California Energy Crisis
The Thermal Energy Storage Solution

Reducing Power Plant Pollution
and Source Energy Requirements
by 35% to 55%,
While Reducing Peak Electrical Demand
and Natural Gas Pipeline Congestion

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Foreword

This paper deals mainly with the energy crises facing California and the Western area power grid. The concepts discussed herein apply to any utility, state or region facing pollution issues, power generation capacity shortages, or transmission and distribution congestion and having the desire to improve power plant efficiency and reduce the need to build new power plants.

Solving our energy problems is a complex undertaking and while there is no one silver bullet, there are many proven technologies and business models that applied collectively or individually can bring real improvements. One such technology that can provide immediate benefits is Thermal Energy Storage (TES).

- Thermal Energy Storage is the simple process of cooling (or freezing) water during the evening hours and storing it for use the next day to air condition large commercial, industrial and institutional buildings.
- TES is the rough equivalent of building electricity generating power plants in the sense that TES taps the unused capacity in our existing power plants at night when they are typically operating at very low output levels.
- Using TES in lieu of building new power plants allows for an effective increase in capacity during the peak usage hours, without any of the negative environmental impacts associated with building new power plants.
- TES simultaneously increases the efficiency of existing transmission and distribution facilities in addition to the benefits it provides for generation plants.

- **With properly crafted incentives and rate structures, the private sector could be enticed to contribute a significant percentage of the capital required to build a very large number of TES systems in California, essentially subsidizing other ratepayers.**

TES is a fully-proven technology that can improve power plant efficiency by 20% to 43%, improve cooling system efficiency by up to 25%, and reduce cooling system related peak electrical demands by 60% to 80% on the hottest summer afternoons, by shifting major air conditioning related electrical loads to the night instead of the afternoon.

Properly designed, implemented and commissioned TES systems provide long term benefits to all ratepayers and the environment.

It is a simple concept on its face – if a power plant can be made more energy efficient, it will use less fuel. If it uses less fuel, it will produce fewer emissions and the environment will be improved from the resulting reduction in harmful greenhouse gasses, acid rain, and toxic pollutants such as mercury.

Sustainable peak demand reduction will reduce the potential for costly brownouts or blackouts as well as reducing the need for expensive infrastructure improvements. This improves the reliability and affordability of electric power for all ratepayers.

One Engineer has been quoted as saying “Think of TES like a 1,000 MW power plant that consumes no natural resources, and reduces pollution from other power plants, and you can persuade building owners to pick up half the cost of the system that benefits all of the ratepayers.”

We feel that TES can and should be part of the long term solution to our energy crises, as well as the multitude of environmental issues that arise when new power plants and T&D systems are constructed.

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1. Executive Summary

Background

Within the State of California, we face a peak-demand related shortage of generation capacity. An April 13, 2005 article in the Wall Street Journal noted that another 5,000 to 9,000 megawatts of installed generation capacity may be retired in the next few years. This will worsen the problem.

We also have transmission and distribution (T&D) bottlenecks known as "congestion" in some areas that restrict the ability to deliver energy where it is needed.

Air conditioning and process cooling loads are key contributors to this peak electrical demand problem. Approximately 35% to 40% of the peak electrical demand for large commercial office and institutional buildings is air conditioning related.

Thermal Energy Storage (TES) can eliminate approximately 60% to 80% of the peak electrical demand related to air conditioning for many large commercial office and institutional buildings by transferring most of that air conditioning energy use to the previous night.

TES is a proven technology that began over 80 years ago, when electricity prices were high, and electrical systems were unreliable.

Description

TES acts as a storage battery for air conditioning systems – the cooling is done at night, when electrical demand is low and generation or transmission and delivery capacity constraints are minimized. This cooling energy is stored in a tank for use the next afternoon. During the afternoon, the main air conditioning equipment is shut off. The cooling is then supplied to the building by the "battery", thus reducing the power usage during peak hours (when electrical demand is at its highest and power generation equipment efficiency is at its worst).

