



Energy Storage, Smart Grid and Zero Energy Buildings:

Building Capacitance Together

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Abstract

Whether the reason is Energy Independence, National Security or Climate Change, reducing our use of Carbon will be critical to our society's future. One critically important aspect about fossil fuels is that they are not just forms of energy, they are forms of “stored” energy. If we are going to reduce our dependence on them by using renewable energy, like Wind or Solar, which are forms pure energy, we will also have to replace the storage aspect of the them. Energy Storage on both the Grid side and Building side of the meter will be covered along with their respective applications.

Learning Objectives

1. Describe why the cost of electricity is much less during off peak hours and how renewable wind energy will reinforce this.
2. Describe why energy storage is a vital component for large scale deployment of renewables
3. Recognize the two major types of storage and how and where they are best applied in commercial buildings
4. Explain how energy storage relates to LEED and Zero Energy Buildings

*“To see the Earth as it truly is,
small and blue and beautiful
in that eternal silence where it
floats,
is to see ourselves as riders on the
Earth together,
brothers on that bright loveliness in
the eternal cold—
brothers who know now they are
truly brothers.”*

Archibald MacLeish, American writer

The New York Times, 25 December 1968



Dr. Michael MacCracken Climate Video

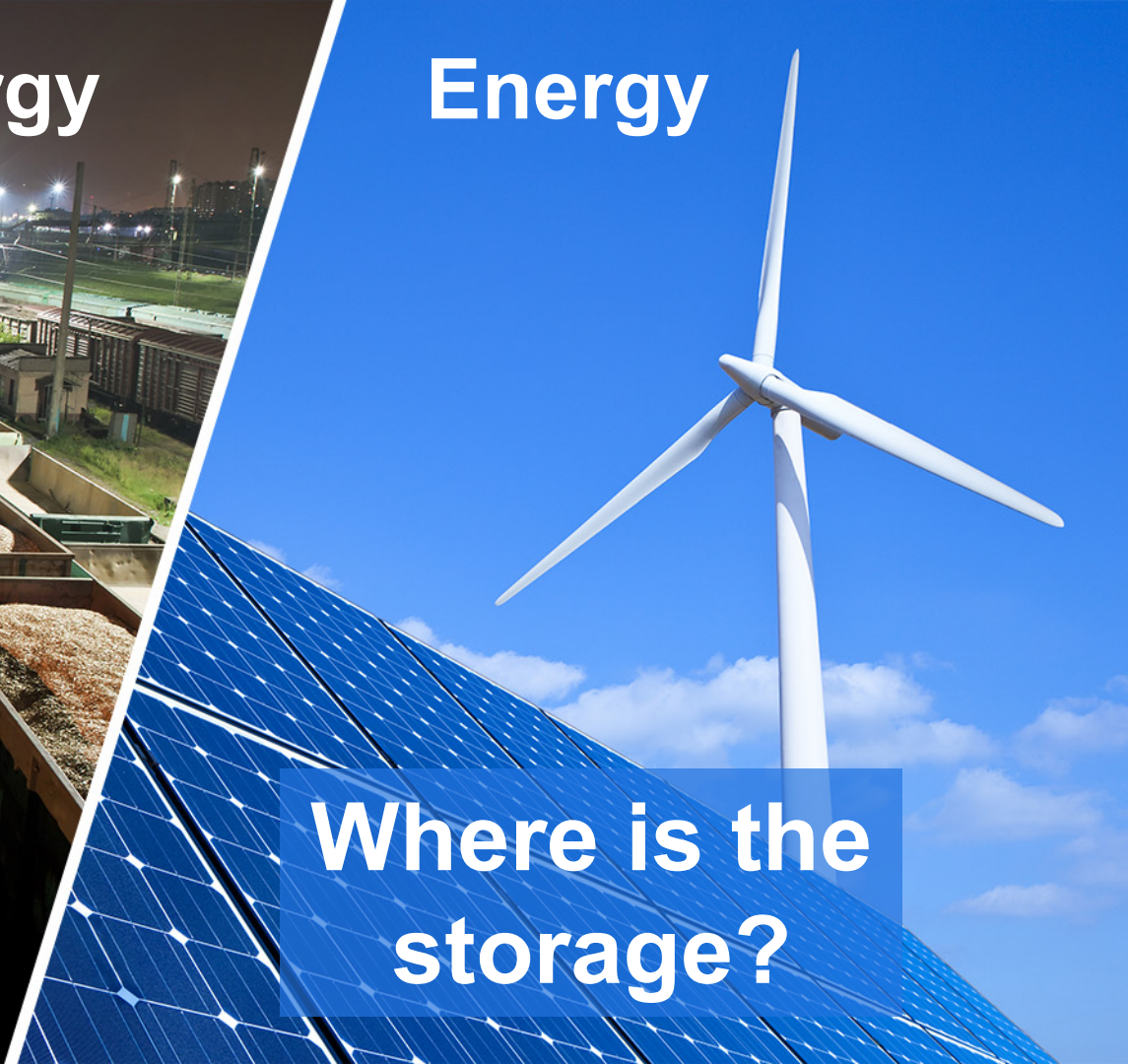
Dr. Michael MacCracken - 1982 Climate Change Presentation - Part 1 of 6



Stored Energy

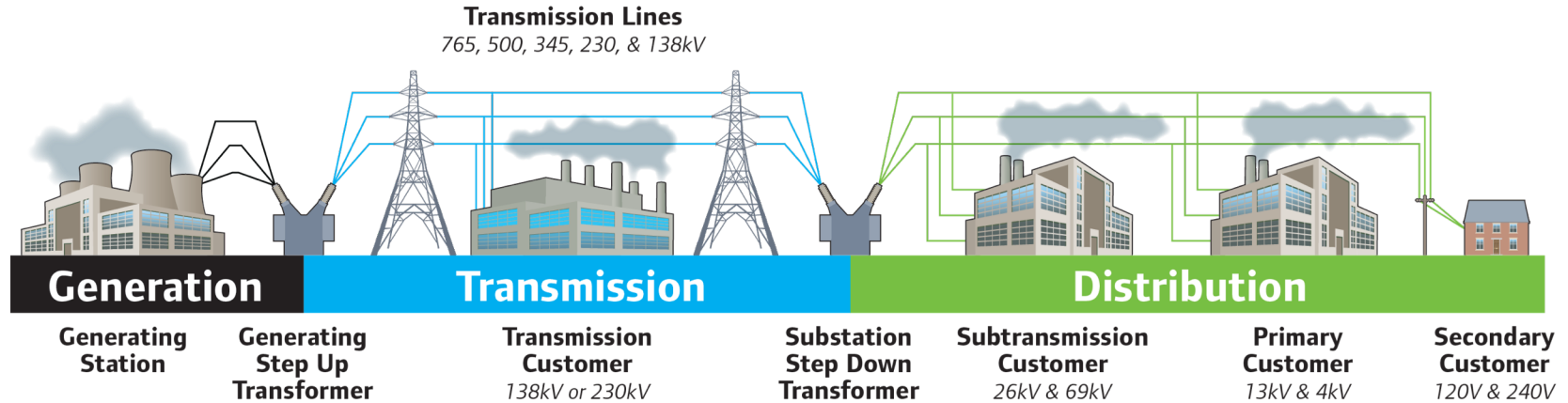


Energy



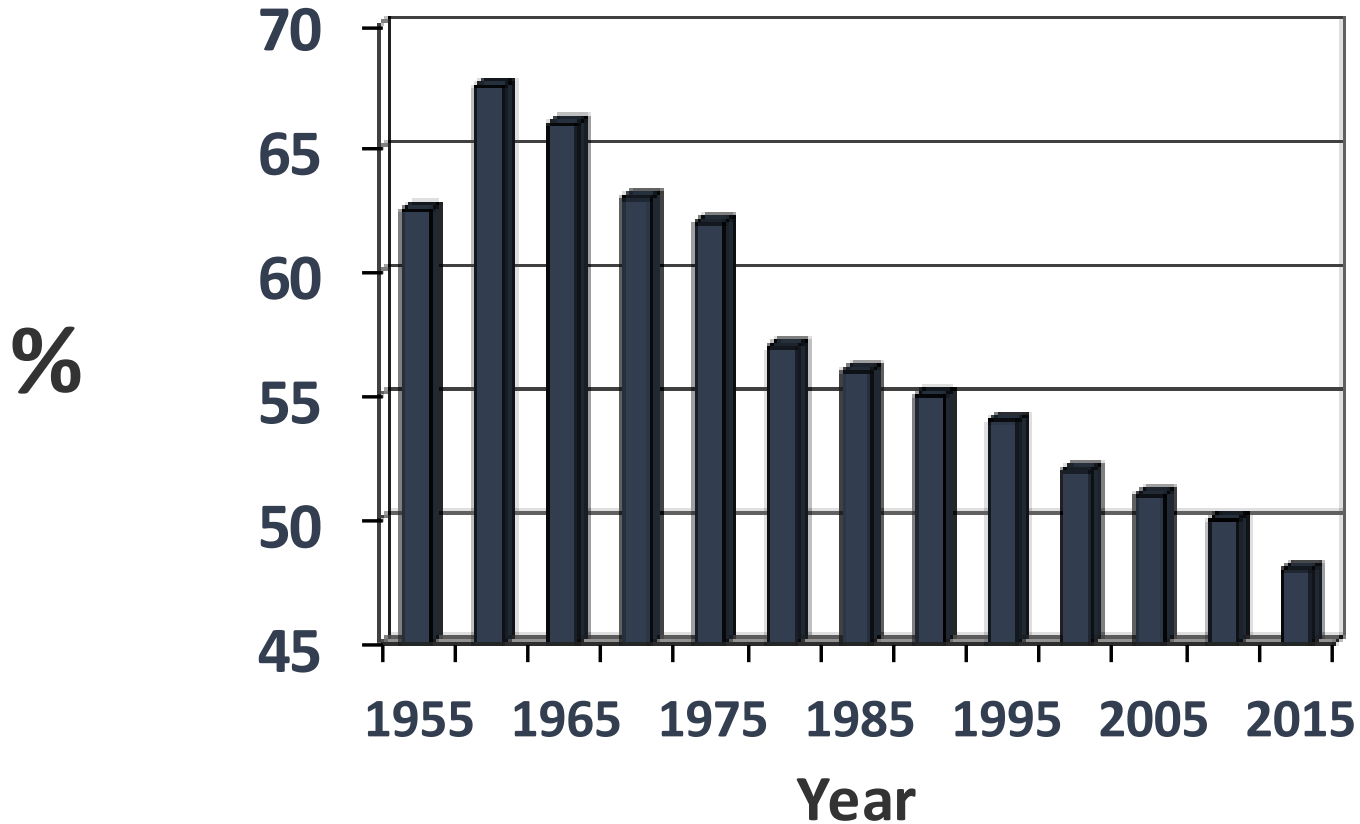
Where is the
storage?

