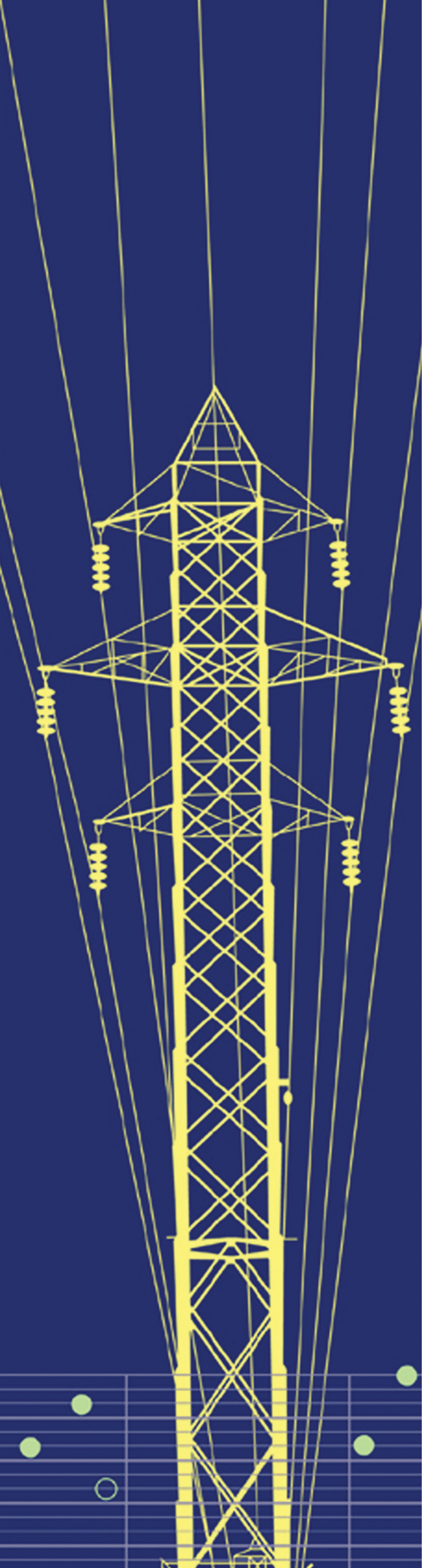

California's Title 24 & Cool Storage

By Mark MacCracken, P.E., Member ASHRAE

Most U.S. states use ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings.* However, the standard does not specifically address permanent peak load reduction. California changed its building codes to more directly approach reducing peak demand. If this innovative strategy proves successful, it could signal the adoption of significant changes to building codes nationwide.

In October 2005, Title 24-2005, *California's Energy Efficiency Standards for Residential and Nonresidential Buildings,* was enacted. Possibly the most dramatic change is the adoption of time dependent valuation (TDV). TDV is the "currency" for evaluating building performance. TDV replaces source energy, which had been the accepted currency since the California Energy Commission (CEC) first instituted energy standards in 1978.[1]

About the Author

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The CEC 2005 Compliance Manual states:

> *TDV, as the name implies, values energy differently depending on the time it is used. This means that electricity saved on a hot summer afternoon will be worth more in the compliance process than the same amount of electricity saved on a winter morning. The value assigned to energy savings through TDV more closely reflects the market for electricity, gas, propane and other energy sources and provides incentives for measures such as thermal storage or daylighting, which are more effective during peak periods.*[2]

Previous versions of the code attempted to restrict a building's consumption of energy in one of two ways, either by prescribing the minimum efficiency a device may have or by a performance-based approach, which was determined by computer simulation. The latter method calculated the kilowatt-hours the building used and then multiplied the total by a constant heat rate (Btu/kWh) factor to obtain a total quantity of source energy for electricity. Adding natural gas use to that total established the total building source energy. That total had to be less than a base building to be in compliance.

California's energy crisis of 2001 made it clear that the state's overall energy consumption is only part of the problem. Conservation of energy in the summer, daytime, high-demand periods is apparently a more immediate and possibly a more critical issue to the stability of California's energy supply than just overall energy reduction. In fact, the CEC Web site states that one of the compelling reasons for changing the code in 2005 was to "emphasize energy-efficiency measures that save energy at peak periods and seasons."[3] The 2001 Title 24 code changes did not address peak load reduction directly though they reduced electricity demand by about 150 MW each year. The new code, under TDV now strongly "favors peak energy-saving measures over off-peak measures."[4] The 2005 codes are expected to reduce electricity demand by another 180 MW each year.[5]

Traditional air-conditioning systems are the single largest contributors to peak demand, greatly aggravating the strain imposed on the existing electrical supply infrastructure. They perform two basic functions, namely to create and distribute cooling. However, the inclusion of storage to the system decouples these two functions, making possible a dramatic reduction of peak demand.

