been selected for the facility in order to minimize the capital investment and maximize returns. The system is designed to shave off the high demand of 1,100 kW during 1200 – 1600 hrs and reduce it to 600 kW by replacing the chiller with stored ice to meet the cooling load. In addition, ice is produced only during the off-peak (2001 – 0759) hours to make use of cheaper night time electricity. From our calculations, it was found that the chiller must operate a total of 6 hours to produce enough ice to cater for the cooling load during 1200 – 1600 hours. Hence, the calculations are designed to always pick the cheapest 6 hours during the 2001 – 0759 hours window. The facility is considered to be on a peak/off-peak rate structure as provided by PSE&G.

Peak/off-peak rate structure as provided by PSE&G for the facility is as follows:

Table 1. Peak/Off-Peak Rates for the Facility Used for Analysis

$/kW	4.001	Annual Demand
$/kW	8.600	Summer Demand [1]
$/kWh	0.082	Off-peak Rate
$/kWh	0.120	On-peak Rate

Results and Summary of Calculations

Calculations were performed to include operating hours for the summer months of May, Jun, July, Aug, Sept and 10 days each from April and Oct for a total of 173 summer days (as per climatic data available for New Jersey). The simulation was carried out in Microsoft Excel using

[1] Summer demand is only applied between the months of Jun, July, Aug and Sept

various spreadsheet models. A summary of important calculations and results is listed in this section.

Savings associated with switching from no TES to TES on peak/off-peak rate structure. Taking into account both energy consumption and demand, we found that the facility would pay a total of $243,590/year[2] with a TES installed and running on peak/off-peak rate structure in contrast to paying a total of $280,390/year[2] without a TES while being billed on a peak/off-peak rate structure. This yields a total savings of $36,800/year[2].

The implementation cost, including the cost of a new 152 ton chiller capable of producing ice, twelve 20 ton storage tanks, other equipment and labor was calculated to be $215,580[3]. This gives us a payback of ~5.86 yrs (70 months). It is important to note that the chiller purchased would qualify for a New Jersey state run NJ SMART program rebate of approximately $1,500 - $2,500. This rebate has intentionally not been taken into account to allow for the universality of the study in terms of capital costs.

Savings associated with switching from no TES to TES on real-time pricing rate structure. Before any calculations could be carried out, recent real-time pricing rate data for facilities located in Newark, NJ was acquired through PJM website for the year 2005-2006. The data was in the form of $/MW for 24 hours / day. This acquired data was then manipulated based on the following formula[4] used by utility companies to calculate bills:

$$\text{Energy Supply Charge} = \left[\overbrace{\sum_{i=1}^{N} \left(\left(\left(PJM\_LMP_i + Anc \right) \times losses \right) + RA + Rcon \right) \times kW_i}^{\text{BGS Energy}} \right] \times SUT +$$

$$\underbrace{\left[\left(\left(TrChg \times TrObl \right) + \left(CapChg \times CapObl \right) \right) \right]}_{\text{BGS Capacity and Transmission Charges}} \times SUT$$

Where,

Anc = EDC specific Ancillary Services Charge (cents/kWh)
N = number of hours in billing period
TrChg = Transmission Rate ($/kW)
kWi = Usage of Customer in *i*th hour (kW)
TrObl = Customers Transmission Obligation (kW)
RA = Retail Margin (0.5 cents/kWh)
CapObl = Customers Capacity Obligation (kW)
CapChg =Capacity Charge ($/kW)
Rcon = Reconciliation Charge (cents/kWh)
PJM_LMPi =PJM LMP Price in *i*th hour (cents/kWh)
SUT = Sales and Use Tax Factor (1.07)
Losses = EDC specific Loss Expansion Factor

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[2] /year implies to calculations performed for the summer months of May, Jun, Jul, Aug, Sept and 10 days each from April and Oct.
[3] This estimate does NOT include rebates of $12-$170 per ton available through the NJ SMART START rebate program in New Jersey.
[4] The formula given here is the same for PSE&G, JCP&L and most other utilities in NJ.

The spreadsheet model was also designed to automatically pick six of the cheapest night-time hours between 2001 – 0759 hours to allow for the highest economic benefit. This can be done at a real-life facility by installing a "smart meter". The simulation was then run for the summer months of May, Jun, Jul, Aug, Sept and 10 days (each) from April and Oct (just like the peak/off-peak rate structure TES model).

Final calculations revealed total electricity consumption worth $235,734.54/year[5] by installing a TES and running it on real-time pricing rate structure. This translates into total savings of $44,655.46/year[5] over the initial no TES running on peak/off-peak rate structure. The calculated payback is 4.83 years (58 months) once the implementation cost of $215,5803 was taken into account.