Old Grid



Energy flows mostly one way

Utility Load Factors* in the USA



Basic Thermal Storage



Thermal Storage Basics

How many Kilograms of ice do you need
per person for a party? ~0.5 Kg

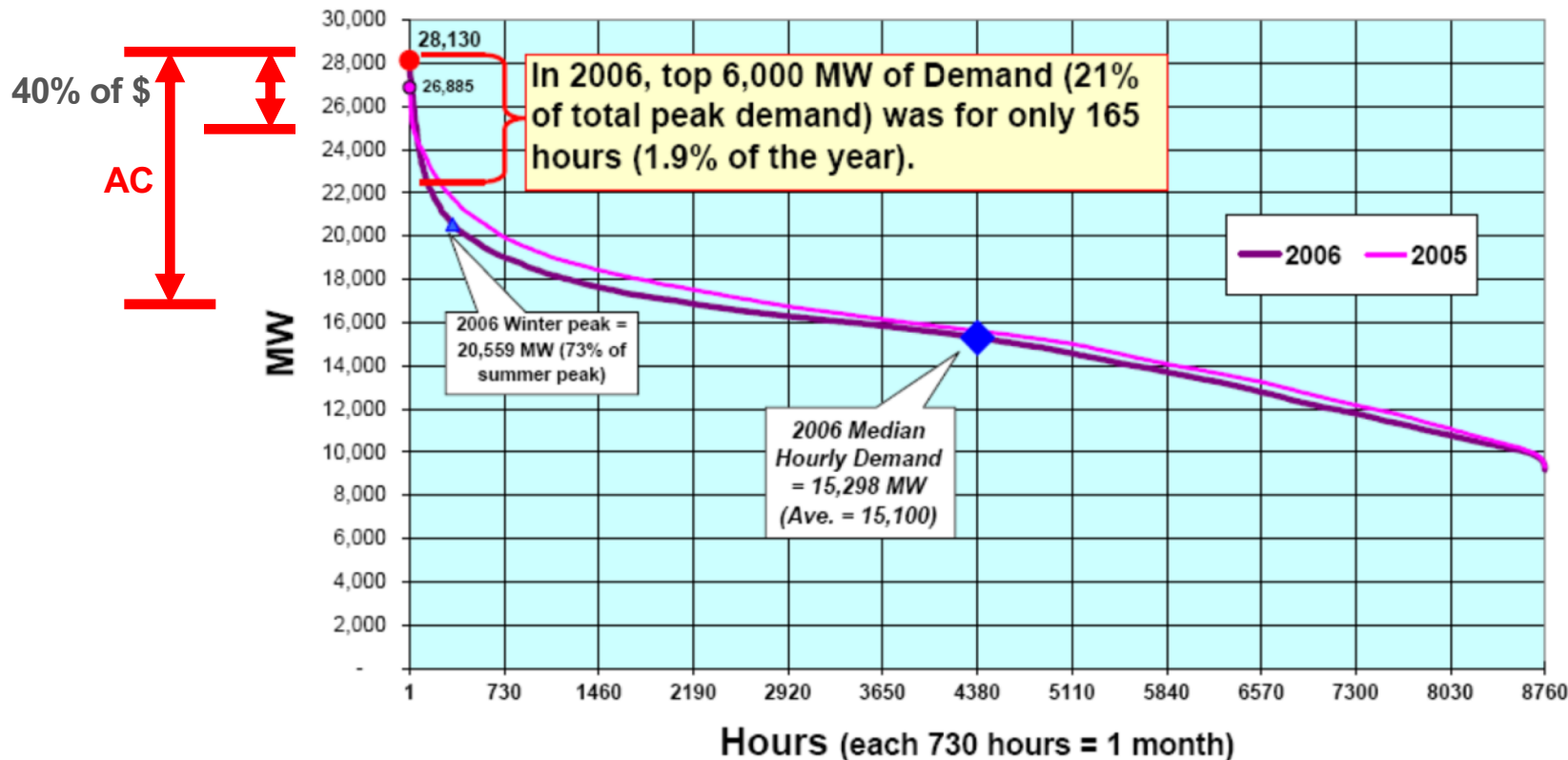
How many Kilograms of ice do you need
per person each day
in the average office building?

10 m²/per person 20 m²/per person

10 m²/kW 12.5 m²/kW 15 m²/kW

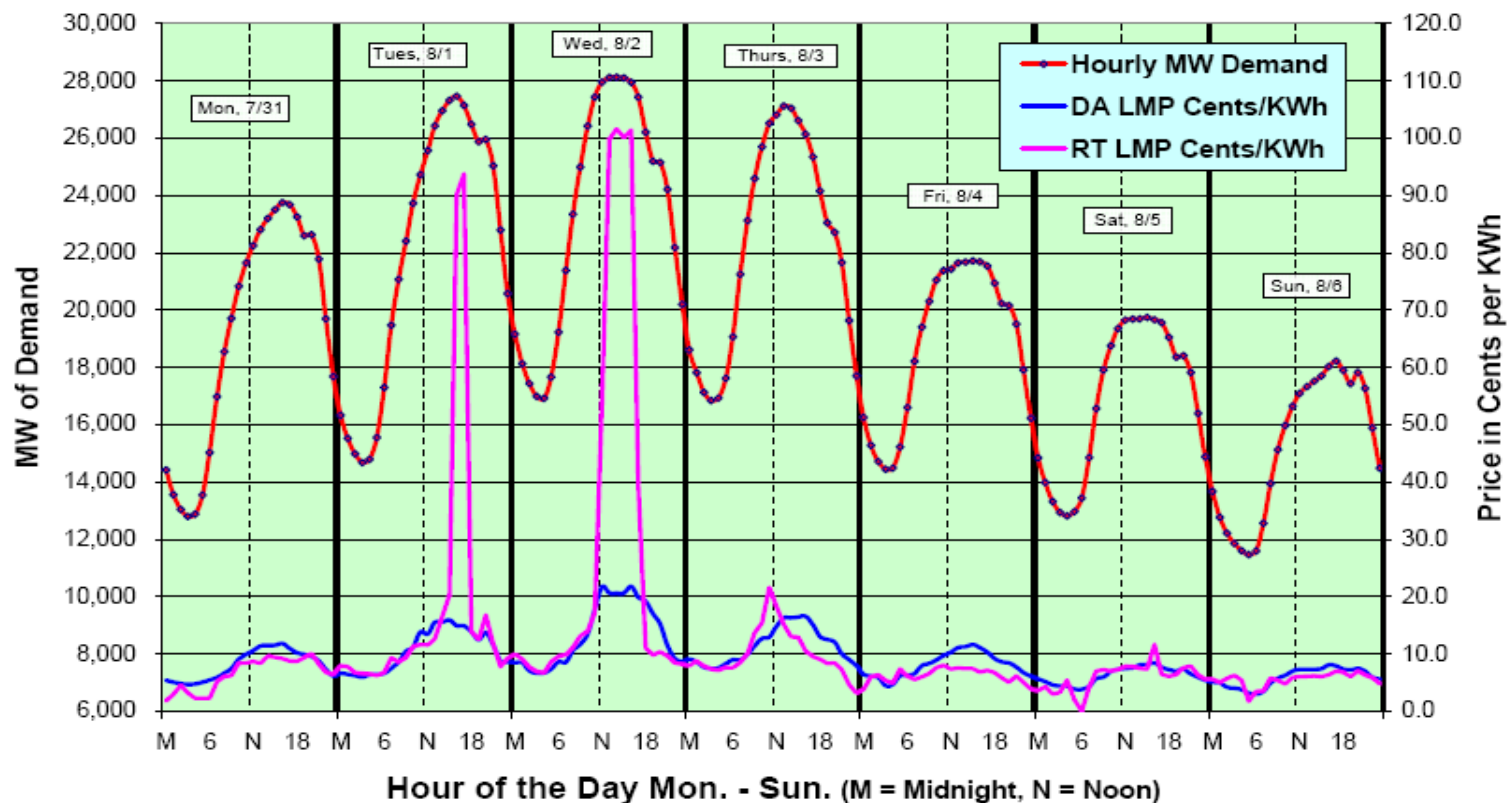
10 m²/pp / 12.5 m²/kW x 8hr = 6 kWh = 70 kg Ice/Person/Day
20 m²/pp / 12.5 m²/kW x 10hr = 16 kWh = 170 kg Ice/Person/Day

