TRANE

Energy Storage Technologies: Building Strategies for More Optimal Grid Operation

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CALMAC

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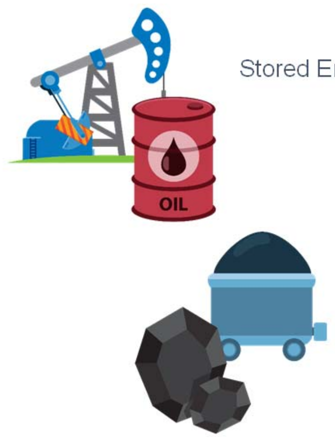
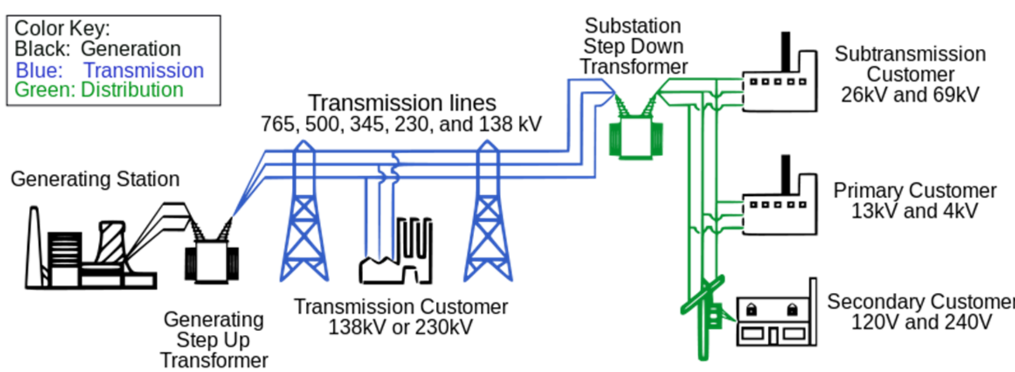


Stored Energy

Energy

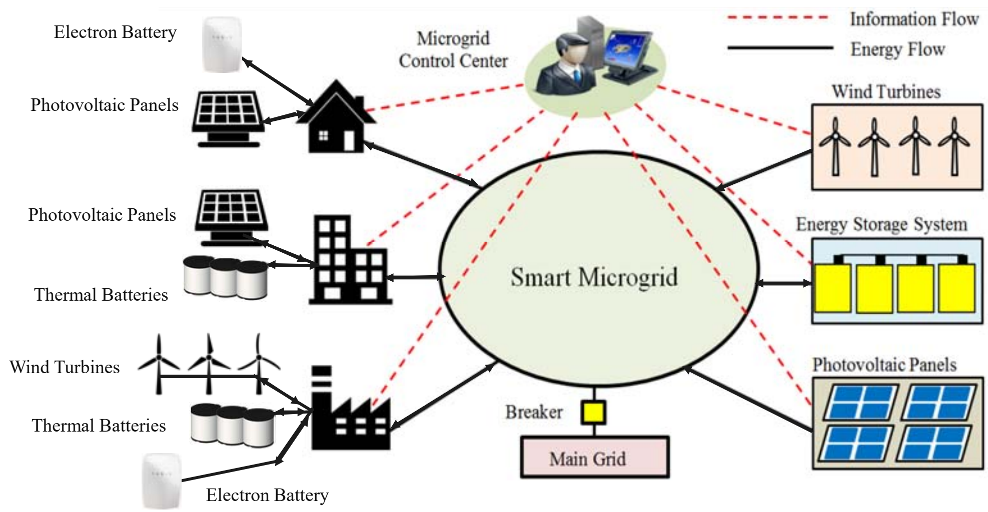
Where is the storage?