TDV Energy Implications and Beyond

A number of studies[6,7] have demonstrated that it is more efficient to generate and distribute power at night than to do so during the day. Although some of the inefficiency was due to daytime power line losses, the study showed that the main cause of the inefficiency was peaking plants. While base load power plants run with heat rates in the range of 8,000 Btu/kWh, peaking plants operate in the 11,000 Btu/kWh range (±2,000). By using off-peak energy, the utility should[*] save source energy, while supplying the same usable unit of energy to the building.

Although the TDV numbers for electricity have the same units as a power plant's heat rates (Btu/kWh) and incorporate those hourly variations, they are much more than simply heat rates. They also reflect the societal and environmental implications of the use of on-peak power such as:

- On-peak power supplied to California is nearly twice as dirty as off-peak;[*,8]
- Peak shifting results in lower greenhouse emissions;[*,9]
- If California were to meet its own energy needs, it would have to locate sites for additional power plants; and
- More plants require more transmission lines and enhancing distribution systems to get energy from the transmission lines to buildings.

On-peak power impacts our society in many ways that are hidden from the kWh the meter records. That's why the CEC has focused on the TDV of energy.

The code uses TDV whereby it assigns a value (k-Btu/kWh) to every hour of the year (8,760 hours/year). *Table 1* shows that in Zone 10 at 4 p.m., for one kWh you will be "charged" 74,385 Btu, while at 4 a.m. it would 16,298 Btu. Whereas this ratio is 4.5:1 from daily high to night low, the average 12 hours from 10 a.m. to 9 p.m. vs. 10 p.m. to 9 a.m. is 2.75:1. This is a large difference for the same kWh. (Designers should remember that this is not related to the actual cost of energy (see sidebar, *How Cool Storage Saves*).

Over the course of the year, the average difference between daytime and nighttime multipliers can be as low as 20% in the winter to more than 275% in the summer.

To comply with the Title 24 code when using the performance compliance approach, a building's TDV Btu use must not exceed a usage amount calculated for a base building. This is determined by taking the engineer's simulated hourly electric and gas requirements for the building, multiplying each hourly requirement by the hourly TDV then totaling them.

Cool storage offers engineers a powerful means of shifting kWh from on-peak to off-peak periods, when the TDV charges might be half of what they are during the day, while being transparent to the occupants (see sidebar). As of Oct. 1, 2005, all new buildings in California seeking a certificate of occupancy were to be analyzed in this way.

Air-Cooled vs. Water-Cooled Chillers

Title 24 code, under Section 144 (i) (which is in the prescriptive section), also states that buildings with chilled water plants larger than 300 tons (1055 kW) total capacity can only use air-cooled equipment to meet up to 100 tons (350 kW) of

* Savings are dependent on utility's specific mixture of generation resources and can vary widely by region.

the load, unless they use a cool storage system.** Though water-cooled chillers operate more efficiently, it was recognized that some applications might not be appropriate to support the maintenance associated with a large water-cooled system. Air-cooled chillers are a simpler alternative despite their higher energy consumption. With lower night-time ambient temperatures, air-cooled chillers run more efficiently at night when charging storage. Coupling that with more efficient power generation and less pollution at night, cool storage with larger air-cooled systems strikes a balance in energy, demand and market realities.

Incentives, Sustainable Buildings and Title 24

The two basic methods for complying with Title 24 are: (1) prescriptive, in which equipment is chosen that meets at least the minimum efficiency requirements, or (2) the performance compliance approach, which is where TDV is used. Although the performance method is more detailed, it allows for greater flexibility. For instance, a daylight atrium could not be considered under the prescriptive method, but it could be computer modeled.

** Two other exceptions include extremely bad water quality and super-high efficiency air-cooled chiller.

Performance compliance allows for an energy budget comparison between a prescriptive building and a proposed building. For California's "Savings by Design" programs, beating Title 24 by 10% qualifies the project for incentive funds and this can only be done using the Performance Compliance (TDV) method.

This is also the case if the goal is to go for a U.S. Green Building Council Leadership in Energy and Environmental Design® (LEED) rating. LEED is widely accepted throughout the country, and is being mandated in about 50 cities.[10] Many California cities are part of that movement. In LEED, the Energy and Atmosphere section requires the use of Standard 90.1-2004 or, if specific requirements are met, the local energy code. The USGBC currently considers Title 24-2005 equivalent to Standard 90.1-2004. Therefore, in California, Title 24 must be used for code compliance and, therefore, TDV is the metric.