ISO-New England 2005 & 2006 Hourly MW Load Duration Curve



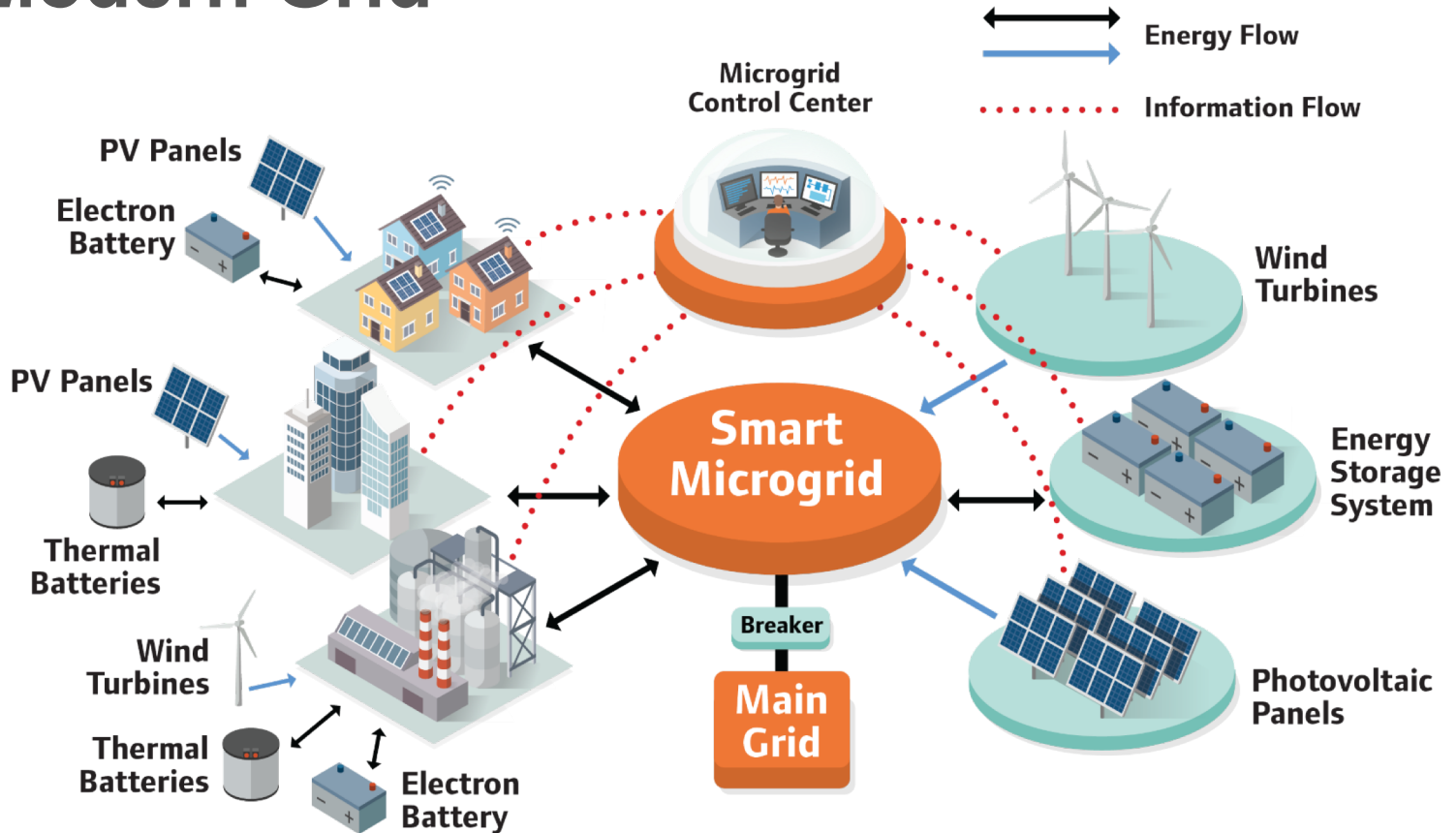
Graph by Clifton Below, NHPUC, from: 2006_smd_hourly.xls and 2005_smd_hourly.xls available at: http://www.iso-ne.com/markets/hstdata/znl_info/hourly/index.html

ISO-NE Hourly Demand & Price Week of 7/31-8/6/06



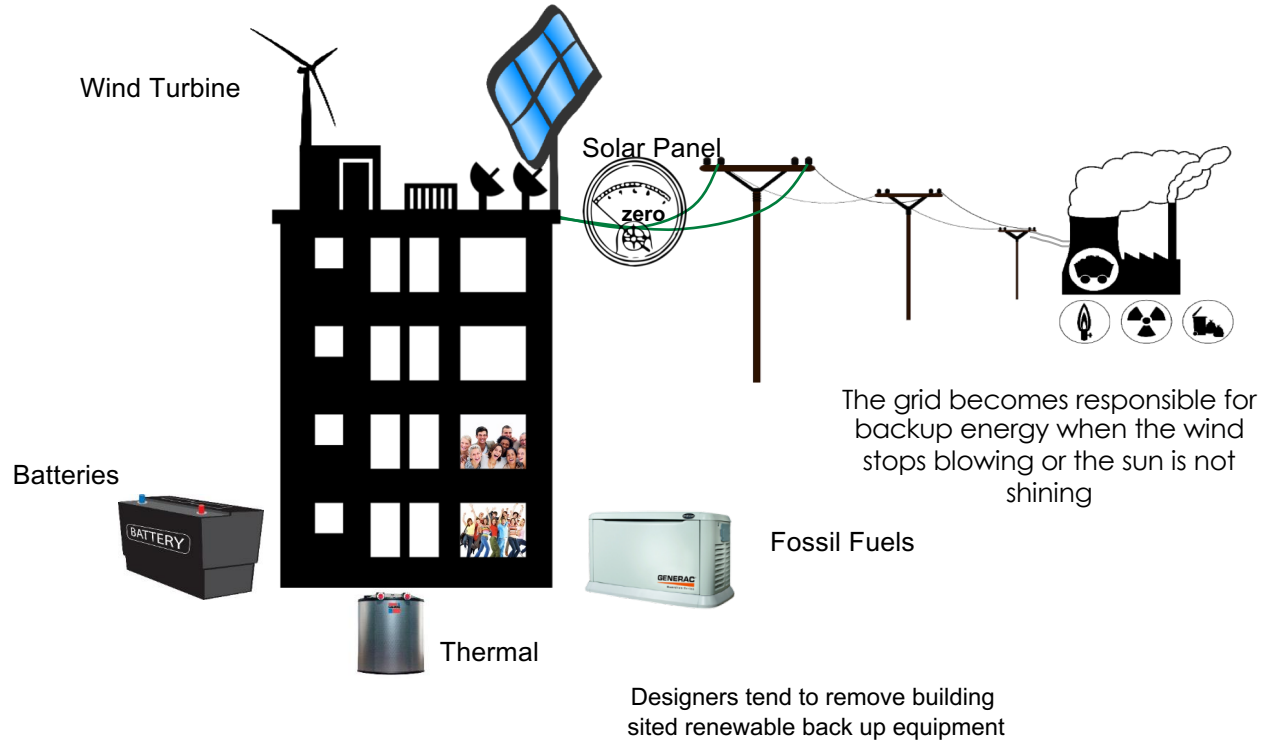
Graph by Clifton Below, NHPUC, from: 2006_smd_hourly.xls, available at: http://www.iso-ne.com/markets/hstdata/znl_info/hourly/index.html

