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

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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

Owner / Operator - Location (approximate data)	CHP Year	CHP (MW)	TES Year	TES Type	TES (ton-hrs)	TES peak shift (MW)
California State Polytechnic U - Pomona	1989	0.4	2000	CHW	25,000	3
California State U - Fullerton	2010	4.6	1993	CHW	37,000	4
California State U - Long Beach	1987	0.2	19??	Ice	40,000	5
California State U - Northridge	2001	0.2	1997	CHW	29,000	3
California State U - San Diego	2003	17.4	1993	CHW	22,000	3
Cornell U - Ithaca, NY	19??	8.0	1991	CHW	38,000	4
Harvard U Allston Campus - Boston, MA	2019	2.5	2019	CHW	13,392	3
New Mexico State U - Las Cruces	1996	4.7	19??	CHW	20,000	2
North Carolina State U - Raleigh	2012	11.0	2020	CHW	25,000	4
Princeton U - Princeton, NJ	1996	14.6	2005	LT Fluid	40,000	7
Stanford U - Palo Alto, CA	1987	49.9	2015	CHW	90,000	12
Texas A&M U - College Station, TX	1996	50.0	2016	CHW	24,000	5

More University Examples with Both CHP & TES

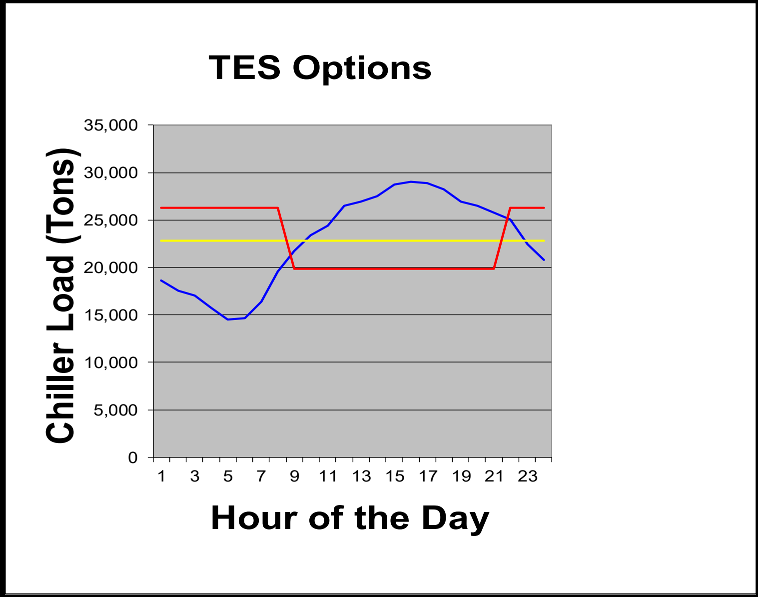
Owner / Operator - Location (approximate data)	CHP Year	CHP (MW)	TES Year	TES Type	TES (ton-hrs)	TES peak shift (MW)
U of California - Los Angeles	1994	48.0	2002	CHW	32,000	4
U of California - San Diego	????	25.6	1994	CHW	35,900	4
U of Cincinnati - Cincinnati, OH	2004	47.7	‘98+’11	CHW	~52,000	6
U of Iowa - Iowa City	19??	21.5	19??	CHW	7,000	1
U of Maryland - College Park	2002	27.3	????	Ice	?,???	?
U of Michigan - Ann Arbor	1897+??	48.5	1986	CHW	17,000	2
U of North Carolina - Chapel Hill	1992	28.0	2006	CHW	40,000	4
U of Texas at Austin	‘??+’09	100.+	‘11+’16	CHW	82,000	8
U of Utah - Salt Lake City	2008	6.5	2010	CHW	26,000	3
Utah State U - Logan	2004	4.5	2012	CHW	~15,000	2
Washington State U - Pullman, WA	1982	2.0	1993	CHW	17,750	2
Yale U - New Haven, CT	’98+’10	37.4	19??	CHW	~20,000	2

