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Cool Trends in District Energy: A Survey of Thermal Energy Storage (TES) Use In District Energy (DE) Utility Applications

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Note: This information has been developed for presentation at the International District Energy Association (IDEA) Annual Conference in June 2005, as an introduction to a panel discussion by owners/operators of District Energy (DE) utility systems using Thermal Energy Storage (TES).

This database considers the use of Cool TES in District Cooling utility applications, not the use of strictly Hot TES in District Heating utility applications. However, there are two identified instances of installations that use both cool and hot TES.

Furthermore, this database considers only instances of diurnal TES. Instances of seasonal TES such as those using deep ocean, harbor, or lake water, or those using an underground aquifer as the TES storage medium, have not been included in the database.

The database considers only TES use in District Energy utility applications, which for this database are considered to be District Energy systems acting as utilities that generate and deliver thermal energy to multiple customer facilities, including urban District Energy utility networks as well as single owner-user government District Energy networks such as those owned and operated by federal, state or local government agencies.

The database does not include instances of campus (university, college or other educational institution) District Energy systems, nor hospital/medical District Energy systems, nor single owner-user industrial District Energy systems. Note that a survey of TES use in campus (university & college) District Energy systems was previously undertaken by this same researcher, with a summary of the data being produced in the article "Cool Trends on Campus: A Survey of Thermal Energy Storage (TES) Use in Campus District Energy (DE) Systems" which was published in *District Energy*, the magazine of the International District Energy Association (IDEA), First Quarter 2005, Volume 91, Number 1, pages 25-30.

It is noteworthy that the campus District Energy-TES database from that survey exhibited a slightly larger number, but a slightly smaller capacity, of installations than does this utility DE-TES database. The campus database differed from this utility database primarily in two respects:

1. An even larger majority of the installations were in the U.S. (94% of the TES installations and 93% of the TES capacity for the campus DE-TES systems *versus* 67% of the TES installations and 72% of the TES capacity for the utility TES systems).
2. An even larger majority of installed capacity used sensible heat (chilled water or low temperature fluid) TES rather than latent heat (ice) TES. (Sensible heat TES represents 78% of the TES capacity for campus DE-TES systems *versus* 65% for utility DE-TES systems.)

A database of industrial District Energy-TES is expected to exhibit a similarly large number and capacity of installations as do the databases for campus and utility DE-TES systems.

All data are reported values, or close approximations, as compiled by John S. Andrepont.

<u>DE Utility TES Summary - Geographical</u>	<u>No. of Installations</u>	<u>Ton-hours</u>
All Identified District Energy Utility Diurnal TES	106 installations	2,610,815
<u>U.S. District Utility TES Installations</u>	67 (63% of total)	1,883,347 (72% of total)
Illinois	8 (12% of U.S.)	437,400 (23% of U.S.)
Texas	16 (24%)	382,778 (20%)
Florida	5 (7%)	281,809 (15%)
California	14 (21%)	133,475 (7%)
Michigan	2 (3%)	68,500 (4%)
Minnesota	2 (3%)	65,400 (3%)
Maryland	2 (3%)	61,000 (3%)
New York	2 (3%)	58,000 (3%)
Louisiana	1 (1%)	52,000 (3%)
Oklahoma	1 (1%)	45,000 (2%)
Colorado	1 (1%)	37,500 (2%)
Arizona	1 (1%)	36,000 (2%)
South Carolina	2 (3%)	33,600 (2%)
Massachusetts	1 (1%)	32,000 (2%)
North Carolina	3 (4%)	30,300 (2%)
Washington, DC	1 (1%)	22,050 (1%)
Connecticut	1 (1%)	20,000 (1%)
New Jersey	1 (1%)	20,000 (1%)
Nebraska	1 (1%)	~17,534 (1%)
Virginia	1 (1%)	14,300 (1%)
New Mexico	1 (1%)	10,000 (1%)
<u>Non-U.S. District Utility TES Installations</u>	39 (37% of total)	727,468 (28% of total)
Malaysia	8 (21% of non-U.S.)	~175,733 (24% non-U.S.)
Japan	6 (15%)	~152,600 (21%)
United Arab Emirates	6 (15%)	108,000 (15%)
France	5 (13%)	~75,063 (10%)
Philippines	1 (3%)	40,000 (5%)
Portugal	1 (3%)	39,807 (5%)
Qatar	1 (3%)	26,000 (4%)
Singapore	1 (3%)	~25,000 (3%)
Sweden	2 (5%)	25,000 (3%)
Saudi Arabia	1 (3%)	20,000 (3%)
Spain	2 (5%)	10,450 (1%)
Finland	1 (3%)	~10,000 (1%)
Canada	1 (3%)	8,500 (1%)
United Kingdom	1 (3%)	6,250 (1%)
Mexico	1 (3%)	4,700 (1%)
Australia	1 (3%)	365 (0%)