Modern Grid

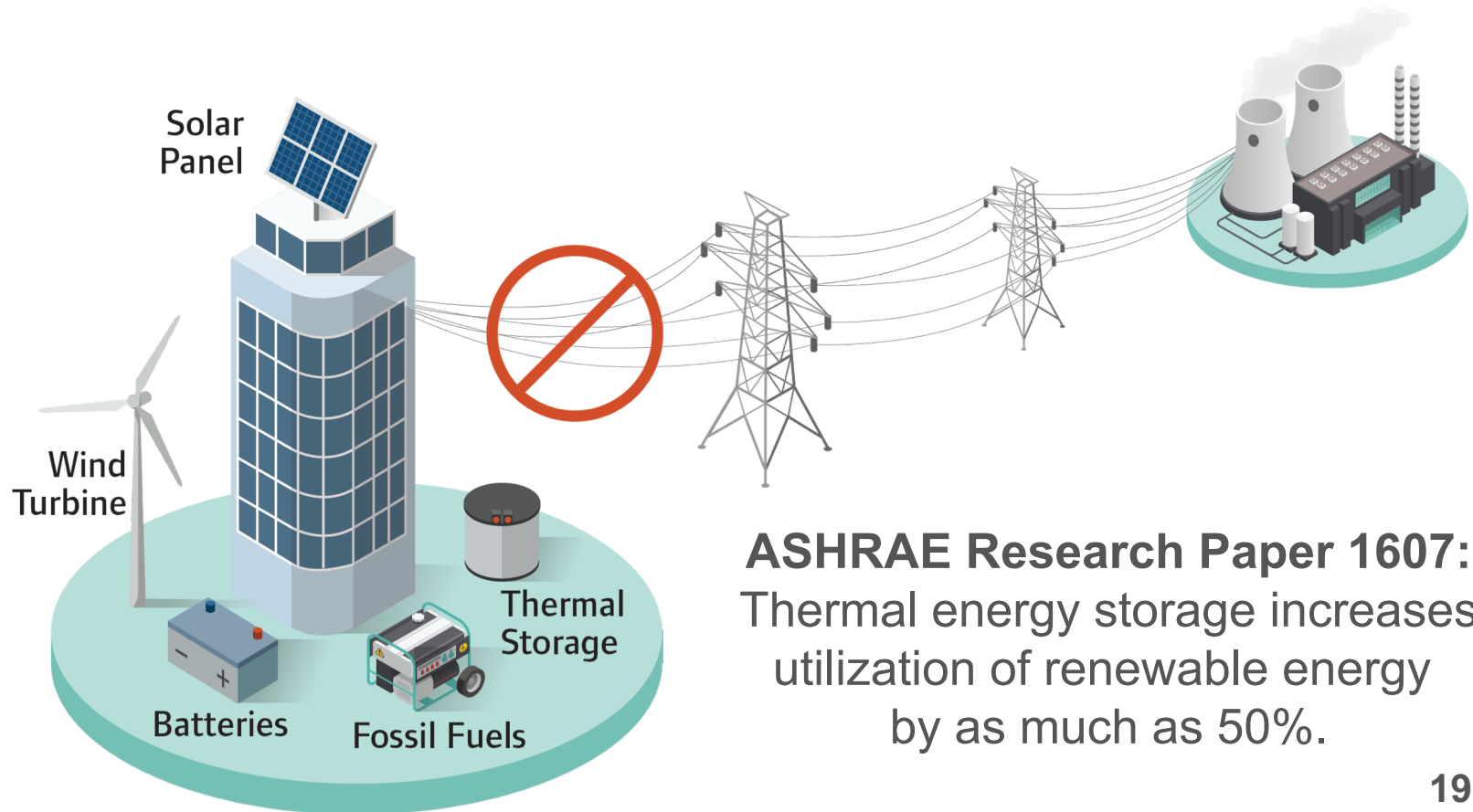


Net Zero Grid Building

Off Grid Building

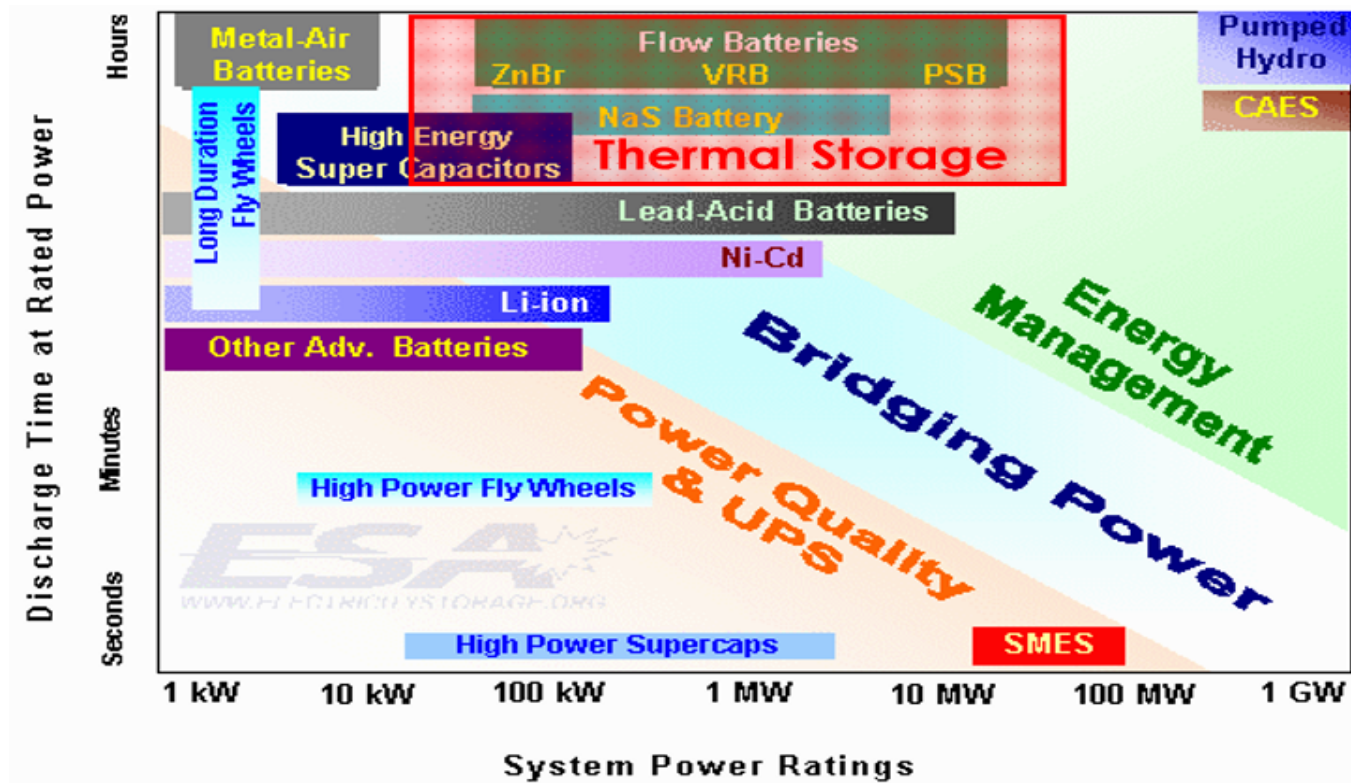


Net Zero Building



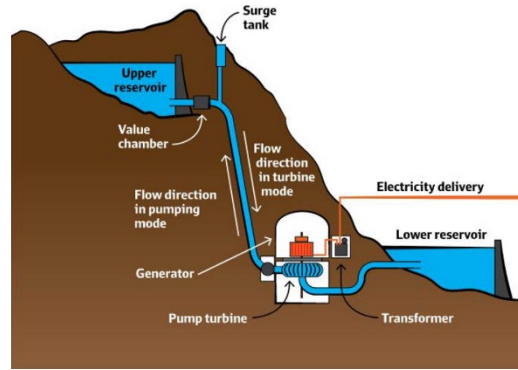
ASHRAE Research Paper 1607:
Thermal energy storage increases
utilization of renewable energy
by as much as 50%.

