Lessons Learned
from 35 Years of
Thermal Energy Storage Projects

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Outline

- Do's and Don'ts from 35 Years and over 100 Thermal Energy Storage (TES) installations, during various project phases:
  - Concept Design & Analysis
  - Detailed Design & Specification
  - Start-up and Operation & Maintenance
- Key Conclusions

Note: These "lessons" are personal, anecdotal, simplifications and generalizations.

Introduction

The value of storage continues to grow:

1. Air-conditioning drives demand growth and widens the gap between peak and baseload demand.
2. Time-of-day differentials grow in terms of: power plant marginal heat rates, emissions, and value of electricity.
3. Power gen from renewable energy grows, but often with a significant intermittent, or even out-of-phase, nature relative to demand (e.g. wind).

Thus, energy storage is critical for the electric power grid; but it must also be economical.

Concept Design & Analysis #1

DON'T

Ignore TES and simply add more chillers.

DO

Consider adding TES at any times of:

- New Construction,
- Retrofit Expansions, and
- Chiller Plant Rehabilitation.

Concept Design & Analysis #2

DON'T

Focus immediately on one TES technology.

DO

Initially consider and compare various TES options:

- Ice TES,
- Chilled Water (CHW) TES, and
- Low Temperature Fluid (LTF) TES.

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

Concept Design & Analysis #3

DON'T

Rely solely on utility rebates to justify TES.

DO

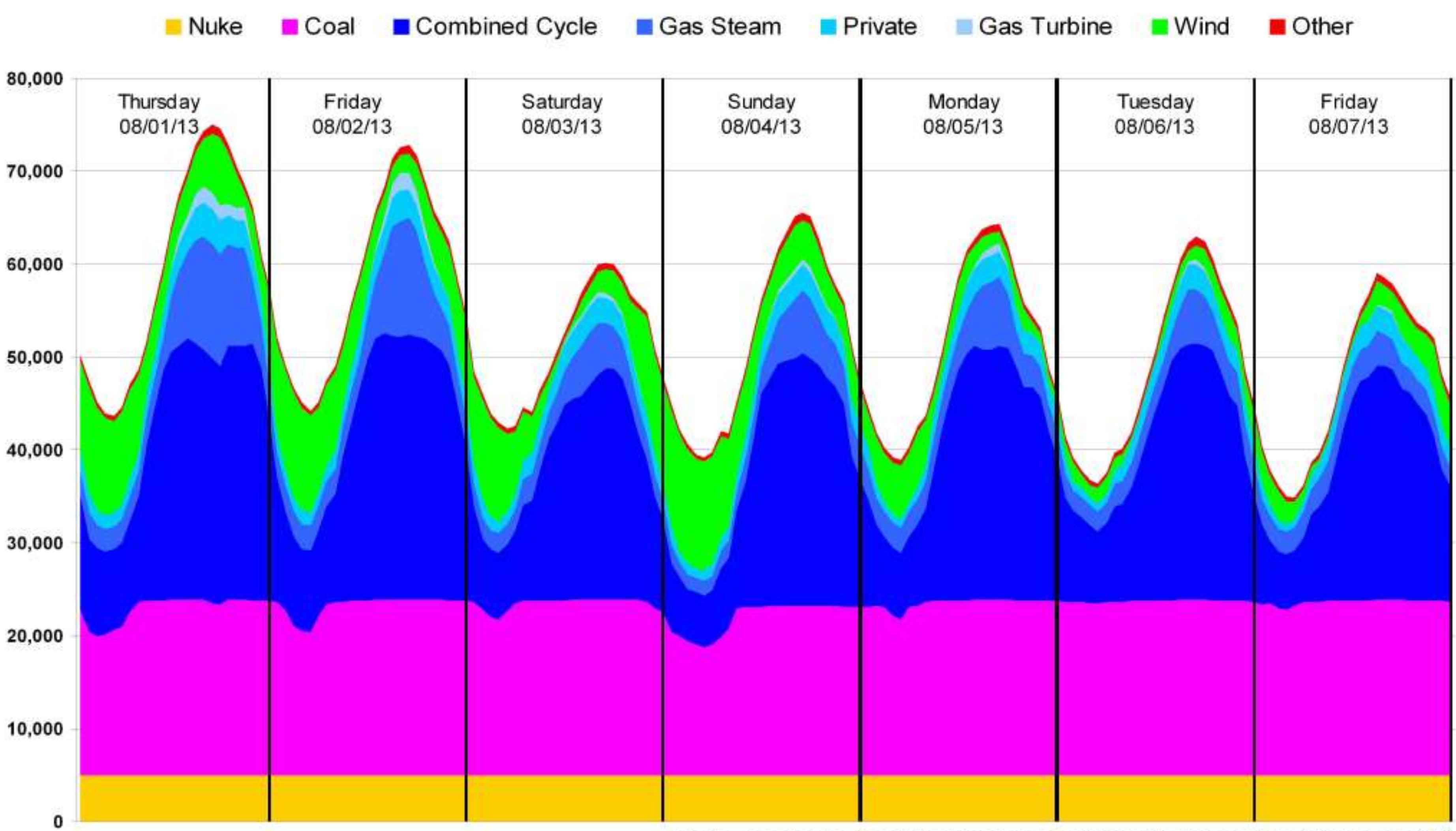
Consider rebates (if available) plus incentives in standard or alternative tariffs, as well as real-time pricing (RTP) or other power procurement options.

