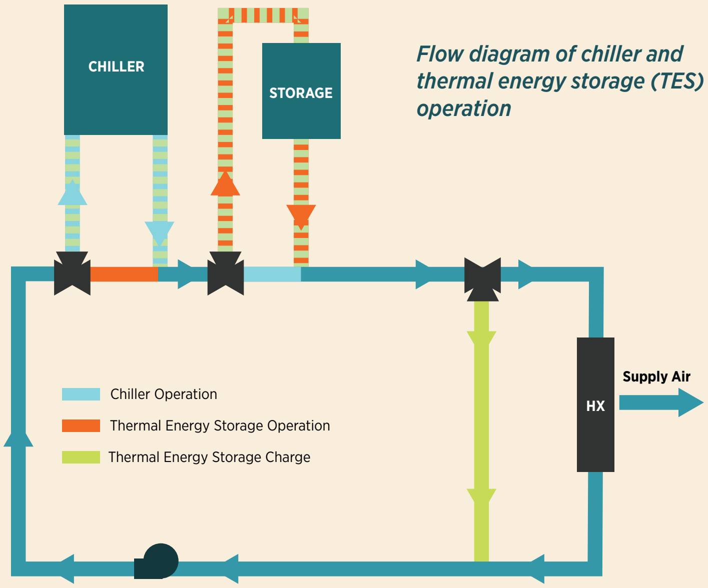
VALUATION OF THERMAL ENERGY STORAGE FOR UTILITY GRID OPERATORS



Flow diagram of chiller and thermal energy storage (TES) operation

ACTUAL ELECTRIC LOAD

Up to **3x**

The predicted load based on standard valuation methods during peak events

> *"As outdoor air temperature increases, the value of stored thermal energy increases.*

PROBLEM

When thermal energy storage (TES) is deployed to offset a cooling load, the grid impact is the electric demand that *would* have been required by the primary cooling system to meet the offset load. Since most building cooling systems use vapor-compression cooling cycles, the system efficiency decreases as outdoor air temperature increases. The result is an elevated electrical demand to meet a given thermal load at hotter ambient air temperatures. Thus, as the outdoor air temperature increases, the value of stored thermal energy increases.

STANDARD PRACTICE

The current method used by California utilities and many other entities for estimating the electric grid impact of TES systems is based on a "10-day average baseline." Using this method for a given hour, the energy use during the same hour for the past 10 days (excluding weekends, holidays and prior event days) is averaged to determine the baseline energy use for that hour. The value provided by the TES system is then determined as the difference between the baseline and the measured energy use for that hour.

RESEARCH METHODOLOGY

Whole-building simulations were used to model the electric grid impact of TES systems. Simulations were performed for four building types and five types of cooling systems in three California climate zones (CZ). The TES systems investigated were ice storage and stratified chilled water tanks integrated into a chilled water loop that supplies the building with cooling. The building types simulated include: a ten-story office building, a "big box" retail store, and a hospital. The types of cooling systems simulated included: a direct expansion RTU, an air-cooled constant-speed chiller, an air-cooled variable-speed chiller, a water-cooled constant-speed chiller and a water-cooled variable-speed chiller. Each building was simulated using weather data for Burbank, CA (CZ 9), Riverside, CA (CZ 10) and Sacramento, CA (CZ 12).

TRACE 700 Load Design software was used to simulate each building type and produce hourly cooling loads for each of the buildings. The cooling loads and ambient weather conditions were then input into a post-processor that calculated the electric-grid impacts incurred from meeting the loads using each type of cooling system, as compared to using a TES system to meet the loads.

The simulation results were used to investigate the "10-day average baseline" valuation of TES. The twelve hottest four-hour periods of the year (excluding weekends and holidays) were chosen as event days. The "10-day average baseline" method was then applied to simulation results and the predicted baseline was compared to the "actual" simulated electricity consumption.

RESULTS

The comparison of the "10-day average baseline" valuation and "actual" simulated electricity consumption offset on the twelve chosen event days for the 10-story office building with an air-cooled variable-speed chiller in Sacramento is shown in Figure 2.

The 10-day average baseline consistently under-predicts the impact that disconnecting the cooling system would have on the electric grid. For this simulation, Monday, July 10th followed a particularly hot weekend; the office building is unoccupied on weekend days over which time the temperature is allowed to drift, resulting in a significantly higher load on Mondays following a hot weekend. Thus, the 10-day average baseline significantly under-predicts both energy use and peak power draw of the cooling system on this day because it excludes weekends, holidays and event days and does not account for the dynamic nature of the building load. Additionally, with weekends, holidays and event days excluded, the average temperature of days used in the 10-day average baseline are significantly cooler than the event days, resulting in a consistent under-valuation of a TES system.