Old Grid:

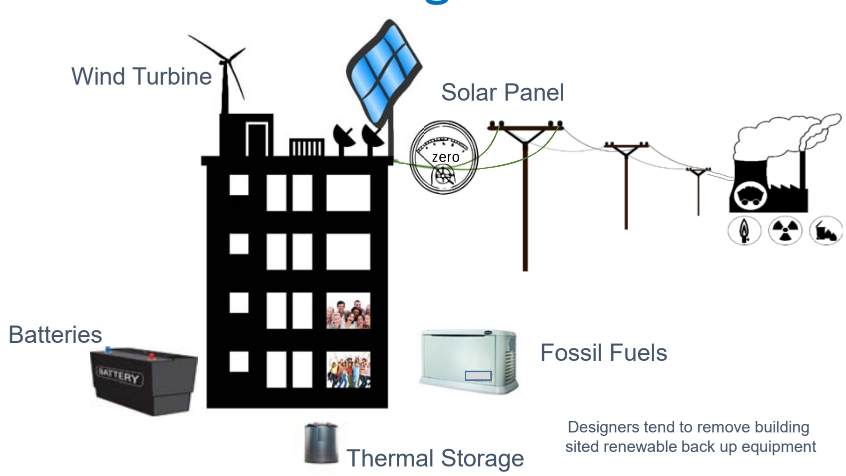


Energy flows mostly one way

Modern Grid

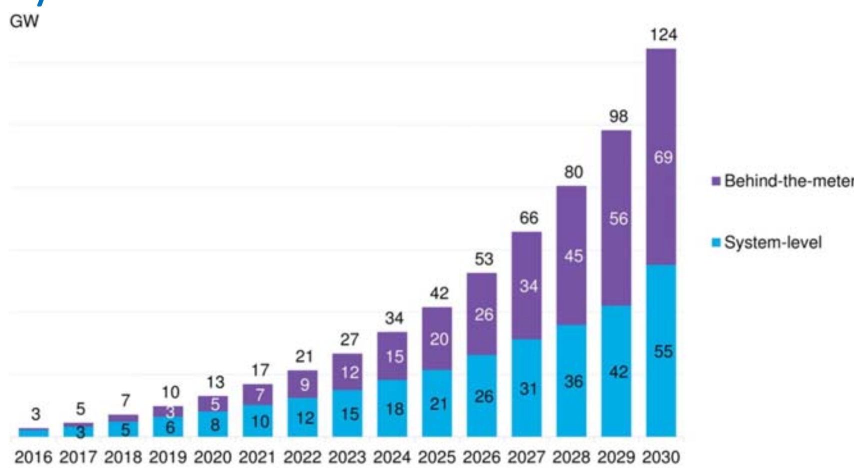


Net Zero Grid Building:



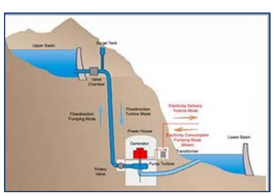
Buildings becoming part of the storage and distribution system

BNEF projections of storage deployment over the next decade



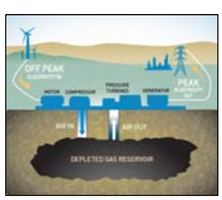
Grid Side (of meter) Energy Storage Technologies