One key difference between this "air-conditioning battery" and a typical battery is that the air-conditioning battery is over 130% efficient – it takes far less source and site energy to charge the air conditioning battery at night when it is cool than it would take to run the air-conditioning system on hot afternoons, when power plant and air-conditioning equipment are at their poorest efficiency levels.

Benefits

TES systems provide multiple benefits, which accrue variously to TES owners, to other ratepayers and users of the electric grid, to electric generators, to T&D system operators, to the general economy, to the environment, to minimizing fuel use and fuel imports, to overall power system reliability, and to the general public:

1. **A California Energy Commission (CEC) study, P500-95-005, concluded that using power at night instead of during the afternoon can reduce power plant energy consumption and pollution by 20% to 43%, as base-loaded power plants running at night when it is cooler are far more efficient than peaker plants being operated in the heat of the day**.

    a. Reducing peaking plant energy consumption reduces the natural gas demand on the system, which is a growing issue in California.

2. This same CEC study predicted an improved electric power grid efficiency of slightly less than 5% due to lower T&D losses. Power is consumed at night when demand is low, and the equipment and transmission lines run cooler. Cooler equipment and power lines exhibit lower losses, reducing costs for all grid customers.

3. A properly constructed TES program can be used to induce building owners to pay for half the cost of the “power plant”, reducing costs for all ratepayers.

4. A properly designed TES system can reduce on-site energy consumption by up to 20% on an annual basis, when compared to a “typical” cooling system that meets Title-24 energy efficiency standards. Energy efficiency improvements of up to 25% can be obtained when comparing a high efficiency TES based system to an existing air conditioning system.

5. TES can be used to reduce the need for additional power plants, while extending the capacity of the existing T&D systems.

6. The overall cost of implementing, operating and maintaining TES systems is lower than the cost to meet the peak electrical demands by increasing generation and T&D capacity.

7. When on-site, T&D, and source (power plant) benefits are combined, TES systems can improve the overall system efficiency by 35% to 55%.

8. **This improvement in efficiency and reduced power plant fuel consumption has a corresponding dramatic reduction in criteria pollutants (NOx, SOx and particulates) and in greenhouse gases emitted to the environment.**

9. TES improves the daily load factor on power plants and T&D systems, benefiting generators, energy suppliers and California's consumers alike.

10. TES can be widely implemented in a fraction of the time it takes to design, permit, install and commission new power plants and infrastructure improvements.

11. When a central station power plant is constructed, the ratepayers pay the entire cost of the system, including overhead and profit, plus ongoing maintenance and repair costs – these costs are all bundled into what ratepayers pay.

12. If utility rates are modified, it is possible to induce building owners to pay for up to half the cost of the TES system. This benefits all of the ratepayers, not just the facility owners.

13. The building owners pay all ongoing operations and maintenance costs that would otherwise be borne by the ratepayers.

<u>TES Hurdles</u>

Many large building and campus sites are conducive to TES installations, if there are adequate financial returns. In the past, many TES installations occurred. However, there exist today substantial barriers to implementing TES projects.

Current utility rates are not constructed in a manner that adequately encourages the use of Off-Peak energy while discouraging the use of On-Peak energy.

Many major on-peak cooling users such as hospitals, industrial processes, and university and college campuses typically have financial constraints that eliminate energy conservation and demand reduction projects such as TES when the simple payback periods are in excess of three years.

Since previous TES installation incentives have been eliminated, the number of major new TES installations in California has dropped to near zero.

Commercial office buildings are excellent TES candidates. Unfortunately, there are essentially no financial benefits to commercial building owners given the meager investment returns and the fact that the utility cost savings that result from installing TES flow mainly to the tenants of the building rather than the building owners that would make the investment.

A large TES system can cost several million dollars to install. Without adequate financial returns, building and facility owners will not make investments in TES systems.

Accordingly, we propose specific actions to encourage and reward the increased use of TES to benefit all ratepayers, the energy supply infrastructure, the environment, and the economy of California.