Princeton U

TECO - Houston

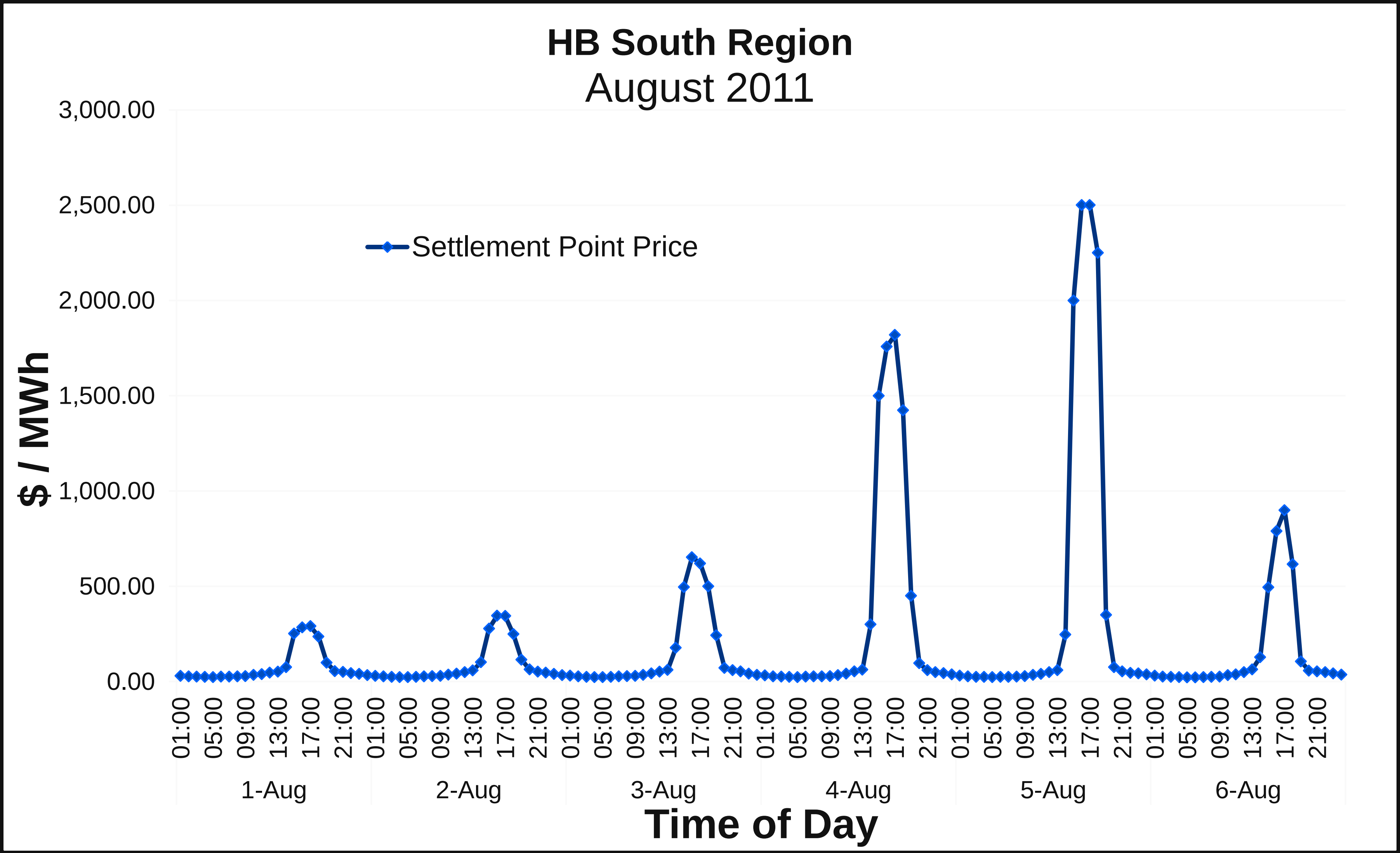
U of Nebraska

2013 Peak Load Week - Generation by Fuel Type



Note – no changes to existing reserves requirements were assumed for this analysis

Range: +$2.50 to -$0.10 per kWh



Source: ERCOT, *www.ercot.com*

Concept Design & Analysis #4

DON'T

Automatically insist on a full capacity chiller plant.