Pumped Hydro



Battery

Compressed Air

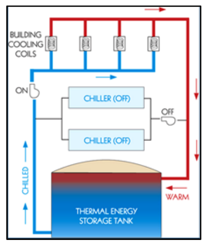


Flywheels

Building side (of meter) Energy Storage Technologies

Battery

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



Thermal Storage

How many lbs. of ice do you need for each person for a party? **~1 lbs.**

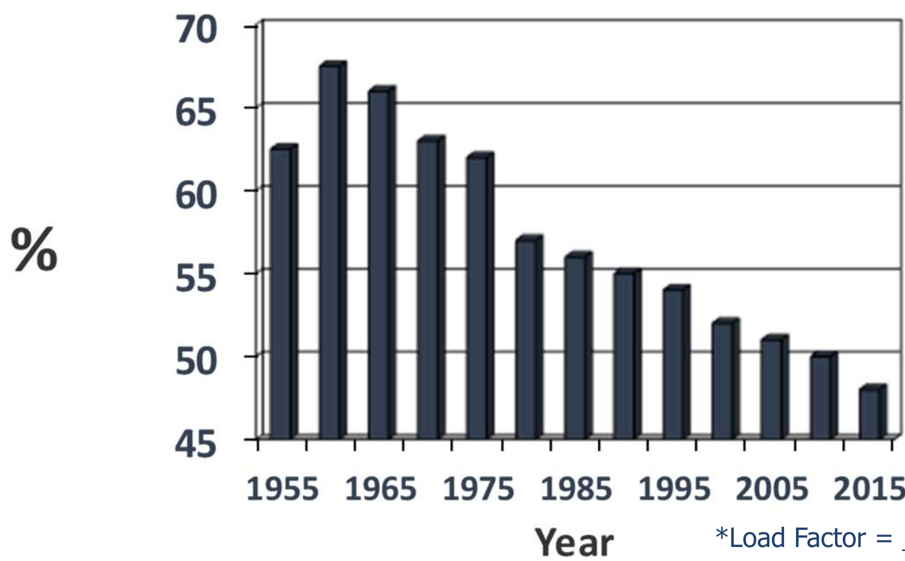
How many lbs. of ice do you need each day to cool each person in a typical office building?

Architect **100 ft^2/per person** **200 ft^2/per person**

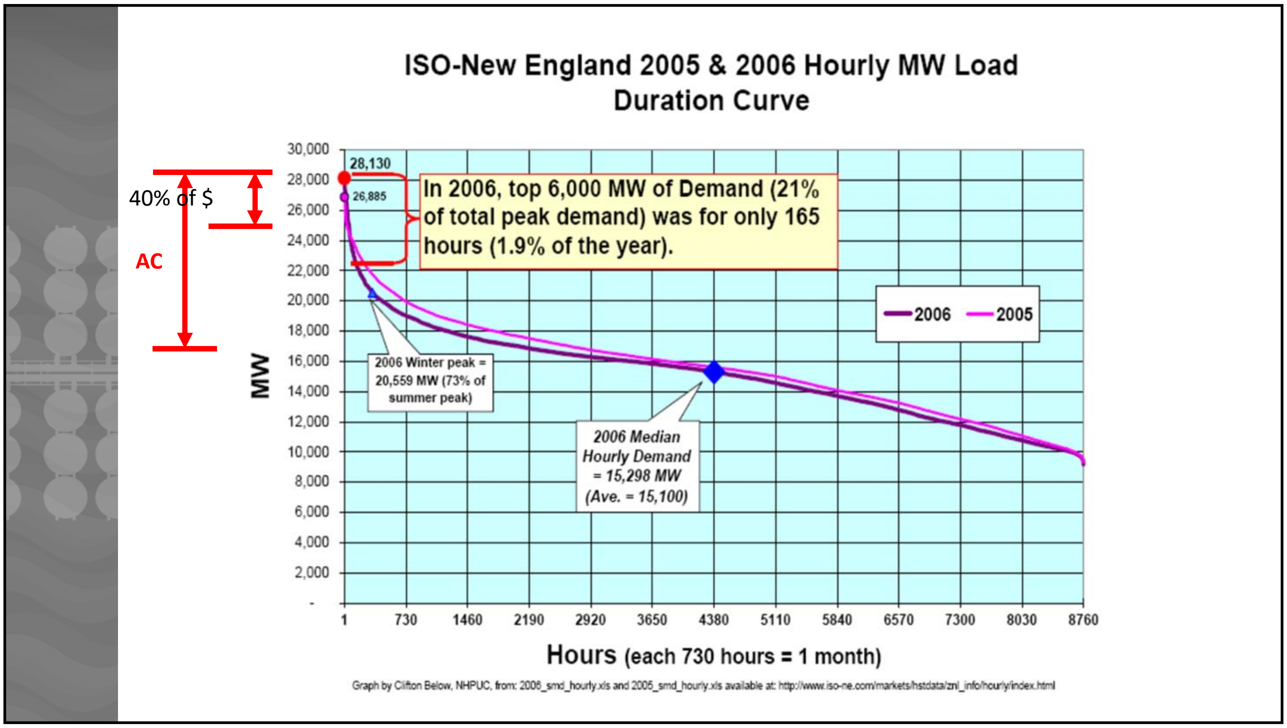
Engineer **300 ft^2/ton** **400 ft^2/ton** **500 ft^2/ton**