2. Recommendations

The following steps will promote investment in TES and provide a sustainable, cost effective, environmentally sound alternative to higher cost traditional power plants, T&D upgrades, and rate designs that discourage business investment and stifle economic growth.

- Encourage TES on a long term basis by making it a priority Demand-Side Management (DSM) technology in energy policy decisions.

- Initiate TES-DSM incentive programs that provide for a reasonable investment recovery period. These incentives could be in the form of buydown payments, rebates, and/or tax incentives.

- Structure TES installation incentives such that projects that yield greater efficiency improvements are eligible to receive larger incentives. Efficiency measurement should be based on the annual efficiency improvement of the system when compared to the existing conditions at the building site for existing buildings and against Title 24 standards for new construction. It is important to note that in order to be more attractive, a greater efficiency improvement should yield a larger incentive.

- Develop long term, stable rate structures that encourage Off-Peak energy use, while providing adequate financial incentives when compared to typical TOU (Time of Use) rates.

- Develop a TES rate structure. The TES rate structure would provide a high reward for off-peak usage and a high reward for on peak reduction when compared to the typical time of use rates for large customers that are currently in place. This would greatly improve the financial returns for TES.

- Direct the CEC to:

    - Work with the EPA Energy Star and the US Green Buildings Council LEED programs to ensure that the on-site and source energy and emissions benefits of TES are recognized in those programs.

    - Develop guidelines and examples for TES-DSM system design based on previous experience with successful projects, to encourage effective TES design and system integration.

    - Work with the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE), the Association of Energy Engineers (AEE) and other engineering and facilities management interest groups to educate their constituents on the new programs and encourage them to implement TES in their facilities.

    - Work with the Building Owners and Managers Association (BOMA) and the American Institute of Architects (AIA) to develop educational seminars for their constituents to educate them on the benefits of TES.

    - Work with environmental advocacy groups to educate them on the benefits of TES, and request their assistance in promoting TES.

3. An Immediate Solution to the Energy Crisis

There is a very simple and time-proven solution to the energy crisis we appear to be now facing; and it can be widely implemented before the peak summer months of 2006 if building owners see it as a financially viable long term investment.

The cooling systems for many large commercial office buildings, universities, colleges, industrial manufacturers, and other private and institutional facilities can be modified to reduce their electricity usage by over 60% during the afternoon summer peaks, when electricity is needed most.

Thermal Energy Storage (TES) is a fully proven technology, and has been around since the 1920's, a time when electricity was very expensive, and the generation, transmission and distribution systems were unreliable.

Circumstances in 2005 are very similar to the early 20th century except for the fact that we now have solutions that have benefited from nearly one hundred years of technological innovation.

4. TES System Discussion

Commercial Property Owners

It is quite possible that the State of California could enlist hundreds of potential private partners in an effort to help solve the capacity crisis in the form of commercial, industrial and institutional property owners. If the State can create the proper conditions to induce these property owners to invest in TES, ratepayers, the general public and the state can all benefit. The incentives will have to have the effect of solving a long-standing, somewhat unique conflict within the realm of commercial property practice. Owners of most investor-owned commercial office buildings do not pay most of the electrical bills. The tenants of the buildings, in effect, pay the bills and receive the majority of the savings that accrue from energy efficiency or Demand Side Management measures.

When a commercial building owner makes a large investment in an energy efficiency and demand reduction system such as TES, a substantial portion of the immediate financial benefits of the installation goes to the tenants, not the building owners. Under the conditions set forth in most, typical commercial leases, there is minimal incentive for an owner to install TES or other demand reduction technologies, since the landlord invests the capital for it, while someone else gets most or all of the financial benefit (the tenants).