Other District Examples with Both CHP & TES

Owner / Operator - Location (approximate data)	CHP Year	CHP (MW)	TES Year(s)	TES Type	TES (ton-hrs)	TES peak shift (MW)
DFW Int'l Airport - Dallas/Ft Worth, TX	2007	110.0	2002	LT Fluid	90,000	21
LAX Int'l Airport - Los Angeles, CA	1985	17.2	2013	CHW	15,500	3
Austin Energy / Dell Children's Hospital, TX	2006	4.6	2005	CHW	8,000	1
Geisinger Medical Center - Danville, PA	2011	5.0	2009	CHW	8,000	1
National Institutes of Health - Bethesda, MI	2004	23.0	2018	CHW	47,500	6
NRG / Univ Med Ctr - Plainsboro, NJ	2011	4.6	2012	CHW	9,850	1
Thermal Energy Corp. (TECO) - Houston, TX	2010	48.0	2010	CHW	70,000	10
Climaespaco - Lisbon, Portugal	1998	5.2	1998	CHW	39,807	5
District Energy St. Paul - St. Paul, MN	2003	25.0	'94+'03	CHW	72,000	8
The Energy Network - Hartford, CT	1989	3.9	1985	CHW	20,000	2
Metro Pier & Expo Authority - Chicago, IL	1997	3.3	1994	LT Fluid	123,000	18
Reedy Creek / Disney - Lake Buena Vista, FL	1988	32.0	1998	CHW	57,000	7
Shell Developm't Westhollow - Houston, TX	1988	3.7	1994	CHW	38,500	5
Trigen-Cinergy (Gen'l Motors) - Lansing, MI	2001	3.6	2001	CHW	36,500	4
Veolia (Trigen) - Trenton, NJ	1983	12.0	1991	CHW	20,000	2

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

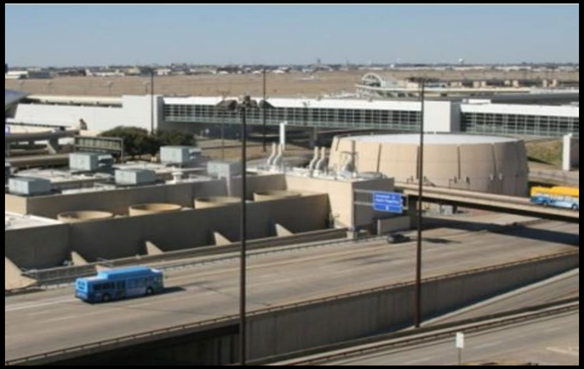
23 MW CHP

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.	TECO	Chicago MPEA	Saudi Electricity Company
Princeton, NJ	Houston, TX	Chicago, IL	Riyadh, Saudi Arabia
40,000 Ton-hrs	70,000 Ton-hrs	123,000 Ton-hrs	190,000 Ton-hrs
1 x 14.6 MW CT	1 x 48 MW CT	3 x 1.1 MW CTs	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 <u>flexibility</u>:

- 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

Princeton U - NJ (CHP in 1996, TES in 2005)

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

TES Project Type	Owner	CHW TES Capacity (ton-hrs)	Savings vs. Non-TES Chiller Plants: Annual Operating Savings	Savings vs. Non-TES Chiller Plants: Initial Net Capital Savings
retro	Washington St U	17,750	$ 260,000 / yr	$ 1 to 2 million
new	Lisbon Distr Energy	39,800	$ 1,160,000 / yr	$ 2.5 million
retro	U of Alberta	60,000	$ 600,000 / yr	$ 4 million
new	Chrysler R&D	68,000	>$ 1,000,000 / yr	$ 3.6 million
retro	DFW Airport	90,000	~$ 2,000,000 / yr	$ 6 million
retro	OUCooling district	160,000	>$ 500,000 / yr	>$ 5 million

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

<u>Auburn Hills, Michigan (new construction)</u>

- 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 <u>immediate net capital cost saving of $3.6 million</u>.

Conclusions and Recommendations

- CHP and TES each provide similar, important benefits for DE.
- But combined, they are often complementary (<u>not</u> redundant).
- Large CHW TES can also <u>reduce capital costs</u> (vs chiller plants).
- Consider TES whenever planning CHP, TIC, or Energy Storage.
- *Consider TES <u>especially</u> 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 ?

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