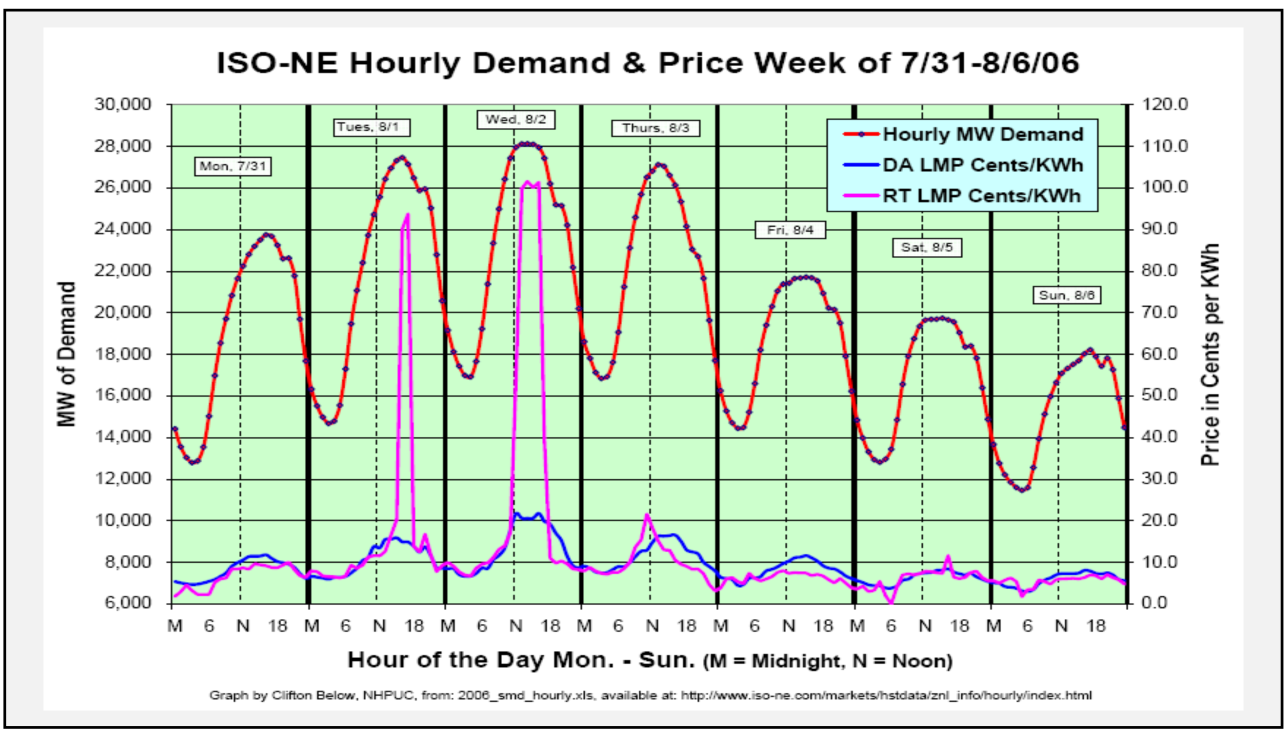
100 ft^2/pp / 400 x 8hr = 2 ton-hrs = 160 lbs of Ice/Person/Day
200 ft^2/pp / 400 x 10hr = 5 ton-hrs = 400 lbs of Ice/Person/Day