Owners can typically recoup part of their investments in energy efficiency and demand reduction projects through their lease arrangements by amortizing the original cost over time. However, if the simple payback period of the project is greater than 3 years, they lose a substantial portion of their investment due to tenant turnover. The simple payback period is defined as the project first cost divided by the annual savings. For example, a project costing $2,000,000 and reducing operating costs by $245,000 per year would have a simple payback period of $2,000,000/$245,000, or over 8 years, far too long for most owners or their capital partners to consider.

However, demand reduction and energy efficiency projects do add value to a building by lowering building operating costs, which in effect, reduces a tenant's rent. This provides some enticement to attract new tenants or for existing tenants to renew or extend their leases. As a result, some owners are willing to look at longer simple payback periods when evaluating these projects; but such owners are few and far between. Therefore, the solution is to provide a tax credit or a rebate, so that the building owner would be able to realize more than an insignificant portion of the TES project's benefit.

5. TES as an Energy Conservation Tool

In addition to reducing the air conditioning related peak electrical demand by 60% to 80%, a properly designed and implemented TES system can be used to reduce annual on-site electrical consumption by up to 20% when compared to Title 24 mandated efficiencies, and up to 25% when compared to the existing systems that they replace.

TES systems use most of their energy at night, when it is cooler (aiding heat rejection) and when the marginal power plant being dispatched for operation is much more fuel efficient). This actually improves the fuel efficiency of the power plants by a substantial margin (documented to be 20 to 43% by a past CEC study), as well as reducing losses in the T&D system (up to an additional 5%.

This was proven and documented in a statewide study conducted by the California Energy Commission in 1996 which evaluated the power plants then owned by PG&E and SCE. (CEC Study P500 –95-005)

Additionally, by removing load from the grid during the peak demand periods, the amount of line losses on the grid are substantially reduced. This reduction lowers overall costs, increases grid efficiency and reduces emissions for all customers.

Installation of TES systems usually results in better trained, more energy efficiency-oriented operating engineers. Once a TES system is installed, the financial penalties associated with running air conditioning equipment during the day can be very high, and building energy managers pay much closer attention to utility costs.

6. **TES as a Power Enhancement Tool**

Most peaking power plants use combustion turbines as their power generation source.

Combustion turbines (CT's) are very sensitive to the entering air temperature to the turbine – as the temperature rises, power production typically drops off by as much as 20% to 30% on the hottest afternoons, just when the highest demand for power exists.

TES can be used to provide the daytime pre-cooling effect in the inlet air to the turbines to improve power production. This is called Turbine Inlet Cooling (TIC).

TES supplied TIC systems can be in place prior to the summer of 2006 to provide additional power to the grid from the many existing peaker plants that are not currently equipped with this technology.

7. Bottom Line Benefits of TES

The bottom line benefits of a properly designed and implemented TES system are summarized below:

- Improves existing power plant efficiency and reduces capital outlays for new power plants and T&D infrastructure which results in lower overall costs to all ratepayers.

- Conserves natural resources by enabling the fleet of existing power plants to run more efficiently, as reported by the CEC study

- Conserves natural resources by reducing the need for new power plants that will burn more fuel and emit more pollutants

- Reduces the need for upgraded transmission and distribution (T&D) lines to deliver power supplanted by TES

- Helps eliminate bottlenecks in the existing T&D system and thereby lower the costs of transmitting power from existing central station power plants

- Quicker deployment of resources. TES systems can be deployed in a shorter time frame than designing, permitting and constructing new power plants. Depending upon the financial returns, large-scale TES systems can be implemented in adequate numbers and capacities to eliminate the short term need for additional generation capacity, and for T&D line upgrades.

- On large scale projects, TES can be effectively coupled with Distributed Generation (DG) to take advantage of the waste heat from the generators and use this heat to power special air conditioning equipment that uses heat to create cooling, improving the DG system efficiency.

- Utilizes private capital to pay for all ongoing maintenance costs, reducing costs for all ratepayers.

- Reduces peak electrical demands

- Improves the load factor on existing power plants

- Improves cooling system efficiency at the site level

- Improves the efficiency of the natural gas pipeline infrastructure

- Mitigates the risks of power shortages, potential power disruptions, energy price spikes, and their economic fallout

- Stabilizes the economy.