Figure 1 shows the minimum, maximum and average percent error of the "10-day average baseline" method for all twelve event days. For these simulations, the 10-day average baseline method for determining the value of a TES system under-predicts its impact on the electric grid by as much as 77%, between 38% and 57% on average, and by a minimum of 3%. The average prediction error of the 10-day average baseline method for each building type, cooling system and climate zone simulated is shown in Table 1.

Figure 1 – The minimum, average, and maximum error between the 10-day average baseline and the actual energy offset for the 10-story office building in Sacramento with each cooling system

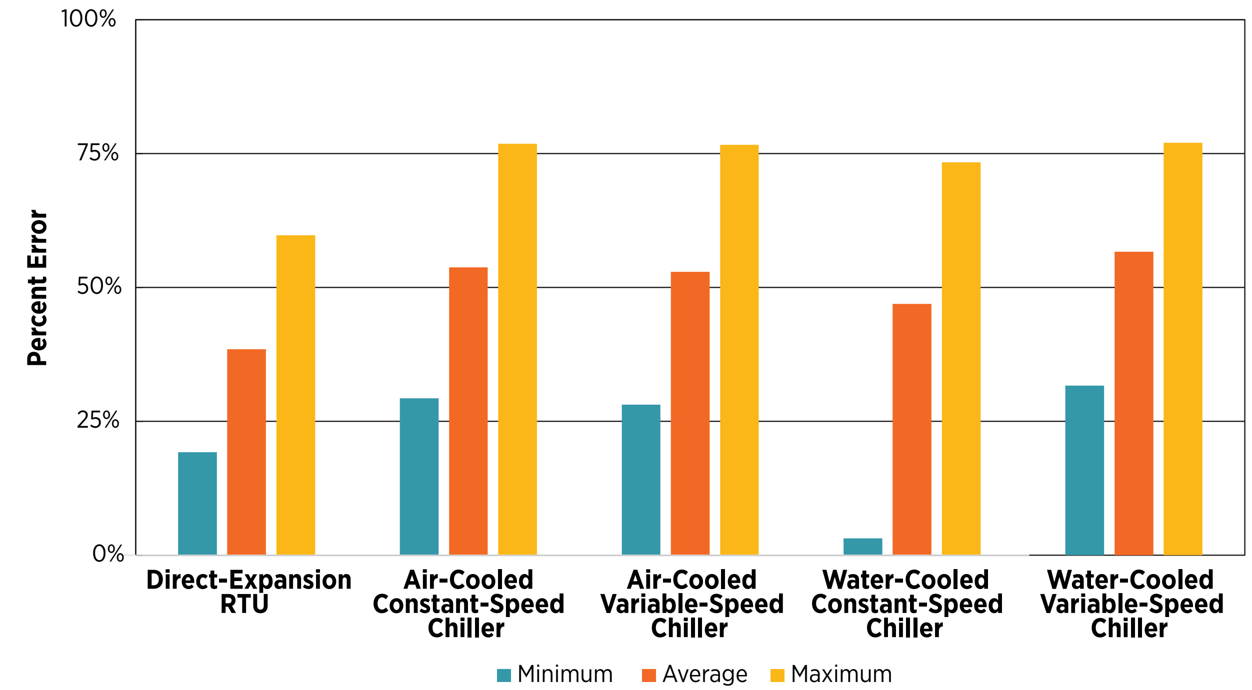
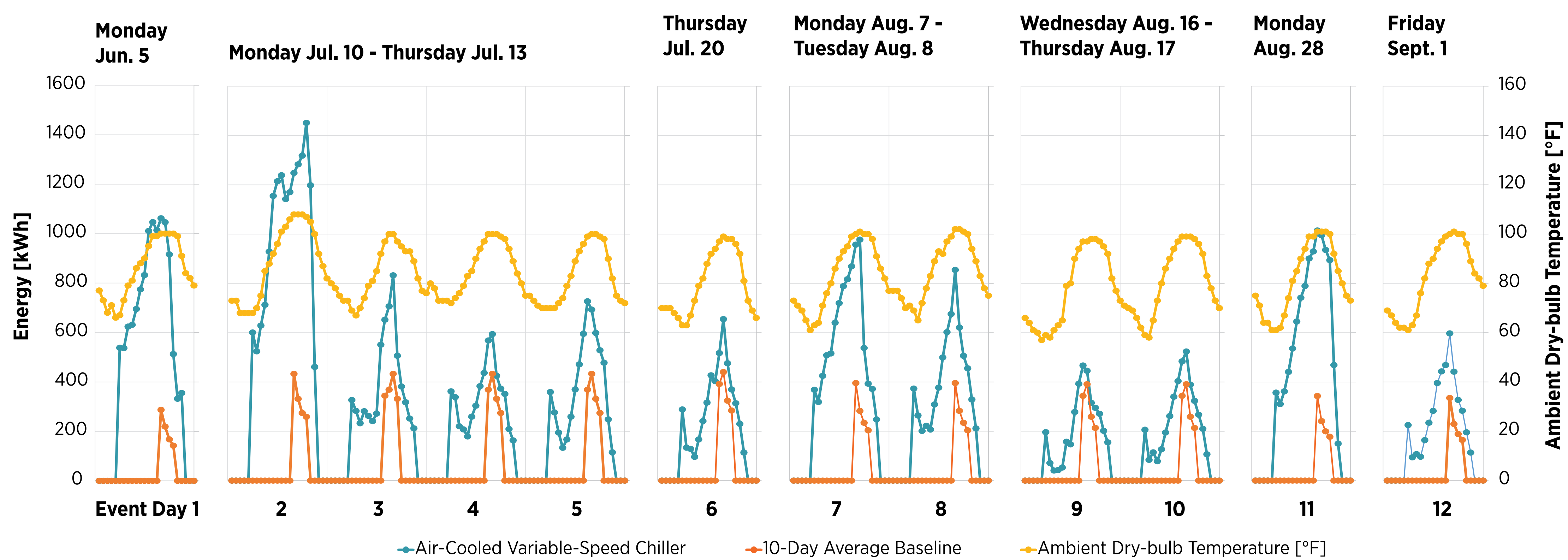