Comparison. Comparing the results for the TES running on both; peak/off-peak and real-time pricing rate structures, we get the following table:

Table 2. Comparison between Economic Impact of No TES, TES on Peak/Off-Peak and TES on Real-Time Pricing Rate Structures

	NO TES	TES (Peak / Off-Peak)	TES (LMP - Real Time Pricing)
Cost of Electricity	**$280,390.00**	**$243,590.00**	**$235,734.54**
Savings in Electricity (compared to NO TES)	**N/A**	**$36,800.00**	**$44,655.46**
Payback W/ Chiller installation	**N/A**	**5.858**	**4.828**

Source: Center for Advanced Energy Systems 2007

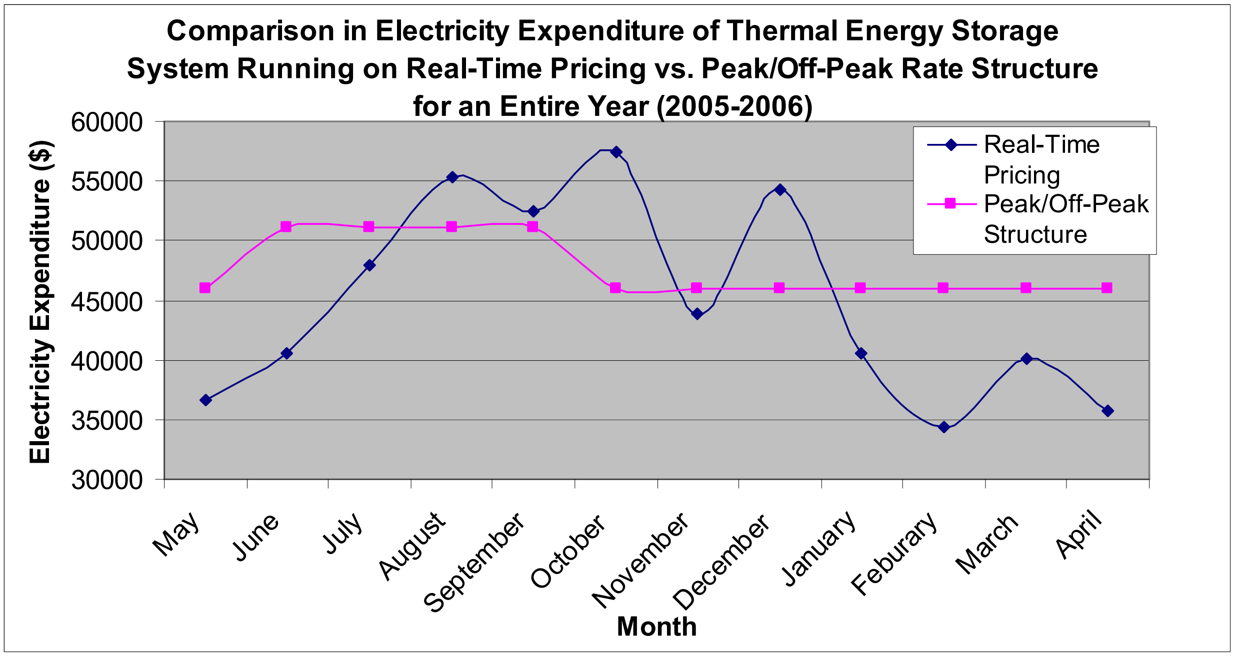
The above table shows an additional cost savings of $7,855.46 for the same TES system running on real-time pricing over if it was running on a peak/off-peak rate structure. These savings result in a reduction of simple payback associated with running the TES on real-time pricing by over 1 yr in contrast with if it was being run on a peak/off-peak rate structure.

Conclusion

As seen in the comparison section, the additional savings associated by switching to RTP rate structure while being considerable; are not significant enough to cause a large hike in implementation of TES in general. In fact, if the rates offered by PSE&G to the facility on peak/off-peak rate structure were a little cheaper, the tables could easily turn such that there would be savings for switching from RTP to Peak/Off-peak rate structure. Hence, no solid conclusion can be attained by this study and the need of more analyses to be carried out is emphasized. The figure below shows a comparison between electricity expenditures incurred by running the TES on the two rate structures if the cooling load and therefore the TES system operation is extended to all year long.

[5] Per year implies to calculations performed for the summer months of May, Jun, Jul, Aug, Sept and 10 days each from April and Oct

Figure 1. Expanding the Study to a Whole Year and Comparing Electricity Expenditure of Thermal Energy Storage System Running on Real-Time Pricing vs. Peak/Off-Peak Rate Structure



Source: Center for Advanced Energy Systems 2007

The above figure clearly shows that in different months either of the two each rate structures may yield an economic benefit over the other even though overall in our case, RTP rate structure yields more savings for our specific load profile.

Even though the initial hypothesis for this study was that there will be positive economic impact on the payback of TES by switching from a peak/off-peak rate structure to RTP, this study has proved that attaining an economic advantage is not a simple matter of switching rate structures. A thorough understanding of the rate structures is vital along with the need to design and optimize plant equipment operations around the rate structure to maximize savings. RTP was developed to help utilities use the carrot-and-stick approach towards large energy consumers i.e. carrot for those who use energy when there is less demand for it and stick for those who use it when it is in high demand. RTP was never really designed to be a straight up economic advantage to businesses just by switching over from another rate structure and not re-adjusting and optimizing their energy load profiles.

It seems however that RTP is heading into the realm of clear cut economic advantage for businesses that choose to switch over due to recent lobbying for availability of real-time pricing for all businesses as well as push for more competitive prices. Depending on the geographical location of the business, both the positive benefit of RTP in general and its impact on TES payback can be well amplified. With the changing politics and prices associated with real-time pricing, the future is yet to be seen however it can be predicted that a clear cut advantage may just be on the horizon. Using smart meters and switching over to real-time pricing, optimizing and carefully designing your processes around energy prices may indeed be the way to go especially with ever more volatile energy prices.

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