8. Financial Incentives Required to Secure Investment Capital from Building Owners

In order to encourage building and facility owners to invest in TES, and reduce the cost of power to all ratepayers, financial incentives must be offered to make the systems cost effective.

To achieve the type of investment that would meet minimum hurdle rates for most building owners, that is a simple payback between 3-5 years, an incentive of approximately $1,000 per peak period kW reduced would be required to ensure implementation of significant large scale TES systems by the summer of 2006.

Alternately, an incentive arrangement such as that offered by SCE for their recent lighting program may also be effective, if the rate structures can be adjusted to better reflect the actual cost of on-peak and off peak power.

If the TES installation incentive were to be set at $750 per on-peak kW reduced, and the per kWh savings incentive were to be set at $0.15 per on peak kWh removed, and $0.10 per mid peak kWh removed from the grid on an annual basis, and the incentive and per kWh incentives were paid to the owners, many owners would respond favorably.

At this level of incentive, some very “green” owners would consider adding TES to their portfolio of buildings, as the long-term value of the building would also be enhanced.

To reduce the simple payback period further to a more realistic 2 to 3 year range, the On-peak utility rate period could be changed to include a super peak cooling period of 4 or 5 hours.

In addition, a long-term utility rate structure contract should be developed and implemented that will ensure owners that their large investment will not be negated when a rate change occurs in a few years.

Many “Green” facility owners in the 80’s invested in TES, only to have the electric rate structures change in a dramatic fashion, which reduced or eliminated their financial returns.

9. Financial Comparison Summary

We have included the calculated results from a TES analysis that summarizes the findings of a specific TES project that was bid (but not ultimately built) in 1999.

The summary included in this report describes the construction costs and the calculated energy cost reductions for a 1,000,000 square foot new construction development project in Southern California. The following table lists the simple payback period for the project based on several installation incentive levels.

This project alone would have removed approximately 2,325 kW of peak electrical demand from the grid, enough to power approximately 1,600 homes.

This developer owns over 20% of the buildings in California that have received the EPA Energy Star energy conservation award.

They are a very “Green” and civic minded company, and were strongly in favor of installing TES. However, TES, with the installation incentives that were offered, did not meet their financial criteria. At the time, the project was offered an incentive of $650 per kW reduced.

After 6 weeks of evaluation by the company CFO and his staff, the TES project was shelved, over the objections of the operations staff, due to financial returns that did not meet the owner’s criteria.

If incentive levels were increased to an adequate level, the owners would gladly have installed TES at this site, and at several other sites that are excellent candidates for TES as well.

Since the TES system described was designed and bid prior to deregulation, the savings were calculated using past TES projects as a guideline, and assumed that savings under the deregulated environment would increase by 35%. The savings for a system analyzed using current rates will be lower than anticipated by this summary, since the pricing differential between off-peak and on-peak energy costs are not as high as was predicted in 1999.

The system was designed to provide a peak demand reduction of 2,325 kW, between the hours of noon and 6:00 PM.

The incremental first cost of the system, based on the bids received, was $3,996,000 ($1,719 per kW). The incremental first cost is the cost premium that the owner would have had to pay in comparison to installing the least expensive system that met Title-24 requirements. The calculated energy savings were $470,813 per year. Most of the savings would go to the tenants of the facility, not to the building owners who were paying for the system.

Below is the simple payback period for the system if various incentive levels are offered.

