The Commercialization of TES in the USA

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ECOSTOCK 5-31-06
Benefits of Thermal Energy Storage

- Reduces Peak Demand at most critical time: 20-40%
- Reduces consumer’s energy costs: 10-20%
- May reduce energy usage at the building: up to 14%
- Reduces source energy usage at power plant: 8-34%
- Reduces emissions: up to 50%
- Increases Load Factor of Generation: up to 25%
- Provides operational flexibility
Storage is Nature’s way of Balancing Supply and Demand.
Most common TES System

Water Heater (Electric)
Assume one low-flow shower
\[ ((2.5 \text{gpm} \times 8.33 \text{lb/gal} \times (110-60)) \times 60 \text{minutes/hr} / 3,414 \text{Btu/kW} = 18.3 \text{kW} \]

East Coast of US
100,000,000 people x 25% x 1/12 Hr/shower x 18.3 kW = 38 Gigawatts = CA Electric Peak on Summer day

Gas Water Heater
Design Load = 2 Showers at a time
\[ 18.3 \text{kW} \times 2 \times 3414 = 124,950 \text{Btus} \]

TES has already impacted US infrastructure
Utility Load Factors* in the USA

*Load Factor = \( \frac{\text{Avg. Load}}{\text{Peak Load}} \)
ASHRAE 90.1 Base Building
Non-Storage Electrical Profile

Total kWh = 28,000/day

Peak Load 2000 kW
Avg. Load 1050 kW

(Load Factor = 53%)
Design 30% better than 90.1
Non-Storage Electrical Profile

Total kWh = 19,200/day  (Load Factor = 53%)
Off Peak Cooling (OPC) Electrical Profile

Total kWh = 19,200/day  (Load Factor = 88%)

Peak Load 900kW
Avg. Load 800kW

40% Peak Load Reduction
3-D Electric Load Profile -- Full Year

4200 ton-hr of Storage
Installed 1990
Water Storage System

Chiller

Warm Water
56 F

Thermocline

Cold Water
40 F

Load
Ice Storage Systems

Chiller Based System
Closed System

So what is “Different”??
Direct Expansion Ice Storage System

“Plug and play” with new & existing refrigerant-based HVAC residential and commercial; packaged and split

Runs at night creating ice 5 Ton condensing unit

300 watts
7.5 Tons cooling during the day

540,000 BTU Energy Storage
7.5 Tons for 6 hours
5 Tons for 9 hours

48 F
Liquid Refrigerant

46 F
Liquid & Vapor Refrigerant
Liquid Overfeed

55 F

Return Air
1 Bryant Park, New York City
Bank of America / Durst Organization

~2.2 Million ft²
Going for LEED Platinum

History Channel
“Sky Scrapers” 9-7-04
1. Uncommon
2. Too Much Space
3. Too Complicated
4. Doesn’t Save Energy
5. Too Expensive
6. Lack of Redundancy (Risky)
7. Rates Will Change
8. Modeling doesn’t Show Results

Reality: TES is a Proven Technology that saves Money and Energy
Thermal Energy Storage and Sustainable Buildings
(Ashrae Journal Sept 04)

Topics:
LEED
Why Green
Safety Factory
Redundancy
Back-up Generation

Thermal Energy Storage In Sustainable Buildings

By Mark MacCracken, PE, Member ASHRAE

This article demonstrates why designing a building with stored cooling is a beneficial approach and how over-sizing the chiller plant for safety factor does not make sense. This article discusses what makes thermal energy storage (TES) a green technology, TES and safety factor, and benefits from incorporating storage.

LEED™ Rating System
One system for rating the "greenness" of buildings is the U.S. Green Building Council's (USGBC) LEED rating system. Based on this unit of measure, TES is considered green. The ratings are based on a point system (10 points are for energy savings).

LEED points are based on ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings, which is based on energy over savings, not energy savings. Cost is the only common denominator for all the different energy-efficient possibilities, as well as the common metric that usually drives a building owner's decision. To receive LEED points, the building must surpass Standard 90.1-1999 by more than a certain percentage for a certain amount of points (20% = 2 points, 30% = 4 points up to 60% = 10 points).

TES and LEED
The raison TES is a green technology is the LEED system in that, in most locations, electricity at night costs less than half as much during the day. As demonstrated in thousands of installations, major energy cost savings are realized by using inexpensive power at night to create and store cooling, and using storage to cool the building during the next day. These savings provide LEED points, which was demonstrated in California's first LEED Gold building built by The William and Flora Hewlett Foundation in the City of Menlo Park.