DO

Consider using a downsized chiller plant, when its supplemented by TES.

But of course, also consider appropriate spare or redundant chiller plant capacity, whether using TES or not.

Concept Design & Analysis #5

DON'T

Focus solely on "Full Shift" TES.

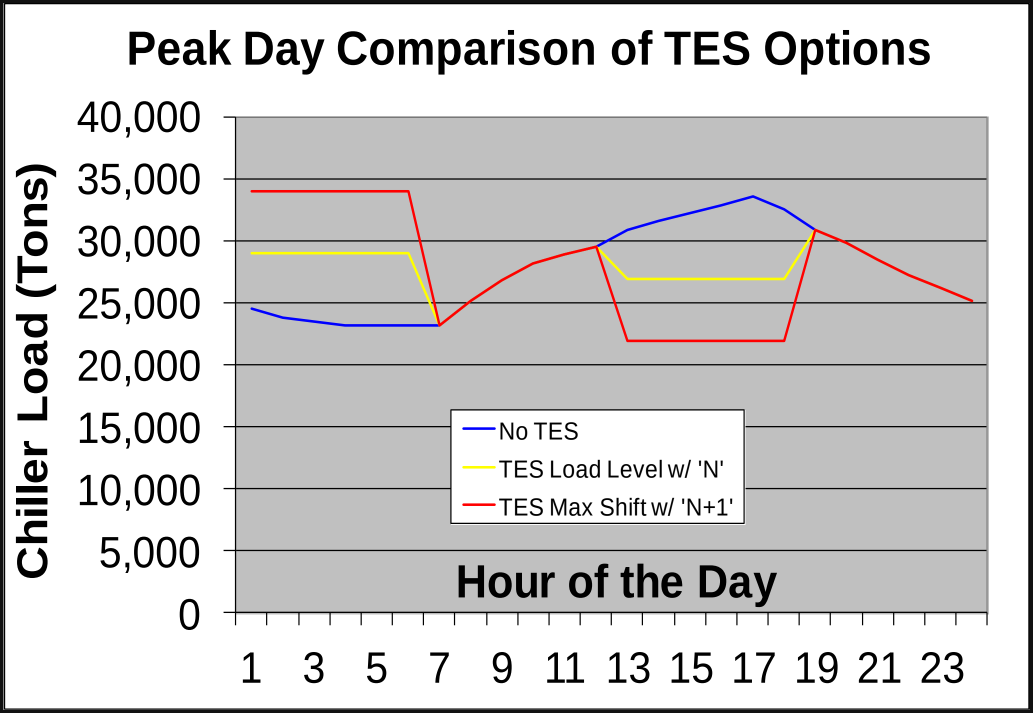
DO

Look at various TES configurations:

- Full Shift (zero chillers running in on-peak),
- Partial Shift, including
- Load Leveling (of cooling load, or of electric load).

U of Illinois - Urbana-Champaign

Analyzed options; then chose: 50,000 T-hrs CHW TES and avoided 7,000 T chlr plt add’n.



Concept Design & Analysis #6

DON'T

Live with a low CHW Delta T.

DO

Consider options to increase Delta T:

- Avoid by-pass, 3-way valves; use 2-way, var. flow,
- Pressure Independent Flow Control Valves (PIFCVs), or
- LTF TES with reduced CHW supply temp.

Enhanced CHW Delta T

North Carolina Dept of Admin - Raleigh, NC (2007)

- 33,370 T-hrs CHW TES
- S/R temps = 39 / 55 °F
- Had been 6-9 °F Delta T
- PIFCVs => 16 °F DT

DFW Int'l Airport - Dallas / Fort Worth, TX (2002)

- 90,000 T-hrs LTF TES
- S/R temps = 36 / 60 °F

Concept Design & Analysis #7

DON'T

Assume that TES is only for electric chiller plants.

DO

Also consider TES in other situations:

- Absorption and/or steam-driven chillers,
- Hybrid (electric & non-electric) chiller plants, and
- Combined Heat & Power (CHP) plants.

Some Examples: Disney (elec & abs chlrs + CHP) and GM (abs & stm turb-driven but no elec chlrs).

Concept Design & Analysis #8

DON'T

Limit TES use to air-conditioning.

DO

Also consider TES for Turbine Inlet Cooling (TIC) if you have an on-site combustion turbine (CT), e.g. for CHP.

TES for Turbine Inlet Cooling (TIC)

Princeton U – Princeton, NJ (2005)

- 40,000 T-hrs LTF TES
- S/R temps = 32 / 56 °F
- DC + TIC for 15 MW CT

Reedy Creek (Disney World) - Orlando, FL (1998)

- 57,000 T-hrs CHW TES
- S/R temps = 40 / 58.3 °F
- DC + TIC for 32 MW CT

Concept Design & Analysis #9

DON'T

First design and install a conventional chiller system, and only then evaluate TES as an add-on option.

DO

Analyze TES as one of the options early in the process, to ensure an optimum design is pursued.

Detail Design & Specification #1

DON'T

Give architects an unlimited budget. They'll exceed it!

DFW Int'l Airport

State of CA

DO

Use std insul mat'ls, creatively.

District Energy St. Paul - St. Paul, MN

37,400 T-hr CHW TES (2003)

An architectural award winner, yet at a minimal extra cost.

Detail Design & Specification #2

DON'T

Use plastic diffuser piping (or pipe hangers) in TES.

U of Virginia

US Army-Ft Jackson

DO

Specify steel piping inside tank.

US Army - Ft Jackson, SC (2008)

new diffuser, after 3 PVC pipe diff's failed

Detail Design & Specification #3

DON'T

Assume TES must be near chiller plant.

DO

Consider remote TES sites. This can aid distribution network and overcome space or aesthetic issues.

Many examples, e.g.:

- U of Alberta - Edmonton
- U of Illinois - Urbana-Champaign
- U of Nebraska - Lincoln, East Campus
- Washington State U - Pullman

U of Illinois - Urbana-Champaign

TES at satellite location, remote from chiller plant.