Energy Storage Types



Grid Side (of meter) Energy Storage Technologies

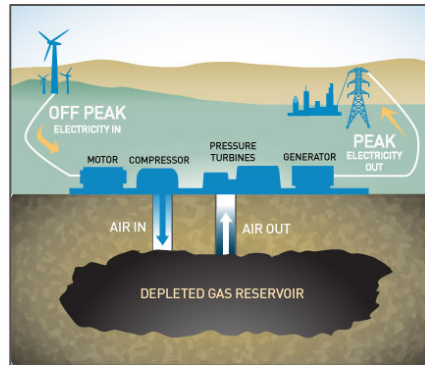
Pumped Hydro



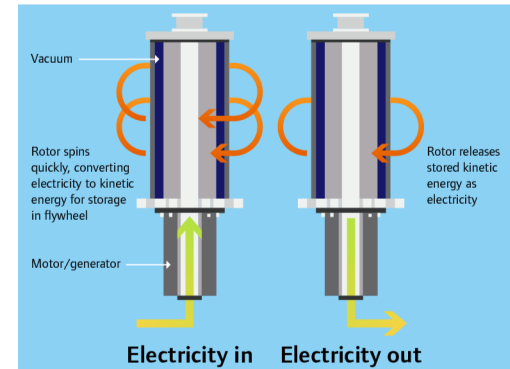
Battery



Compressed Air

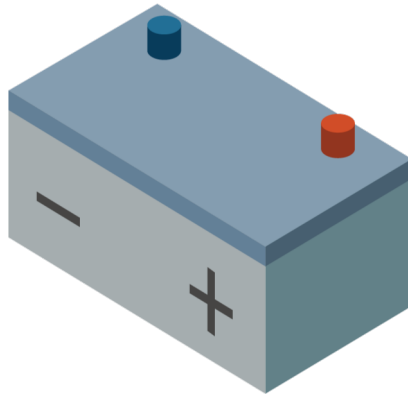


Flywheel

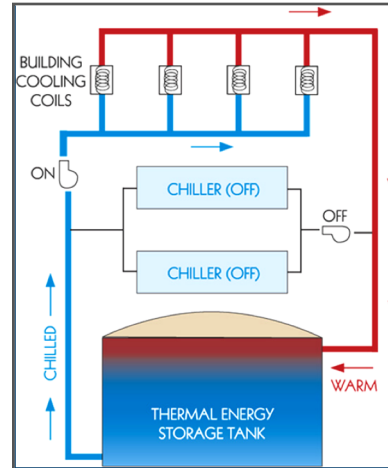


Building Side (of meter) Energy Storage Technologies

Battery



Thermal Energy Storage (TES) Hot, Cold or Ice, Active or Passive

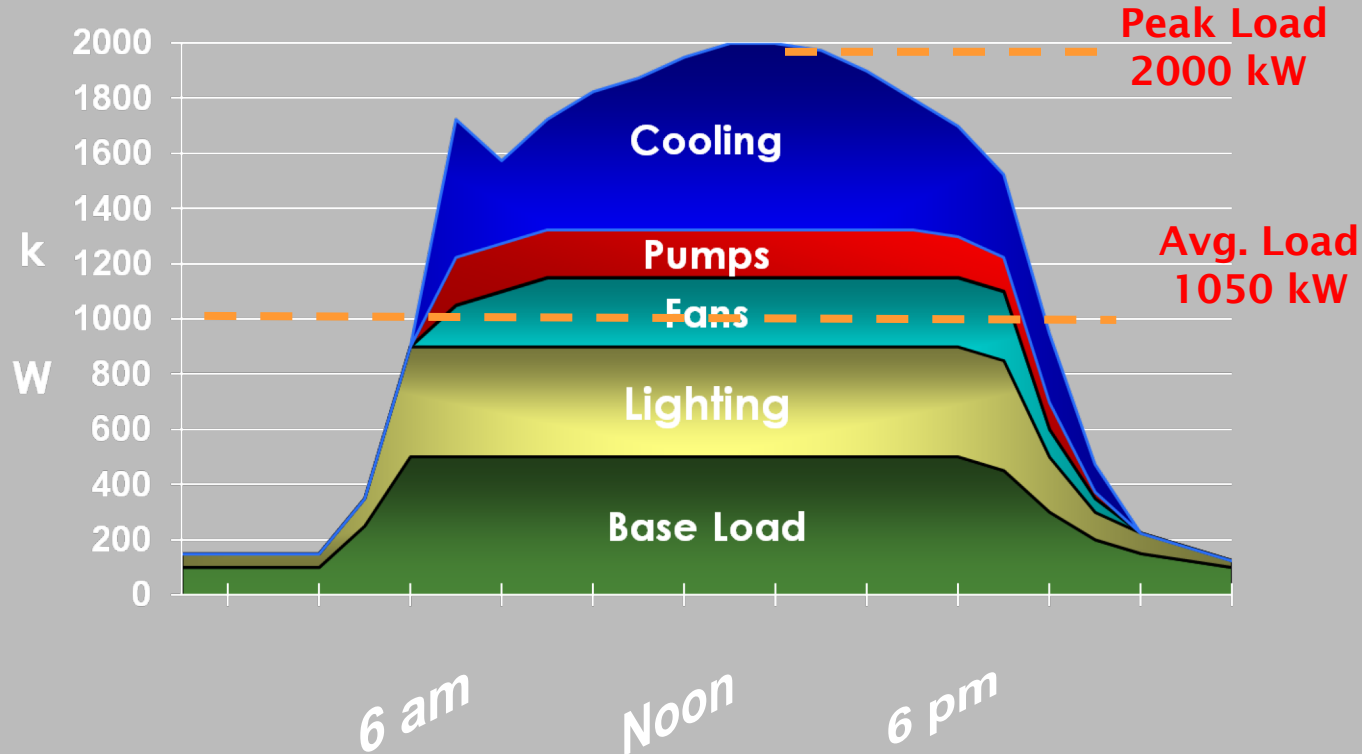


Comparison: Energy Storage Options

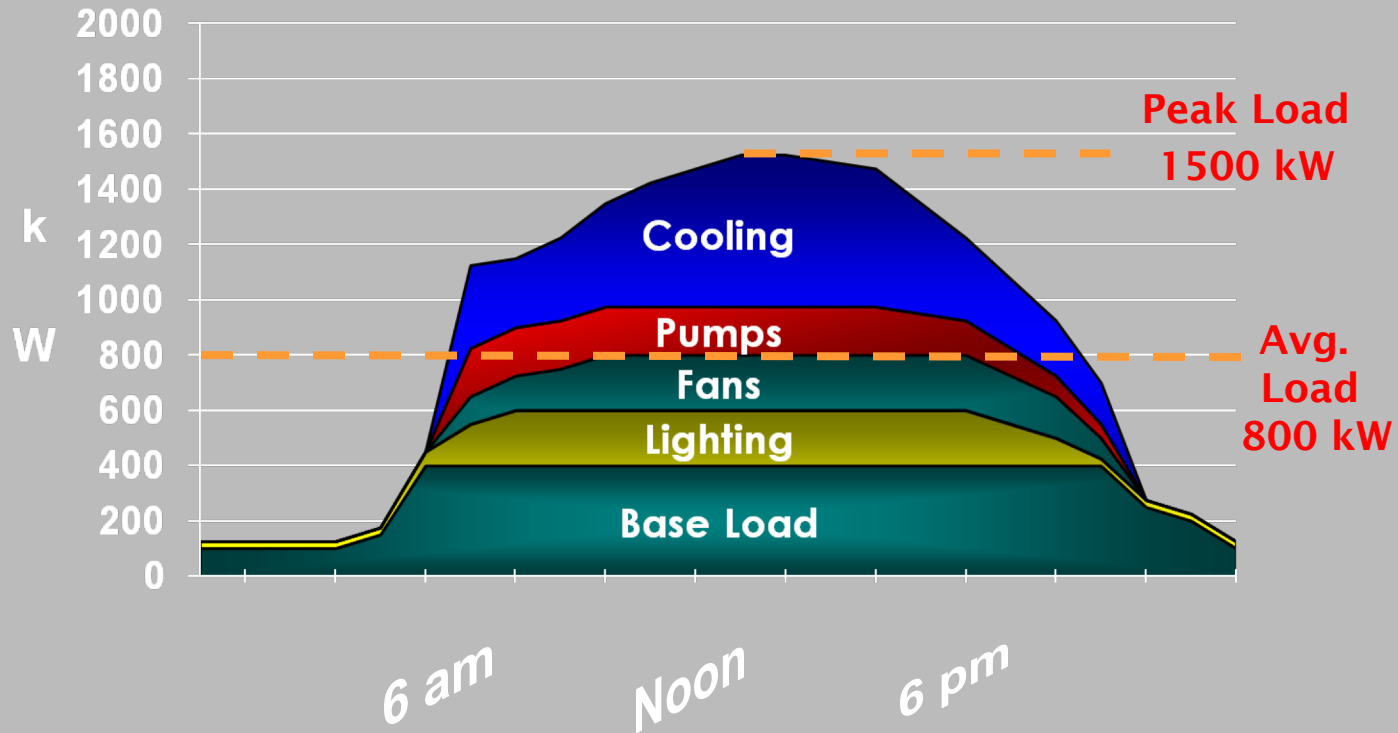
Energy Storage Technology	Tech Maturity	Useful Eff (%)	Life (Yrs.)	Capital Costs (\$/kWh)
Pumped Hydro	mature	70-80	40+	310-380
Na-S Batteries	mature	80	5	650-700
Lead-acid Batteries	mature	85-90	7-15	500-750
Li-Ion Batteries	new	80-90	7-10	450-1125
Flywheels	new	90	20	7800-9000
Compressed Air	demo	70-80	40+	80-150
Thermal Storage	mature	90-100+/-	50+	30-500

Thermal Energy Storage (TES) has low initial cost, high efficiency, and longer useful life

ASHRAE 90.1 Base Building Non-Storage Electrical Profile

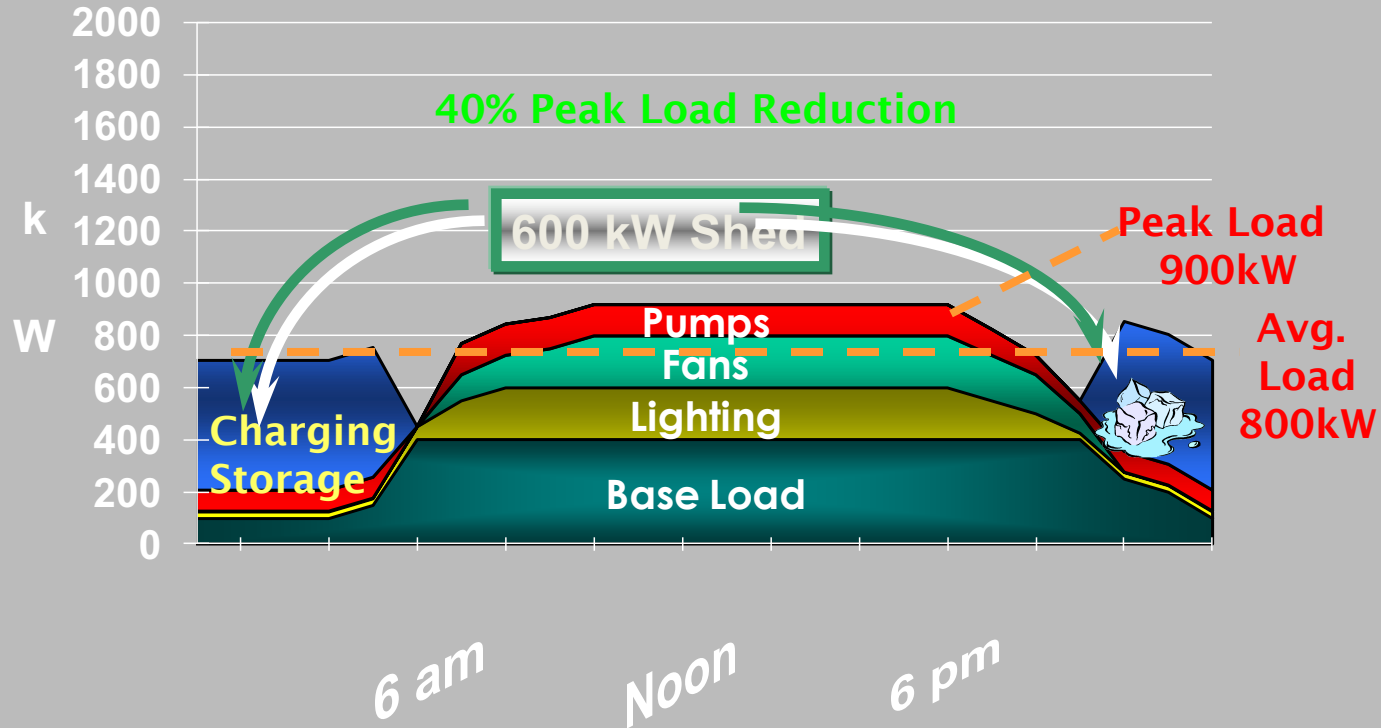


30% Better than ASHRAE 90.1 Non-Storage Electrical Profile



Total kWh = 19,200/day (Load Factor = 53%)