The building had a total of 43 points (out of 69), of which five were because of the 33% energy cost reduction. This project took advantage of four major cost-energy-saving techniques including:
- External shading, natural lighting, natural ventilation and off-peak cooling (OPC) using ice-based thermal storage.
- The four were reducing the amount of mechanical cooling, and the OPC system shifts most of what mechanical cooling is required to the inexpensive off-peak period.

Real Reason Thermal Storage is Green
Many studies, most notably by the California Energy Commission, have demonstrated that, for many reasons, it takes less fuel to make an off-peak kWh. The main reasons are:
- Off-peak, base-load plants are much more energy-efficient than peak plants, with 7,900 to 8,500 Btu/kWh (3335 to 3970 L/kW) heat rates typical for base-load plants. The existing stock of "peaking" plants, which are comprised mainly of simple-cycle combustion turbine units, are in the range of 9,000 to 12,000 Btu/kWh.
- Line losses are less off-peak because much less power is transmitted at night.
- Spinning reserve requirements are lower. (Spinning reserve essentially means power plants are forced to spin turbines at night, without generating power. So, the plants are ready to help meet the following day's peak load). Therefore, lower on-peak power requirements translate into less waste from spinning reserves.

The results of the California Energy Commission's study showed that for the two major California utilities, it required...
Costs of Storage

What’s the Installed Cost of a ton of Chiller Plant?
$1000/ton, $1200/ton, $1400/ton, $1600/ton, $1800/ton

Storage Costs installed ~ $100 to $150 per ton-hr
Depending on location, application and design

For each 1 ton of chiller you reduce you need about 8 to 9 ton-hrs of storage.

Costs are about the same
Detroit Edison Electric Rate

Energy:
Day: $0.059/kWh
Night: $0.054/kWh

Demand: $12.58/kW/Month

Day: $0.125
Night: $0.054

56% less costly at night
Market Segments for Storage

- **Water Storage**
  Universities, Industrial, District Cooling

- **Ice Storage Internal-Melt**
  All above plus, Office Buildings, K-12 Schools

- **Ice Storage External Melt**
  Universities, Industrial, District Cooling

- **Unitary DX Ice Storage Units**
  Small Retail Stores, Large Residential
National Air and Space Museum, Washington, DC USA

4,700 Ton Hrs of Storage
On-Peak Chiller – 1122 Tons
On-Peak Ice Contribution – 729 Tons
40% On-Peak Chiller Demand Avoided

Ice Storage Tanks for the entire Project
Durst Headquarters Retrofit
1155 Avenue of the Americas

41 Stories
3400 Ton Hours Storage
Avoids ≈ 600kW out of
3500kW Original Total
Ice Plant in Series with Water Chiller

~1200 TONS
TO LOAD
FROM LOAD

DEMAND LIMITED TO 700 TONS

490 ICE-MAKING TONS

403 ICE STORAGE
403 ICE STORAGE

VFD PUMP
TS
HX
Credit Suisse
11 Madison Ave., New York, NY

30 Stories, 2.2 Million Ft²
6200 Ton Hours Storage
Avoids ~ 900 kW
NYSERDA Incentive $620,000

Main reason for Storage:
Resiliency
Retrofit in Downtown Chicago
Encapsulated Ice
University of Arizona

Campus Statistics
- 28,300 Tons of Refrigeration
- 12 Million Sqft.
- 130 Buildings
- 35 MW Peak
- 14 MW of Gas Turbine Gen.
- 14,000 ton-hr of Ice Storage

Main reason for Storage:
Optimizing Gas Turbine Generator’s Efficiency, Emissions and Heat output
First Truck Delivers June 7
Making and Using Ice July 1
14,000 ton-hr
New Orleans Regional Medical Center
52,000 ton-hr
Ice-on-Coil External Melt
Orlando District Cooling System

17.6 million gallons (223.5 ft Dia. x 60 ft High)
TES tank footprint: 39,232 sq ft (<2 sq ft/ton)
160,000 ton-hr, 20,000 ton discharge rate
Approved by California Energy Commission for use under Title 24 for Building Energy Efficiency

Commercial
- Offices (1, 2, 3 stories)
- Retail merchandise and services (small and big box)
- Food Service chains

Government
- Offices and facilities (1, 2, 3 stories)
- Schools and Education
- Military facilities

Residential
- Semi custom homes (>2500 sq. ft.)
- Mid range production homes (1600-2500 sq. ft.)
- Energy Star and Net-Zero, Solar PV
Off-Peak Cooling… in over 6000 installations in 35 countries, many installed over 20 years ago
New York’s Most Environmentally Friendly Office Tower.
Summary

Storage is Nature’s way to Balance Supply and Demand

Engineer’s Paradigm must change.
Instead of adding 20-30% to estimated Load, reduce by 20-30% and add Storage for Safety at no extra Cost.

Cool Storage reduces
Operating Costs
Load on Grid
Impact on Environment