Utility Load Factors* in the USA

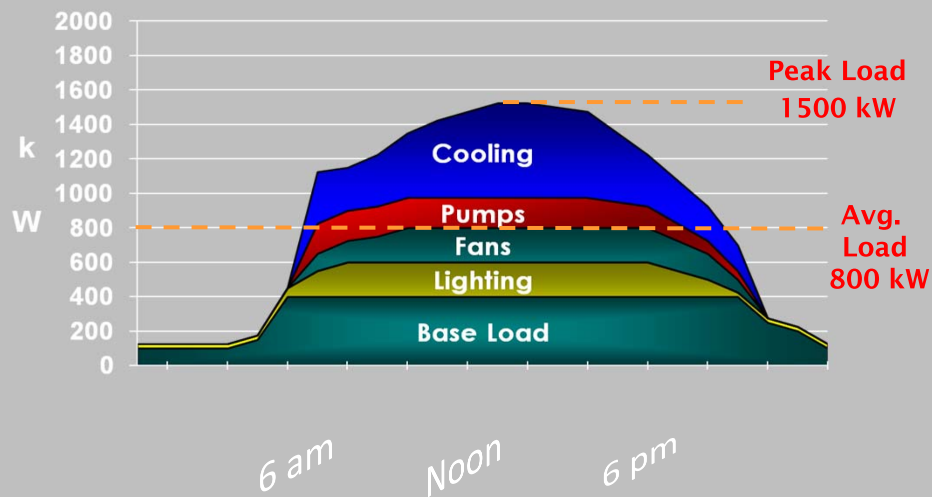


*Load Factor = Avg. Load / Peak Load


ISO-New England 2005 & 2006 Hourly MW Load Duration Curve
40% of $
AC
28,130
26,885
In 2006, top 6,000 MW of Demand (21% of total peak demand) was for only 165 hours (1.9% of the year).
2006 Winter peak = 20,559 MW (73% of summer peak)
2006 Median Hourly Demand = 15,298 MW (Ave. = 15,100)
2006
2005
MW
Hours (each 730 hours = 1 month)
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

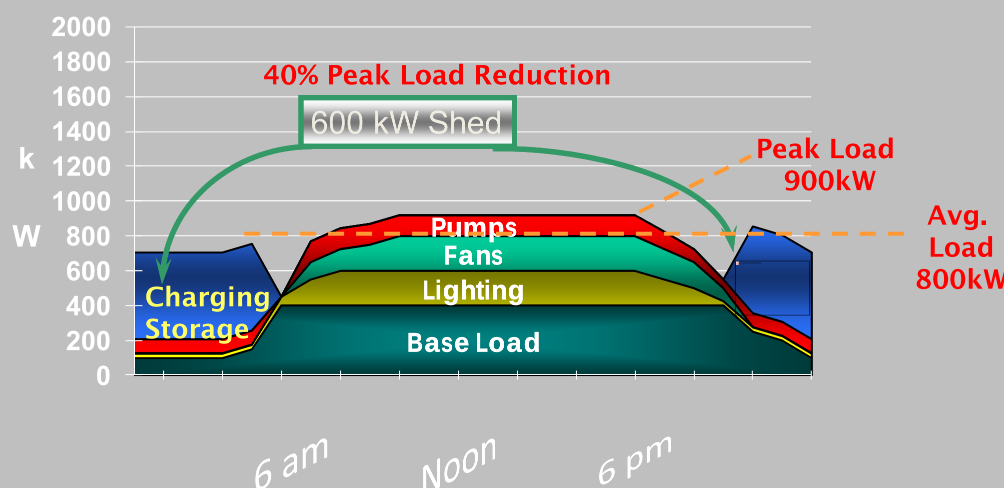

ISO-NE Hourly Demand & Price Week of 7/31-8/6/06
Mon, 7/31
Tues, 8/1
Wed, 8/2
Thurs, 8/3
Fri, 8/4
Sat, 8/5
Sun, 8/6
Hourly MW Demand
DA LMP Cents/KWh
RT LMP Cents/KWh
MW of Demand
Price in Cents per KWh
Hour of the Day Mon. - Sun. (M = Midnight, N = Noon)
Graph by Clifton Below, NHPUC, from: 2006_smd_hourly.xls, available at: http://www.iso-ne.com/markets/hstdata/znl_info/hourly/index.html