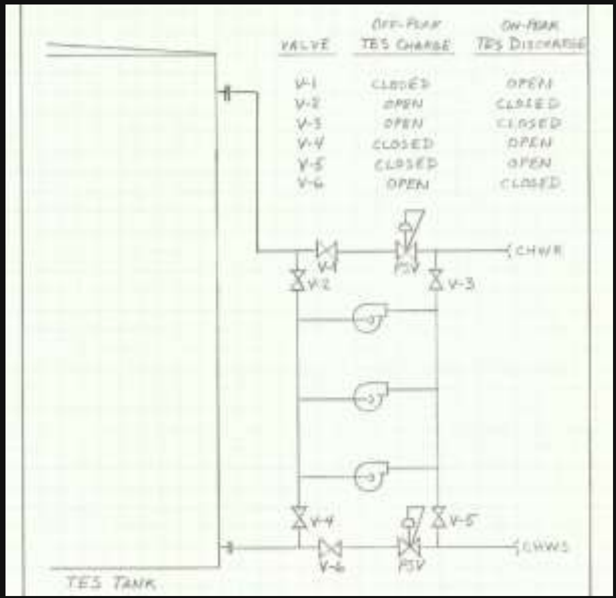
Detail Design & Specification #4

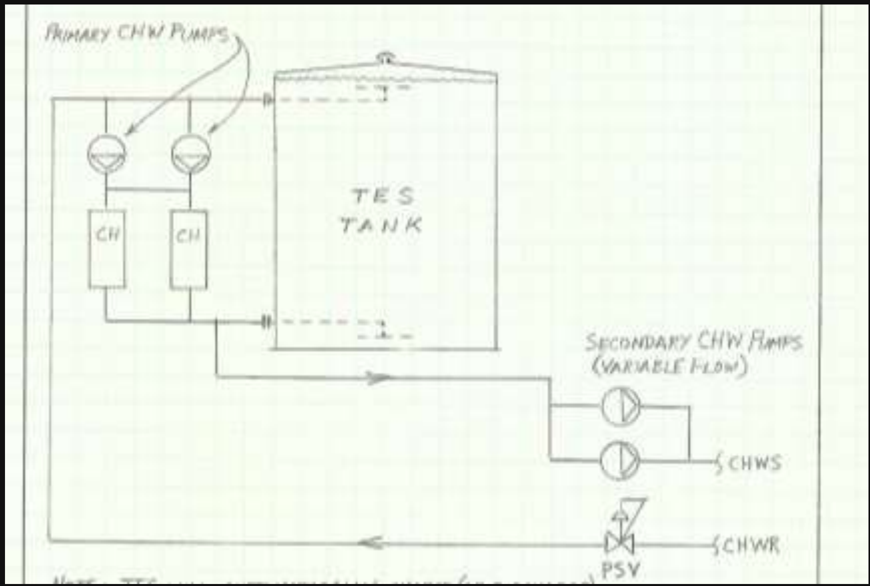
DON'T

Pump both in & out of TES (a rare exception: TECO).

DO

Consider just pumping from TES; or just use Primary & Secondary CHW Pumps if TES is near chillers.





Detail Design & Specification #5

DON'T

Necessarily use a HX to isolate a vented TES tank from a pressurized CHW system.

DO

Use PSVs to manage the pressure difference.

Or, consider recovery turbines if Delta P is very high (as done at District Energy St. Paul's 1st TES tank).

Or, consider HX if Low Temp Fluid is used in TES but not in the piping network (as at Princeton U).

Detail Design & Specification #6

DON'T

Try to control tank level.*

DO

Simply monitor that level remains within a proper operating range, allowing for thermal expansion.

* Exception: When two (or more) TES tanks are on the same system, they must be kept in balance (e.g. at N. Carolina Dept of Admin bldg complex).

Detail Design & Specification #7

DON'T

Use dissimilar metals together underwater.

US Army - Ft Jackson, SC

DO

Use CS thermowells in CS tank shells.