Incentive level, per On-peak kW reduced	Resulting first cost to Owner	Calculated simple payback period (Using estimated "post-deregulation" rates in 1999)	Approximate Simple payback period (Note 1.) (Note 2.)
$0.00 (no incentive offered)	$3,996,000	8.5 years	9.5 to 10 years
$500	$2,833,500	6.0 years	7 to 7.5years
$600	$2,601.000	5.5 years	6.5 to 7 years
$700	$2,368,500	5.0 years	6 to 6.5 years
$800	$2,136,000	4.5 years	5.5 to 6 years
$900	$1,903,500	4.0 years	5 to5.5 years
$1,000	$1,671,000	3.6 years	4.6 to 5.1 years
$1,100	$1,438,500	3.0 years	4 to 4.5 years
$1,200	$1,206,000	2.6 years	3.6 to 4.1 years
$1,300	$973,500	2.1 years	3.1 to 3.6 years

Note 1, using current utility rates instead of the rates that were estimated in 1999, the calculated simple payback periods would be extended by approximately 1 to 1.5 years (or more), as current utility rates are not "off-peak energy use friendly"

Note 2, The current rates in effect in SDG&E territory for large energy users effectively discourages the installation of TES, since the difference in energy costs per kWh between on and off peak is very small, and the difference between on and off peak demand charges is also relatively small.

Shortening the on-peak period from 6 hours down to 4 hours could reduce the first cost of the system, and thus shorten the simple payback period.

10. Price-Responsive HVAC Systems Interaction with TES

We have several air conditioning systems installed that combine the use of TES with basic thermodynamic principles to further reduce peak electrical demand from other parts of the air conditioning system, based on pricing signals.

When electricity gets expensive, the first instinct of many building operating engineers is to "demand-limit" the chiller systems, or shut a chiller off to reduce its power consumption. When this happens, the fans must use more energy to deliver a higher volume of warmer air in an attempt to cool the facility, outweighing the savings from the demand-limitation placed on the chiller system.

A TES system sized for ample capacity, while drawing minimal power during the peak afternoon loads, provides a means to modify the typical operating strategies, without any discernable negative impacts on building or facility operations or occupant comfort.

If one allows the room temperature to increase by one or two degrees, in conjunction with a lower supply air temperature, one can reduce the fan energy by over 80%.

These added demand reductions require that the TES system be properly designed and controlled as an integrated system with the air handling units. This can be easily accomplished, given adequate funding and proper commissioning.

11. Use of the California Energy Commission Paper

Much of the information contained in this report has been based on the California Energy Commission white paper titled "Source Energy and Environmental Impacts of Thermal Energy Storage" dated February 1996. The document number is P500-95-005.

Other information has been obtained from personal experience of the Author, the editors of this report, affiliated industry colleagues, and from many different building owners and/or their representatives.

12. **Our Qualifications**

We are Consulting Engineers who have worked with the CEC, PG&E, SCE, SDG&E, the L.A. DWP, the Riverside Public Utility and SMUD on TES and other demand reduction/energy efficiency projects over the past 20 years.

We have been involved in several dozen successful TES projects.

Our TES projects have won Utility and Federal Energy Conservation Awards, proving that TES and energy conservation are not mutually exclusive terms, if they are properly designed and implemented.

We have collaborated on many projects, and in the preparation of this report, with affiliated industry colleagues and end-users whose experience and qualifications reinforce and complement ours. One consulting colleague has over 20 years of experience on over 100 large TES projects, on 5 continents, representing hundreds of Megawatts of peak demand management. Another colleague oversees energy use for a State University campus system, currently employing TES on 14 campuses and already reducing peak power demand by over 30 Megawatts.

But much more should, can, and will be done --- with the proper TES incentives and rates in place. Properly designed rates and TES installation incentives will not cost the State, but will SAVE energy, emissions, infrastructure problems, and money, compared to the “business as usual” option of building more central station power plants to meet increasing electrical demands.

If you would like more information regarding TES or other demand reduction and energy conservation technologies, or our ideas as to how an implementation plan to expand TES applications could be put into effect in a short period of time, we would be very interested in meeting with you.

Construction time may impact the ability to install large-scale demand reduction projects. If you are interested in reducing pollution, reducing the need for new power plants and improving the efficiency of the existing power plants and T&D systems, please feel free to contact us at your earliest convenience.

13. **Report Editors**

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Their concern for the future of California is appreciated.

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