CHP and TES: strange bedfellows or a match made in heaven?

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The Cool Solutions Company

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Outline

• CHP & TES: Two ways to similar benefits for District Energy
• But how often are they used together?
  – Numerous examples.
• Why do both?
  – Synergies (illustrated by brief case studies)
• Capturing Capital Savings
  – How & When
• Conclusions and Recommendations
Introduction

• District Energy systems and their customers draw value from:
  – Redundancy, Reliability, Resilience
  – Operational Flexibility
  – Environmental Responsibility
  – Management of Peak Electric Loads
  – Economics

• Combined Heat & Power (CHP) and Thermal Energy Storage (TES) can, and generally do, each provide all these benefits.

*But if one is implemented, does that reduce the value of the 2nd?*
Combined Use of CHP and TES

• In fact, these two technologies can complement one another, adding to the overall value for DE systems and their customers.

• A small study for US DOE (2003) identified 33 CHP installations where TES was also employed.

• Since that study, many others have been identified.

• Examples include applications in industry, but also for:
  – University & College campuses
  – Airports, Military, and other Government facilities
  – Healthcare / Medical / Research facilities
  – District Cooling utility systems
### Some University Examples with Both CHP & TES

<table>
<thead>
<tr>
<th>Owner / Operator - Location</th>
<th>CHP Year</th>
<th>CHP (MW)</th>
<th>TES Year</th>
<th>TES Type</th>
<th>TES (ton-hrs)</th>
<th>TES peak shift</th>
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## More University Examples with Both CHP & TES

<table>
<thead>
<tr>
<th>Owner / Operator - Location</th>
<th>CHP Year</th>
<th>CHP (MW)</th>
<th>TES Year</th>
<th>TES Type</th>
<th>TES (ton-hrs)</th>
<th>TES peak shift</th>
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### Other District Examples with Both CHP & TES

<table>
<thead>
<tr>
<th>Owner / Operator - Location</th>
<th>CHP Year</th>
<th>CHP (MW)</th>
<th>TES Year(s)</th>
<th>TES Type</th>
<th>TES (ton-hrs)</th>
<th>TES peak shift (MW)</th>
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<tr>
<td>DFW Int’l Airport - Dallas/Ft Worth, TX</td>
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<td>110.0</td>
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<td>Austin Energy / Dell Children’s Hospital, TX</td>
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<td>Geisinger Medical Center - Danville, PA</td>
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<td>National Institutes of Health - Bethesda, MD</td>
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<td>Metro Pier &amp; Expo Authority - Chicago, IL</td>
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<td>1994</td>
<td>LT Fluid</td>
<td>123,000</td>
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<td>Reedy Creek / Disney - Lake Buena Vista, FL</td>
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<td>1998</td>
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<td>1994</td>
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<td>Veolia (Trigen) - Trenton, NJ</td>
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<td>12.0</td>
<td>1991</td>
<td>CHW</td>
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</table>
TES Flattens Load Profiles for CHP

- CHP is expensive; needs high operating hrs/yr to be cost effective.
- Elec power above CHP must be purchased at high $/kW & $/kWh.
- TES “flattens” peak day elec & thermal profiles.
- This allows:
  - use of larger CHP (at lower Cap$/kW),
  - more hrs/yr of fully loaded CHP operation,
  - fewer kWh/yr of peak elec power purchases, and
  - thus, improved economic results for CHP.

_Sometimes, CHP is economically justified, when it wouldn’t be w/o TES._
TES Flattens Load Profiles for CHP

A few examples:

- Texas A&M Univ., College Park, TX
  - 24,000 Ton-hrs
  - 50 MW CHP

- Nat’l Inst’s of Health, Bethesda, MD
  - 47,500 Ton-hrs
  - 23 MW CHP

- U of Texas at Austin, Austin, TX
  - 30 + 52,000 Ton-hrs
  - >100 MW CHP

- DFW Int’l Airport, Dallas / Ft Worth, TX
  - 90,000 Ton-hrs
  - 110 MW CHP

Flatter profiles = More hrs/yr of fully loaded CHP = Better CHP economics.
Turbine Inlet Cooling (TIC) of Gas Turbines

• Gas or Combustion Turbine (CT) machines are constant volume.
• High ambient air temps = low air density, mass flow, and power.
• Cooling inlet air with TIC = higher CT power output.
• Various types of TIC:
  – Evaporative cooling: low $; needs water; lmtd cooling & power
  – Chiller-based cooling: much more cooling & power; higher Cap$
  – Chillers with CHW TES (vs Chillers w/o TES):
    • reduced chiller plant size & cost (often saves more than $ of TES)
    • Increased on-peak power; lower Capital $/kW; TES essentially free!
Turbine Inlet Cooling (TIC) of Gas Turbines

A few examples:

Princeton Univ.  Princeton, NJ  40,000 Ton-hrs  1 x 14.6 MW CT
TECO  Houston, TX  70,000 Ton-hrs  1 x 48 MW CT
Chicago MPEA  Chicago, IL  123,000 Ton-hrs  3 x 1.1 MW CTs
Saudi Electricity Company  Riyadh, Saudi Arabia  190,000 Ton-hrs  10 x 75 MW CTs

Hot weather CT outputs are increased by 15 to 30 %, at very low Cap$/MW.
Optimizing Value via Maximum Flexibility

Changing, new, or future electric markets can reward flexibility:

- Various “demand charge” and “Time-of-Use (TOU)” rates
- “Interruptible” rates
- “Real-Time Pricing (RTP)” rates
- “Coincident Demand” rates
- “Global Adjustment (GA)” charges, as in Ontario, Canada
- Short “Super On-Peak” periods met by rapid response

_Some utilities pay cash incentives for peak load mgmt via TES._
Optimizing Value via Maximum Flexibility

15,000 Tons of electric & non-electric chillers
14.6 MW CT, with TIC recovering 2.5 MW
40,000 Ton-hr LT Fluid TES (32/56 °F) in 2.7 M gallons

Low supply temp enhances capacity of DC network (and CT output via TIC).
Real-time hourly electric prices. Can fully discharge TES in only 4 hours.
On some days, TES cycles **more** than 100% of TES capacity, discharging ~33%
in morning, recharging mid-day, then discharging 100% in late afternoon.

All combined: <2 MW on-peak grid purchase, meets 27 MW campus demand.

*In 2012’s Superstorm Sandy, PU was haven/staging point for 1st responders.*
Optimizing Value via Maximum Flexibility

TECO - Houston, TX (CHP & TES in 2010)
Serves Texas Med Ctr, world’s largest med complex
120,000 Tons of electric & non-electric chillers
48 MW CT, with TIC recovering 10.4 MW
70,000 Ton-hr CHW TES (40/53 °F) in 8.8 M gallons
Convertible to LT Fluid TES, e.g. for 107,000 Ton-hrs at 32/52 °F
Real-time hourly electric prices. Can fully discharge TES in only 5 hours.
Some nights (w/ excess wind), they are paid ~$0.10/kWh to recharge TES.
Some days (grid peaks), TES saved up to ~$3.00/kWh or ~$25,000 per hour.

Through 2017’s Hurricane Harvey, TECO maintained service to its customers.
Capturing Capital Savings – How & When

Without TES, installed chiller plant capacity must be equal to instantaneous peak load, plus any necessary spare capacity.

But with TES, installed chiller plant capacity need only equal 24-hr peak day average load, plus necessary spare capacity.

Saving in chiller plant CapEx offsets CapEx of TES.

For large-scale CHW TES, this is often a net CapEx saving.

This occurs if TES is used in lieu of some non-TES investment:

1. New Construction
2. Retrofit Expansion
3. Retirement / Replacement of Aging Chiller Plant Equip
## Capturing Capital Savings – A Few Examples

<table>
<thead>
<tr>
<th>TES</th>
<th>CHW TES</th>
<th>Savings vs. Non-TES Chiller Plants</th>
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<tbody>
<tr>
<td><strong>Project</strong></td>
<td><strong>Type</strong></td>
<td><strong>Owner</strong></td>
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<td>retro</td>
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<td>new</td>
<td>Lisbon Distr Energy</td>
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<tr>
<td>retro</td>
<td>U of Alberta</td>
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<td>new</td>
<td>Chrysler R&amp;D</td>
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<td>DFW Airport</td>
<td>90,000</td>
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<tr>
<td>retro</td>
<td>OUCooling district</td>
<td>160,000</td>
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</table>

Net Capital Savings accrue from downsizing chiller plants, while adding CHW TES during new construction or retro expansions.
Capturing Capital Savings – Case Study

Chrsyler Motors corporate R&D center
Auburn Hills, Michigan (new construction)

- Peak cooling load = ~16,000 Tons
- If no TES, needed chillers = 17,700 Tons
- With TES, only need chillers = 11,400 Tons
- 68,000 ton-hrs of CHW TES (at 43/61 °F CHWS/R temps) in two 3 Mgal tanks
- CHW TES tanks also provide dual-use as emergency fire protection
- TES peak load shift = 7,600 Tons (~5.3 MW electric)
- Annual demand charge savings of over $1 million

And by down-sizing chiller plant by 6,300 Tons (to match avg vs peak load), CHW TES produced an immediate net capital cost saving of $3.6 million.
Conclusions and Recommendations

- CHP and TES each provide similar, important benefits for DE.
- But combined, they are often complementary (not redundant).
- Large CHW TES can also reduce capital costs (vs chiller plants).
- Consider TES whenever planning CHP, TIC, or Energy Storage.
- Consider TES especially when planning Chilled Water capacity investments, specifically at times of:
  - New construction,
  - Retrofit capacity expansions, or
  - Retirement / replacement of aging thermal plant equipment.
Questions / Discussion?

Or for a copy of this presentation, contact:

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