Cool Storage and California

California has its share of cool storage installations, many of which were installed from 1988–1995 when utilities were giving out large incentives to a relatively young technology. Although many installations were successful, many were not because most had unproven technologies and poor applica-

How Cool Storage Saves

With large cool storage systems, the distribution of cooling in a building still relies on circulating a chilled heat-transfer-fluid to fan-coils around the building, however, the chillers operate during off-peak periods to create the cooling. The "coolth" created at night is then available to provide cooling during the more expensive on-peak periods. Whether you check utility rates in New York, Detroit, Dallas, Atlanta, Florida or California, summertime electricity is 50% to 70% less expensive at night when demand charges are factored in. And, even in areas where flat rates are offered, with no demand charge, the rate you receive normally will be based on your load factor (the higher the load factor, the lower your flat rate). Cool storage not only dramatically reduces the use of peak-period, high-cost energy; it can also reduce total energy usage by as much as 13%.[12,13]

The chillers produce either ice or chilled water during lower-priced,[14] off-peak periods. When the higher daytime rates come into effect, the stored cooling can be used to meet the entire cooling load or used to supplement the system. If used to supplement the system, chiller efficiency is improved by allowing more continuous chiller operation at outputs closer to full capacity and at elevated leaving chilled water temperatures, minimizing part-load losses.

Some of these systems also reduce the size of the building's air-conditioning equipment including chillers, cooling towers, pumps and electrical service.[13]

In new construction (multi-chiller system), initial costs for cool storage are often comparable to non-storage cooling systems.[15] The installed cost of a ton of chiller plant varies widely across the U.S., however, a range of $1,000 to $1,500 normally covers it. Storage also has a wide range depending on the type and size of system (water or ice, 1,000 or 100,000 ton-hr [3500 kWh or 35,000 kWh]) however a reasonable range is $80 to $150/per ton-hr ($23 to $43 per kWh). Normally, for office buildings or school applications, 8 to 10 ton-hr (28 to 35 kWh per kW cooling) per ton of building load is needed. Therefore, storage can cost less or more than the chiller plant it is replacing, depending on the specific applications.[16]

In retrofit applications the opportunity to add storage is normally driven by combining with some other required change in the buildings HVAC system: replacing worn out chillers, building expansion, increase in building electrical requirements or even new financial incentives from the local power suppliers. Retrofit simple payback periods normally range from two to six years but can vary widely with application. The U.S. Department of Energy reports that many ice storage "applications can result in lower first costs and/or higher system efficiency compared to non-storage systems."[17] The *ASHRAE GreenGuide* acknowledges that because ice storage "allows downsizing of the refrigeration system, the resulting cost savings may substantially or entirely cover the added incremental cost of the storage system."[18]

tions.[11] However, after another decade of experience, cool storage has matured as an industry and has more than 6,000 installations of water or ice, shifting thousands of megawatts from on- to off-peak.

Conclusion

TDV recognizes that although a kilowatt of power provides the same amount of energy all of the time, it is more valuable during the day than it is at night. California has devised a means to incorporate the societal impacts of not only how much energy is used, but when energy is used. To conform to Title 24-2005, architects and builders need to document that the new building's proposed design outperforms the standard design for a building with similar square footage. Engineers need to carefully analyze demand and consider any technology that reduces it without sacrificing comfort.

Although other technologies reduce peak demand, cool storage addresses the largest moveable electric load in most buildings. Systems are available in sizes ranging from residential to the largest public or private applications. Cool storage is a time-tested technology for shifting the use of energy from high-demand to low-demand periods. As Title 24 is better understood and adhered to, Storage will help engineers, architects and owners meet and exceed the code stipulations while helping reduce energy and greenhouse gas emissions to the atmosphere. With California leading the way in building codes, it is likely that other states will follow.

Time	kBtu/kWh	Time	kBtu/kWh
10 a.m.	22.7295	10 p.m.	21.7227
11 a.m.	44.7760	11 p.m.	19.2206
12 p.m.	54.4716	12 a.m.	18.4768
1 p.m.	59.5638	1 a.m.	18.1549
2 p.m.	65.6748	2 a.m.	17.0175
3 p.m.	71.7795	3 a.m.	16.6066
4 p.m.	74.3851	4 a.m.	16.2981
5 p.m.	70.9266	5 a.m.	16.4607
6 p.m.	54.3763	6 a.m.	17.3810
7 p.m.	31.6903	7 a.m.	18.6771
8 p.m.	26.3406	8 a.m.	18.9721
9 p.m.	25.6602	9 a.m.	19.3239

***Table 1:** Time dependent valuation (TDV) Zone 10, Aug. 13.*

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