DE Utility TES Summary - Technical

All Identified District Energy Utility Diurnal TES	106 installations
Total TES capacity	2,610,815 Ton-hrs
Average TES capacity per installation	24,630 Ton-hrs
Smallest single TES installation	365 Ton-hrs
Largest single TES installation	160,000 Ton-hrs
Total peak cooling load served by TES	372,974 Tons
Average peak cooling load served per installation	3,519 Tons
Total peak electric load management from TES	279.7 MWe
Average peak electric load management per installation	2.6 MWe
<u>Those with Diurnal Latent Heat (Ice) TES</u>	27 installations (25% of total)
Subtotal for all Latent Heat TES capacity	912,832 Ton-hrs (35% of total)
Average capacity per Latent Heat installation	33,808 Ton-hrs
Smallest single Latent Heat TES installation	7,500 Ton-hrs
Largest single Latent Heat TES installation	125,000 Ton-hrs
<u>Those with Diurnal Sensible Heat TES</u>	79 installations (75% of total)
Subtotal for all Sensible Heat TES capacity	1,697,983 Ton-hrs (65% of total)
Average capacity per Sensible Heat installation	21,493 Ton-hrs
Smallest single Sensible Heat TES installation	365 Ton-hrs
Largest single Sensible Heat TES installation	160,000 Ton-hrs
CHW Sensible Heat TES	75 installations (95% of all sensible heat)
CHW (LTF convertible) Sensible Heat TES	9 (11%)
LTF Sensible Heat TES	4 (5%)
CHW and HW Sensible Heat TES	2 (3%)
Sensible Heat TES above ground	69 installations (87% of sensible heat)
Sensible Heat TES fully below ground	8 (10%)
Sensible Heat TES partially below ground	2 (3%)
Sensible Heat TES in steel tanks	60 installations (76% of all sensible heat)
Sensible Heat TES in concrete tanks	19 (24%)
<u>Sites with TES in multiple TES phases</u>	12 sites
Multiple TES equipment installation phases	9 (75% of sites with multiple TES phases)
Expansion via increased CHW Delta T	4 (33%)
Expansion via conversion from CHW to LTF	2 (17%)
<u>Owners/operators with TES at multiple sites</u>	13 owners (63 TES installations, in 56 systems)
[one of which has at least part ownership in	15 TES installations, in 13 systems]

DE Utility TES Summary - Chronological

All Identified District Energy Utility Diurnal TES 106 installations

<u>Year</u>	<u>No. of TES Installations</u>	<u>Ton-hours Started-up</u>	<u>Cumulative Ton-hours</u>
1981	0	0	0
1982	1	4,500	4,500
1983	0	0	4,500
1984	0	0	4,500
1985	1	20,000	24,500
1986	1	26,400	50,900
1987	1	25,433	76,333
1988	2	14,700	91,033
1989	2	32,000	123,033
1990	1	4,000	127,033
1991	2	63,433	190,466
1992	3	34,440	224,906
1993	5	73,847	298,753
1994	8	190,103	488,856
1995	6	147,550	636,406
1996	8	273,928	910,334
1997	5	187,520	1,097,854
1998	8	230,500	1,328,354
1999	6	121,800	1,450,154
2000	3	65,300	1,515,454
2001	7	173,050	1,688,504
2002	7	141,667	1,830,171
2003	8	315,485	2,145,656
2004	5	91,967	2,237,623
2005	5	106,000	2,343,623
2006	8	160,642	2,504,265
2007	1	50,000	2,554,265
2008	2	56,550	2,610,815
Totals	106	2,610,815	2,610,815

<u>5-year period</u>	<u>No. of TES Installations</u>	<u>Ton-hours Started-up</u>	<u>Average Ton-hours per Year</u>
1981-1985	2	24,500	4,900
1986-1990	7	102,533	20,507
1991-1995	24	509,373	101,875
1996-2000	30	879,048	175,810
2001-2005	32	828,169	165,634
2006 (1-year)	8	160,642	160,642
Totals (26-yr)	103	2,504,265	96,318