Figure 2 – 10-Day average baseline and actual energy offset for the 10-story office building with an air-cooled variable-speed chiller in Sacramento



RESULTS SUMMARY

		Direct-Expansion RTU	Air-Cooled Constant-Speed Chiller	Air-Cooled Variable-Speed Chiller	Water Cooled Constant-Speed Chiller	Water Cooled Variable-Speed Chiller
Burbank	Large Office	41%	54%	54%	45%	47%
	Big-box retail	41%	55%	56%	49%	52%
	Hospital	33%	44%	44%	35%	34%
Riverside	Large Office	41%	54%	54%	45%	47%
	Big-box retail	34%	48%	48%	45%	46%
	Hospital	29%	40%	41%	37%	33%
Sacramento	Large Office	38%	54%	53%	47%	57%
	Big-box retail	30%	43%	43%	38%	50%
	Hospital	23%	34%	34%	27%	33%

Table 1 – Average prediction error of the 10-day average baseline

PROPOSED ALTERNATIVE METHODOLOGY

A potentially more accurate method for determining the electric grid impact of TES systems would be to measure the cooling delivered by a TES system, and then compare it with the electricity that would have been consumed to deliver that cooling at that time in that application. Determining the electric demand that *would* have been required by the primary cooling system, which may depend upon cooling equipment type and the particular application, becomes the primary challenge. One solution is to continuously monitor the performance of the particular cooling equipment in that application, and use the data to build a model of the relationship between ambient conditions, cooling delivered and electricity use.

SUMMARY

The accurate valuation of thermal energy storage devices is important for both resource adequacy planning and providing proper financial compensation for the service that they provide. Since system capacity values in electric power transactions are based upon predicted, but rare, heat storm impacts, a reliable and verifiable methodology is a critical missing link in equitably and accurately valuing, verifying, and compensating distributed energy resources in the marketplace. We believe that the current valuation methodology is unacceptably inaccurate, and that the proposed alternative merits further detailed investigation.

ABOUT WCEC

The Western Cooling Efficiency Center was established along side the UC Davis Energy Efficiency Center in 2007 through a grant from the California Clean Energy Fund and in partnership with California Energy Commission Public Interest Energy Research Program. The Center partners with industry stakeholders to advance cooling-technology innovation by applying technologies and programs that reduce energy, water consumption and peak electricity demand associated with cooling in the Western United States.

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