Detail Design & Specification #8

DON'T

Take short-cuts with the insulation.

DO

Consider heat gain, but also surface condensation.

Follow good engineering practice in specifying a vapor barrier for all cold system components.

Pay attention to details at transitions and penetrations.

Detail Design & Specification #9

DON'T

Blindly accept inexperienced contractors or subs.

DO

Specify minimum experience and check references.

Recognize that building a tank is not the same as installing a TES system.

Example: wind damage to improperly installed roof insul'n

Detail Design & Specification #10

DON'T

Forget about significant potential secondary benefits.

DO

Consider the value of:

- Fire protection (Abbott Labs, Chrysler, GM, others)
- Extended hrs/yr of "free cooling" (Abbott Labs)
- Turbine Inlet Cooling (Disney World, Princeton U)
- Hot Water TES in winter (District Energy St. Paul)
- And other secondary benefits of TES.

Detail Design & Specification #11

DON'T

Blindly design to match a current utility tariff.

DO

Consider alternate & future elec purchase realms.

Design for potential rapid discharge (in 3 to 5 hours).

- TECO: 64,285 T-hrs in 4.67 hrs, for ~9.6 MW
- Princeton U: 40,000 T-hrs in 4 hrs, for ~7 MW
- DFW Airport: 90,000 T-hrs in 3.1 hrs, for ~24 MW

Detail Design & Specification #12

DON'T

Assume the need for TES will remain unchanged.

DO

Plan for potential future capacity expansion, e.g.:

- Add a 2nd TES tank (District Energy St. Paul)
- Increase tank height (Cal State U - Sacramento)
- Increase CHW Delta T (NC state bldg complex)
- Convert to Low Temp Fluid TES (DFW Int'l Airport)

Start-up and O&M #1

DON'T

Leave hydrotest water untreated for a long time, or you risk a giant biology experiment.

DO

Develop/follow plan of water monitoring & treatment:

- Corrosion inhibition
- Microbiological control
- or use a Low Temp Fluid, which can perform both.

Consider saving hydrotest water as final CHW, or use as cooling tower make-up rather than dump it.

Start-up and O&M #2

DON'T

Forget to plan and execute tasks with care.

DO

Avoid embarrassing oversights, such as:

- After draining the hydrotest water,
  and then insulating a new TES tank,
  one owner ran fresh water into his new tank,
  un-attended, over a 3-day holiday weekend,
  before realizing the drain valve was never shut!

Start-up and O&M #3

DON’T

Let contractors swap the CHWS with the CHWR.

DO

Use clear labeling of CHWS & R lines, to ensure external piping connects to proper internal lines.

Suspect that failure to stratify at start-up indicates CHWS & R lines may be crossed.

Start-up and O&M #4

DON’T

Forget to plan and run performance testing.

DO

Specify it as part of thermal performance guarantees.

Review and pre-approve a performance test plan.

Conduct or witness the testing.

Document and review the test results.

Maintain records for comparing future performance.

Start-up and O&M #5

DON’T

Forget about scheduled maintenance.

DO

Obtain an O&M Manual with as-built drawings.

Review and follow the scheduled maintenance, although its not very involved for a TES tank with no moving parts.

Start-up and O&M #6

DON'T

Fail to train and re-train the operating staff.

DO

Measure the performance.

Optimize the operation.

Re-evaluate as changes occur in operating needs or in energy procurement options.

Add-up and enjoy the savings and other benefits.

Advertise those benefits to your administration.

Share your experiences with colleagues (e.g. IDEA).

Key Conclusions

DO

Evaluate TES whenever planning CHW investments (new constr, retro expansion or chiller plant rehab).

Incorporate flexibility for rapid TES discharge.

Plan flexibility for future TES capacity expansion.

DON'T

Repeat the only 2 common complaints of owners:

1. "I wish we'd gotten our TES sooner."
2. "I wish we'd gotten our TES larger."

Questions / Discussion ?

Or for a copy of this presentation, contact:

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