Thermal Energy Storage (TES):
Load Management? Of Course.
Economical? Certainly.
But Is It Energy Efficient?

John S. Andrepont, President
The Cool Solutions Company

IDEA Annual Conference
Indianapolis, Indiana – June 2010

Outline

- Introduction to Thermal Energy Storage (TES) for District Cooling
- Load Management Impact of TES
- Economics of TES
- Energy / Environmental Aspects of TES
- Role and Value of TES for District Energy
- Summary and Conclusions

Terminology

- CHP - Combined Heat & Power (cogen)
- CHW - Chilled Water
- CT - Combustion Turbine
- DC, DE - District Cooling, District Energy
- LTF - Low Temperature Fluid
- RTP - Real Time Pricing
- TES - Thermal Energy Storage
- TIC - Turbine Inlet Cooling

Introduction and Background

- TES is often employed in DC systems:
  - district energy utility systems
  - college / university campuses
  - hospital / medical facilities
  - military / other government facilities
  - private industry
- What are the impacts in terms of:
  - Peak electric demand management?
  - Operating and capital costs?
  - Energy use and environmental issues?

Types of TES for District Cooling

- Latent Heat TES Systems
  - Typically, *Ice* TES

- Sensible Heat TES Systems
  - Typically, *Chilled Water (CHW)* TES
  - Also, *Low Temp Fluid (LTF)* TES

Latent Heat TES Systems

- Phase change TES - latent heat of fusion
- The TES medium:
  - usually water (ice) - 32 ºF phase change temp
  - eutectic salts and paraffin waxes have also been used - warmer (or cooler) phase change temps
- Latent Heat TES System Types:
  - *Static* - solid is frozen, stored, and melted all in one place
  - *Dynamic* - solid is frozen, but then stored and melted away from where it was frozen

Latent Heat TES Systems

- Inherent Benefits, typically:
  - relatively compact storage volume
  - capability (of some ice TES designs) for low supply temps during discharge (34 to 44 ºF typ.)
  - standard modular units for small to moderate sizes
- Inherent Drawbacks, typically:
  - low temps required for charging ice TES
  - relatively little economy-of-scale

Sensible Heat TES Systems

- Sensible heat TES - sensible heat (Delta T)
- The TES medium:
  - usually water - 39 to 42 ºF supply temps typ.
  - alternatively, LTF for stratification below 39 ºF
- Sensible Heat TES System Types
  - *Thermal Stratification* - warmer & less dense return fluid stored above cooler & more dense supply
  - others - multi-tank, baffle-tank, diaphragm-tank, labyrinth-tank; rarely installed since the 1980s

Sensible Heat TES Systems

- Inherent Benefits, typically:
  - relative simplicity and efficiency - due to relatively constant, warm oper’g temps (discharge = charge)
  - dramatic economy-of-scale - low capital cost per ton-hr or per ton, for large applications such as DC
- Inherent Drawbacks, typically:
  - Large storage volume (but reduced by 33 to 50% for LTF TES, though still larger than with Ice TES)
  - CHW supply temp limit of 39 to 40 ºF for stratified CHW (but 36 ºF, 32 ºF, and lower, with LTF)

Inherent Characteristics of TES

(typical generalizations only)	Ice	CHW	LTF
Volume	good	poor	fair
Footprint	good	fair	good
Modularity	excell	poor	good
Economy-of-Scale	poor	excell	good
Energy Efficiency	fair	excell	good
Low Temp Capability	good	poor	excell
Ease of Retrofit	fair	excell	good
Rapid Charge/Dischrg Capability	fair	good	good
Simplicity and Reliability	fair	excell	good
Can Site Remotely from Chillers	poor	excell	excell
Dual-use as Fire Protection	poor	excell	poor

Peak Load Mgmt with CHW TES

DE Owner - Location	Capacity (Ton-hrs)	Demand Svg (MW x hr/d)
Washington St U - Pullman	17,750	2.1 x 7
Climaespaco - Portugal	39,800	4.3 x 7
U of Alberta - Canada	60,000*	5.8 x 8
Chrysler Tech Ctr - Michigan	68,000	5.3 x 9
OUCooling - Florida	160,000*	16.6 x 8
SEC (TIC) - Saudi Arabia	193,000	30.0 x 6