30% Better than ASHRAE 90.1 with Thermal Energy Storage



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

Power continues to be less expensive at Night because of Generation Load Factor



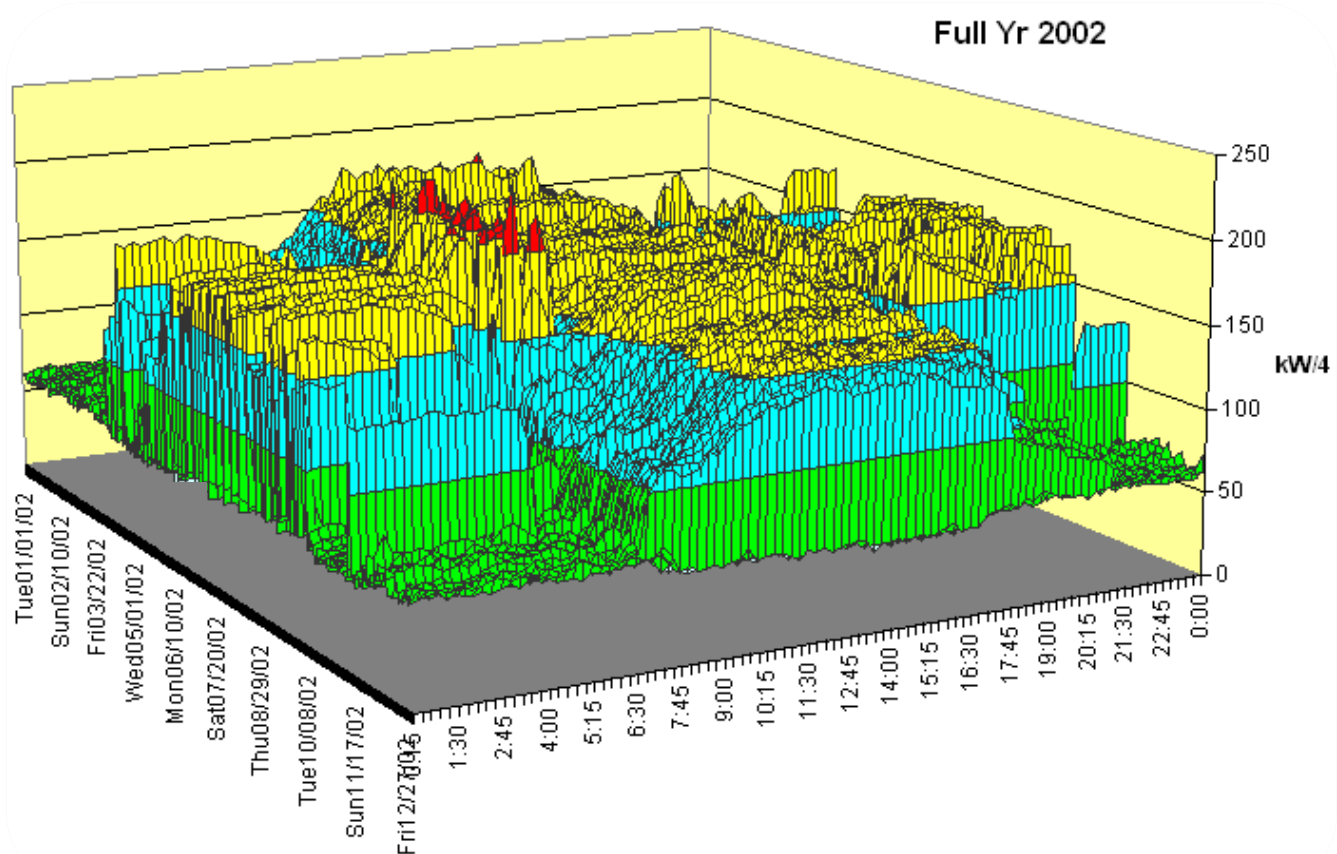
4 Buildings x 1 Megawatt
= 4 Megawatts
8,000 MW-h Sold



5 Buildings with TES @ 0.8 MW
= 4 Megawatts
10,000 MW-h Sold!

**The same generator produces
25% more sellable MW-h**

3D Electric Profile, Full Year



Cool Storage Systems

Two Basic Systems:

- Water
- Ice



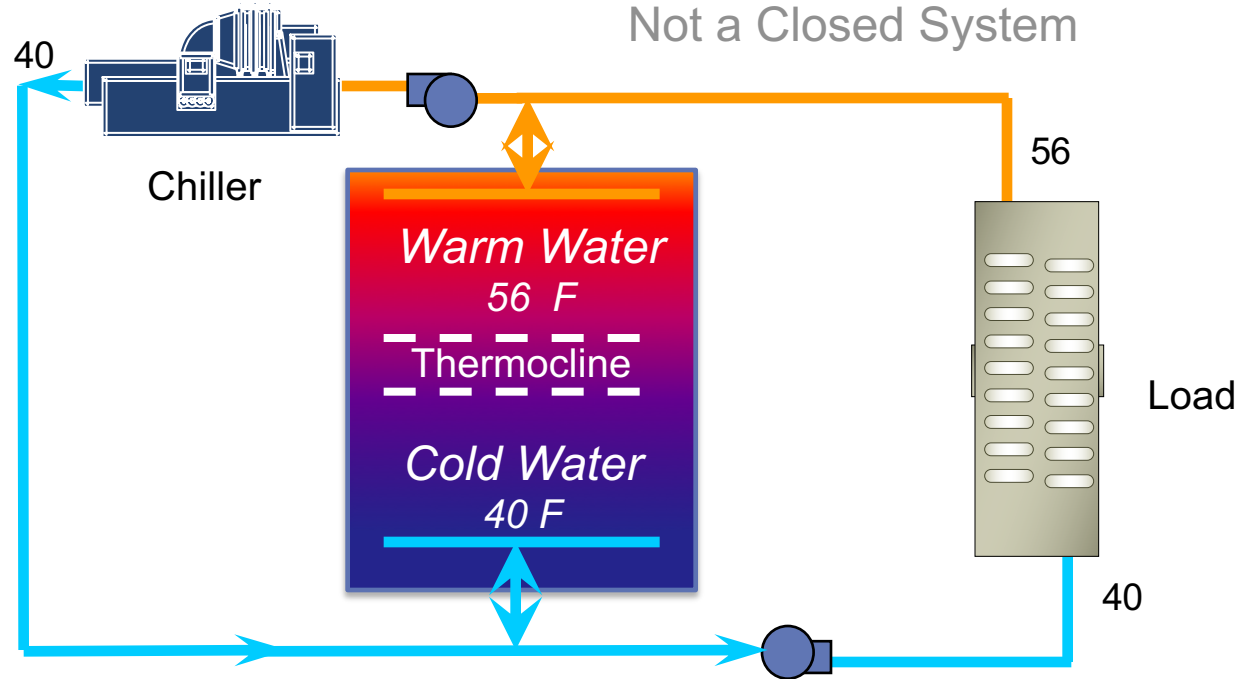
Water Storage

So what is “Different”?