* pre-designed to expand (56-70%) from CHW to LTF

Net Capital Savings with CHW TES

(TES v chiller plant capacity) DE Owner - Location	Capacity (Ton-hrs)	Capital Svg (millions)
Washington St U - Pullman	17,750	$1 to 2
Climaespaco - Portugal	39,800	$2.5
U of Alberta - Canada	60,000*	$6.0
Chrysler Tech Ctr - Michigan	68,000	$3.6
OUCooling - Florida	160,000*	over $5
SEC (TIC) - Saudi Arabia	193,000	over $10

* pre-designed to expand (56-70%) from CHW to LTF

Environmental Benefits of TES

On-site energy efficiency

- Inherent inefficiencies of TES can be small:
  - e.g. ambient heat gain + extra pumping energy
- Inherent efficiencies of TES can compensate:
  - night condensing + no low load oper (+ more “free” cool)
- Some TES document 5 to 15% less annual kWh/T-h

“Source” power plant efficiency & emissions

- TES shifts the power plant that is “on the margin”:
  - From on-peak times (high fuel use, high emission plants) to off-peak times (lower fuel use, lower emission plants)
  - Fuel, SO_2, NO_X, CO_2 often reduced 15 to 30% and more!

On-Site Energy Efficiency Benefits

Annual On-Site Energy Use for TES (vs Non-TES) System:

DC-TES Owner	CHW TES	Ice TES
Simulations		
• California State Univ.	87%	
• Los Angeles County	75-85%	
• State Farm Insurance	97%	
• hypothetical system	94-95%	105-106%
Measured / Reported Data		
• Arizona State Univ.	87%	
• Brazosport College	91-92%	
• Texas Instruments	88%	
• various (averaged)	0.63 kW/Ton	0.84 kW/Ton

Source Energy & Emission Benefits

Annual Source Energy & Emissions Savings:

	Chilled Water TES versus No TES	
	Wisconsin util #1	Wisconsin util #2
Energy Savings		
• fuel	15 to 18%	15 to 18%
Emission Savings		
• SO_2	19 to 29%	18 to 22%
• N_2O	20 to 30%	16 to 19%
• NO_x	16 to 19%	16 to 19%
• CO_2	11 to 17%	11 to 17%

Savings in: TX - 10-25%, CA - 20-35%, FL - 30-50%.

Savings increasing with growing use of Wind Power.

TES - Complement to Renewables

- E.g. consider a 40,000 Ton peak load DC system:

	Conv'l DC Sys	Deep Water DC Sys w/o TES	Deep Water DC Sys w/ TES
Chiller plant	40,000 T	0	0
Deep pipes/HX	0	40,000 T	30,000 T
Plant capital	$1,500/T	$3,000/T	$3,000/T
CHW TES	0	0	75,000 T-hr
TES capital	0	0	$80/T-hr
Total capital	$60 M	$120 M	$96 M
Energy use	0.7 kW/T	0.1 kW/T	0.1 kW/T

The Role of TES in Power Gen'n

- TES flattens/matches thermal & elec load profiles.
- CTs are increasingly used for power generation, including in DE / CHP systems. But CT power is derated at high inlet air temps, when power is most in demand and most highly valued.
- By cooling air from 90-100 ºF to 40-50 ºF, TES (either Ice, CHW, or LTF TES) can typically:
  - increase CT power output by 20 to 30%,
  - improve CT heat rate by ~5%,
  - and do so for ~1/2 the $/kW of a simple cycle CT.

Value for Future Market Conditions

- TES can have rapid charge/discharge capability:
  - Good match for RTP, “coincident demand”, spot mkt $’s.
- TES capacity can have phased expansion, e.g.:
  - Add modules of Ice TES
  - Increase Delta T of CHW TES
  - Convert CHW TES tank to LTF TES or Ice TES
- TES enhances use and economics of renewables:
  - Deep lake or ocean cooling sources; “free cooling” towers
  - Better matches loads for CHP or wind energy resources
- Increasing TES use in non-traditional applications:
  - Emergency cooling reserve for mission critical facilities
  - Supply-side energy storage in Turbine Inlet Cooling (TIC)

Summary and Conclusions

- TES reduces demand, cuts energy costs.
- Large CHW TES can save multi-million$ in CapEx.
- TES can reduce energy & emissions:
  - on-site energy; plus “source” fuel and emissions.
- TES can enhance the economics of DE & CHP.
- TES can enhance the economics of renewables.
- TES is demand-side & supply-side energy storage.

DE, CHP, and TES are in fact economical, and therefore truly sustainable envir’l technology.

Questions / Discussion ?

Or for a copy of this presentation, contact:

John S. Andrepont

The Cool Solutions Company

CoolSolutionsCo@aol.com

tel: 630-353-9690