Storage Tank

Keeping System ΔT is a must

Not a Closed System

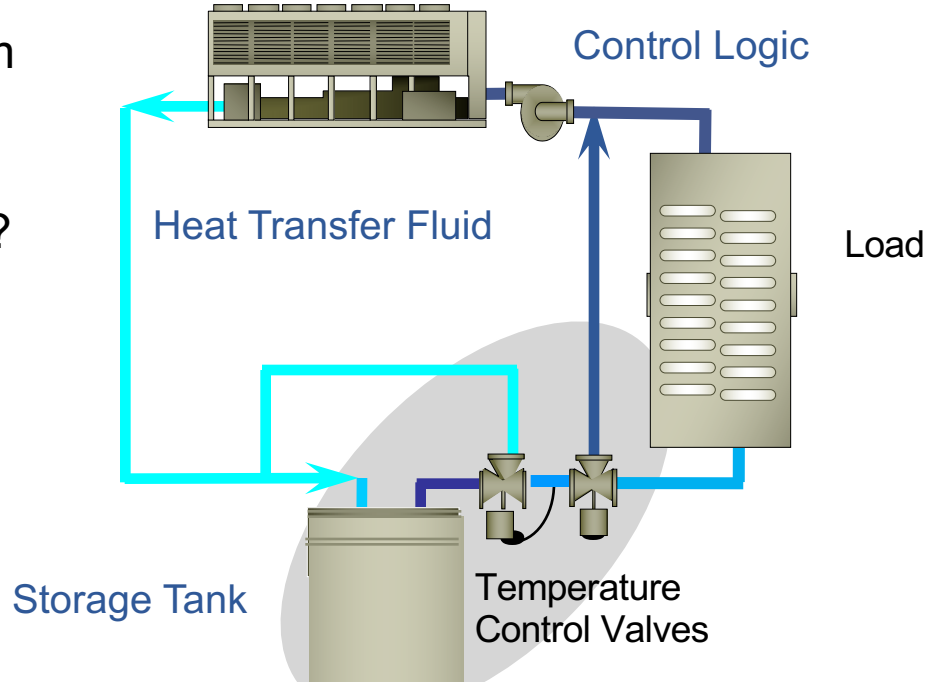


Ice Storage Systems

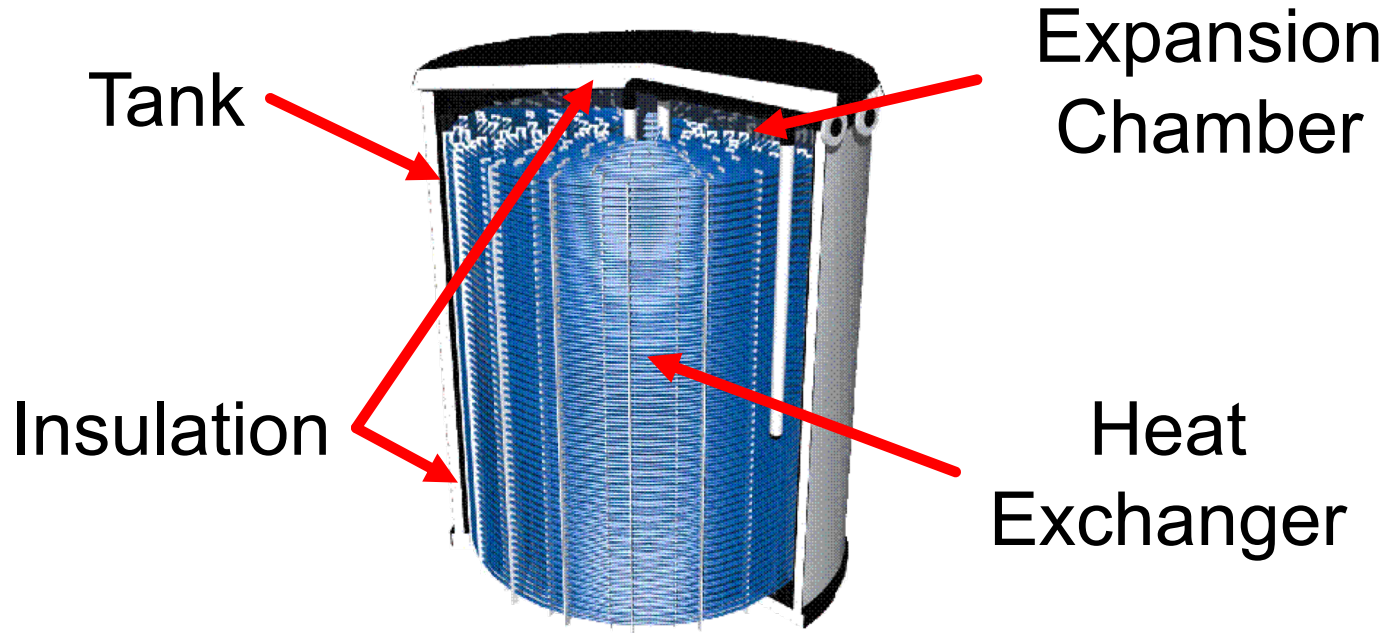
Chiller Based System

Closed System

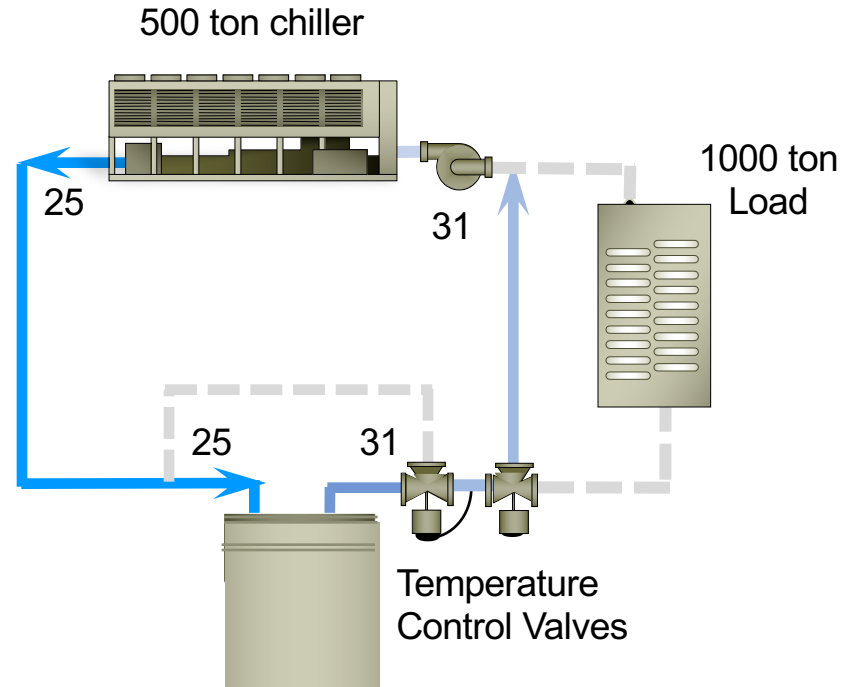
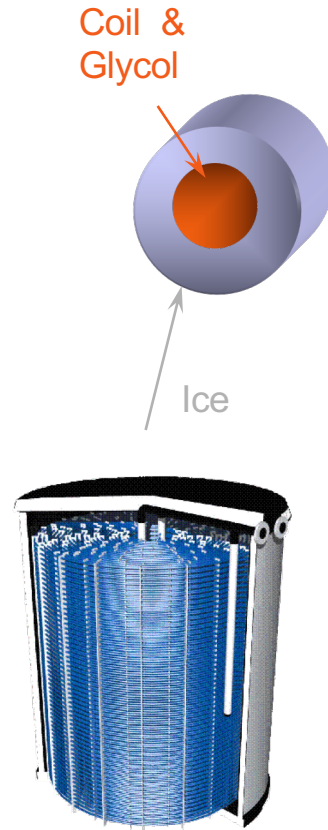
So What is Different?



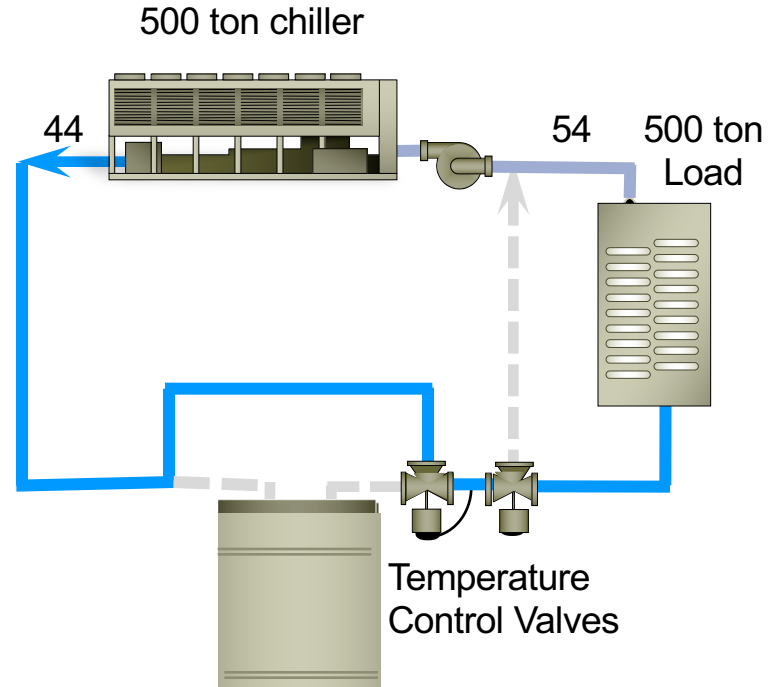
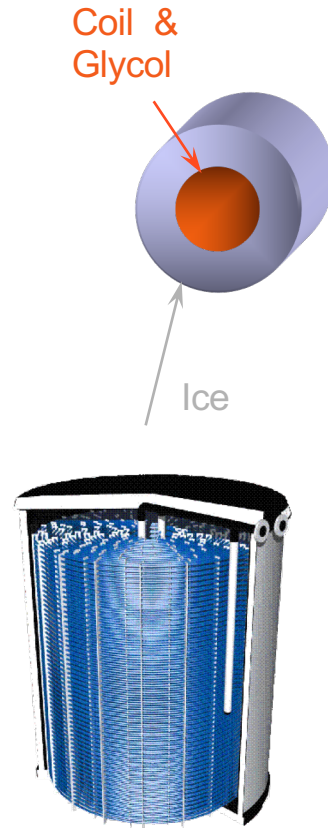
Thermal Storage Tank Ice-on-Coil Internal Melt



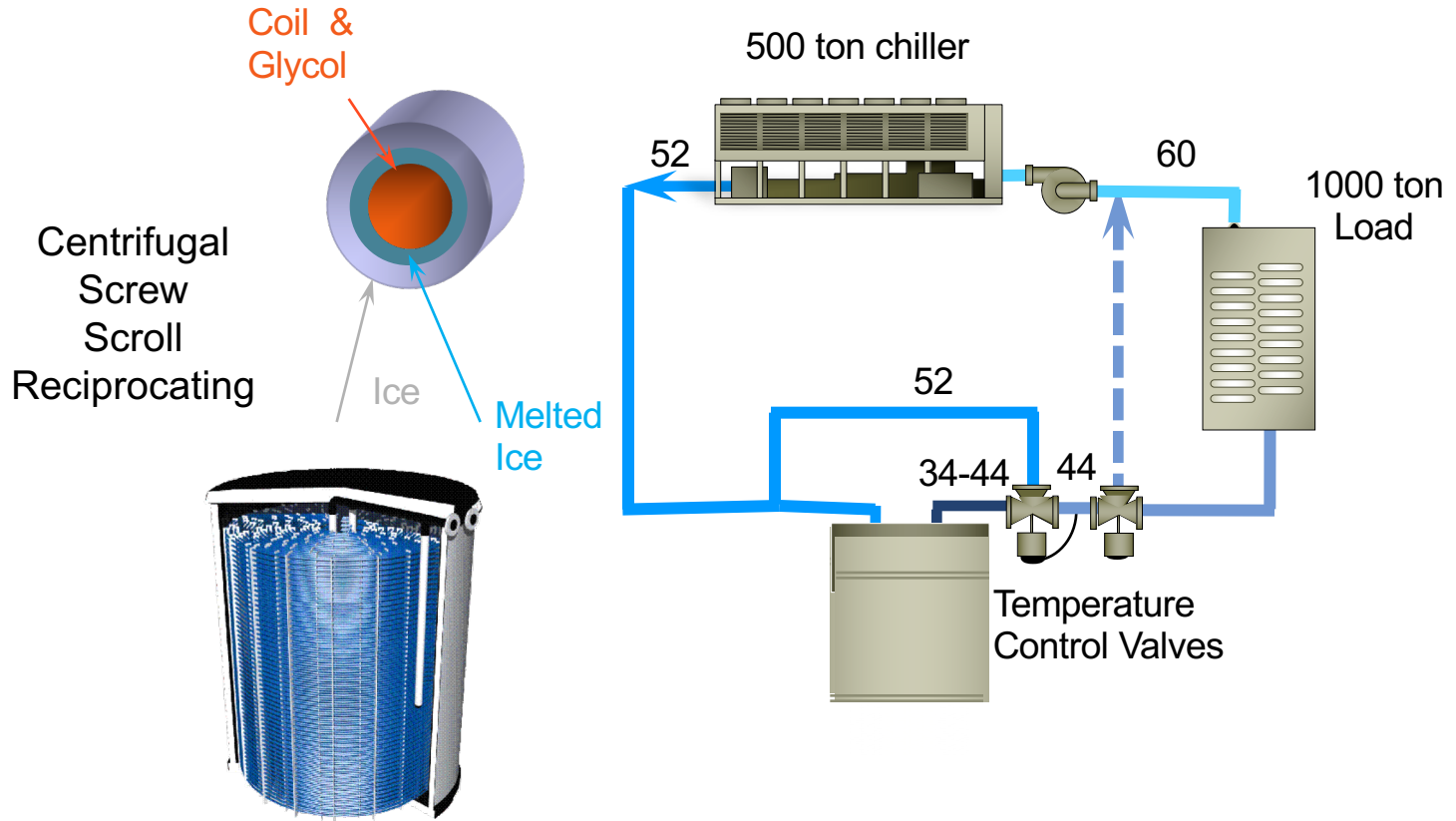
Ice Making



Direct Cooling



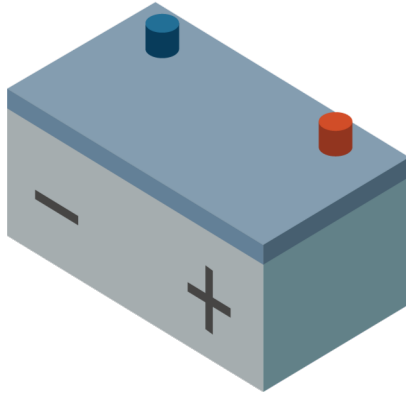
Ice Melting and Chilling



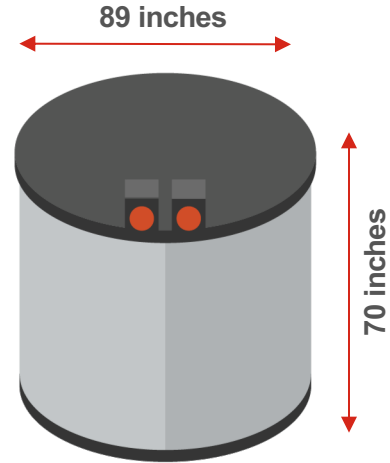
Jefferson Community College- Watertown, NY



Chemical Battery ~~vs~~ ~~with~~ Thermal Storage (Battery)



18 kW shift over 3-6 hours



18 kW shift over 6 hours
Cool 7,500 sq. ft. 6-8 hours

Comparison Costs*


	Equip	Hours of discharge	Impact Output	kWh per day	Installed cost	Cost / kW	Cost / kWh
Ice Storage	Qty-1 Ice Tank	1 Ice Tank discharging over 6 hrs.	18 kW Cooling	108	\$22,000 \$7,000	\$1,222 / kW \$ 388/ kW	\$ 203 / kWh \$ 64 / kWh
Battery	Qty. 6 18 kWh Batteries	6 Batteries discharging over 6 hrs.	18 kW Electron	108	\$100,000	\$5,600 / kW	\$925 / kWh
Battery	Qty-3 18 kWh Batteries	3 Batteries discharging over 3 hrs.	18 kW Electron	54	\$50,000	\$2,800 / kW	\$925/ kWh

* COSTS ARE APPROXIMATE AND VARY BY LOCATION AND PROJECT

Commercial Building Example

	Equip	kW	kWh per day	Installed cost	Cost / kW	Cost / kWh
Ice Storage	(20) Ice Tanks	360	2160	\$440,000 \$140,000	\$1,222 \$ 388	\$ 203 \$ 64
Battery	(60) 18 kW Batteries	360	1080	\$1,000,000	\$2,800	\$925
Ice with Battery	14-1098 Ice tanks with 20 -18kW Batteries	360	1872	\$641,000 \$441,000	\$1,780 \$ 1,226	\$342 \$236

* COSTS ARE APPROXIMATE AND VARY BY LOCATION AND PROJECT



**For the best customer focused solutions, have
Thermal Batteries meet thermal loads and
Electrical Batteries meet electric loads**

Commercial building example

- Over 8,000 installations in 60 countries
- Over 1GigaWatt of Peak Load, 6 GigaWatt-Hrs



NEW YORK CITY ICE STORAGE INSTALLATIONS ~ 120 MW-HR



Thermal Energy Storage Myths Article

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

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Thermal Energy Storage MYTHS

Uncommon Too Much Space Too Complicated Doesn't Save Energy Too Expensive Lack of Redundancy (Risky) Rates Will Change Modeling doesn't Show Results

Electric Rates Change Expensive

By Mark M. MacCracken, P.E., Member ASHRAE

Using thermal energy storage has shifted gigawatts of power off of daytime peaks in a cost-effective manner. However, thermal energy storage (TES) market penetration is small in comparison to its potential. Why? In TES' infancy (early 1980s), a small number of manufacturers carefully researched the technology and installed equipment. In the technology's adolescent years (late 1980s and early 1990s), dozens of manufacturers, chasing the new demand-side management rebate incentives, jumped into the marketplace. These difficult adolescent years resulted in tarnished reputations and the spread of misinformation about the technology.

This article attempts to set the record straight on the myths and reality of this technology by demonstrating how TES is well-positioned to help the move towards more energy-efficient and environmentally friendly air-conditioning systems. The obvious reason for installing TES is to reduce energy costs. Although degradation of the electric industry has created localized anomalies in energy costs, the basic reality of supply and demand is that on-peak power is more expensive than off-peak power.¹ One consistently proven aspect of TES is that it saves energy costs, which has more significance now that ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential*

Buildings, and the LEED rating system are based on energy cost savings. Several TES projects that have won ASHRAE's Technology Award^{2,3,4} detail the cost-saving aspect. However, less emphasis has been given to the reductions of equipment size and infrastructure that normally occurs.

The basic TES cooling systems that I base most of my analysis on are: **Chiller-based systems.** Throughout the adolescent years of TES, a variety of systems including site-built liquid overfeed refrigeration systems, ice-harvesting equipment and others, were used successfully in other applications. However, 99% of commercial air-conditioning TES systems installed use a standard chiller to

produce the cooling. Chillers are familiar, reliable, capacity rated, and competitively priced. They cool water or a glycol water solution.

Ice-based storage. For projects where space is not as much of a consideration, chilled water storage is becoming widely used.⁵ However, since so much HVAC work involves retrofits where space is a concern, ice is the likely choice.

Closed system. Large district cooling systems use either water and/or ice as the storage media and the heat transfer fluid. These "open" systems create added hydraulic complications that need to be

About the Author
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September 2003

Thermal Energy Storage in Sustainable Buildings

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



BUILDING FOR THE FUTURE

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Thermal Energy Storage In Sustainable Buildings

By Mark MacCracken, P.E., Member ASHRAE

This article demonstrates why designing a building with stored cooling is a beneficial approach and how oversizing 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 cost 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 decisions. 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 reason TES is a green technology in the LEED system is that, in most locations, electricity at night costs less than half as much as during the day.¹ 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 2.0 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 35% 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. Three

of the four are 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 one by the California Energy Commission,² 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 on-peak plants, with 7,900 to 8,500 Btu/kWh (8335 to 8970 kJ/kWh) 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 (9495 to 12,660 kJ/kWh).

- Line losses are less off-peak because that 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

Questions?

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