ASHRAE 90.1 Building Electrical Profile Non-Storage



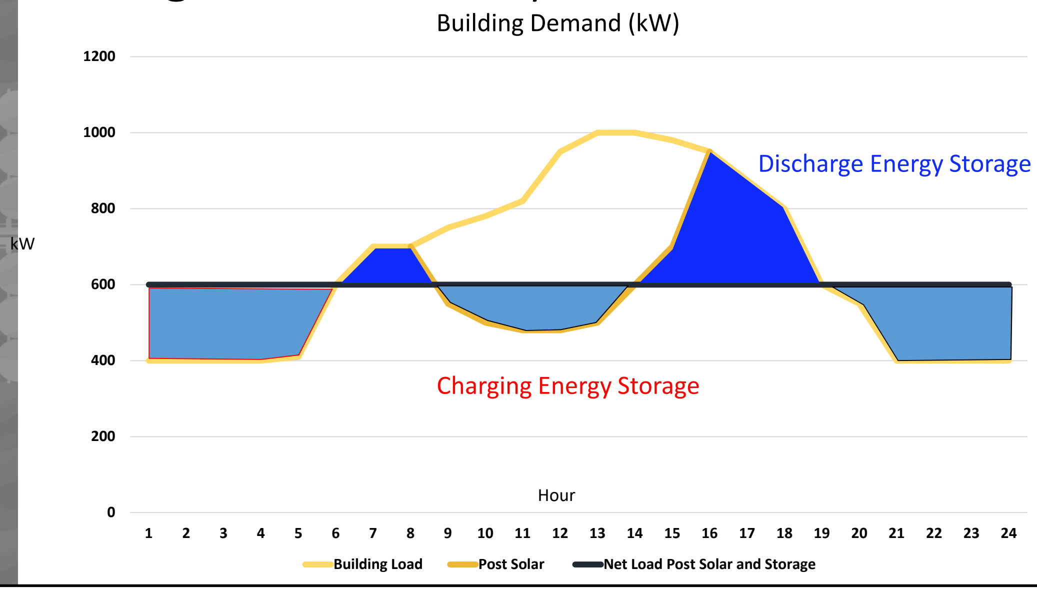
Total kWh = 19,200/day **(Load Factor = 53%)**

ASHRAE 90.1 Building Electrical Profile with Cool Storage



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

Building Load Flexibility



Daytime

$ 2.49/gallon

Nighttime

$ 0.99/gallon

When Would you Fill-up?

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The Demand Charge Effect Simplified

Tucson Energy LSG -13 Rate

Energy (usage):

Day: ~~$0.054/kWh~~ **$0.146/kWh**

Night: ~~$0.054/kWh~~ **$0.054/kWh**

Demand: $~~15.25/kW/Mo~~nth

How big an effect is the Demand Charge??

Energy is 63% less expensive at night

For a daytime peaking building

Utilities with Demand above $14 / kW

- ConEd
- SCE
- PG&E
- SDG&E
- LIPA
- Eversource
- HECO
- O&R (NY)
- Santee Cooper (SC)
- Austin Energy
- United Illuminating (CT)
- PSEG (NJ)
- Dominion (VA)
- Appalachian Power
- Forked Deer (TN)
- Delmarva
- City of Batavia (IL)
- Mon Power (WV)
- Potomac Edison
- Duke Carolinas
- Tucson Electric Power
- Lincoln Electric Service (NE)
- LG&E (KY)
- Hydro One (Qu.)
- Rocky Mountain Power (UT)
- Toledo Edison
- Duke Indiana
- Consumers Energy (Mich.)
- NV Energy
- Arizona Public Service
- El Paso Electric
- Public Service of NM

Representative List – a small fraction

Many types of Energy Storage will be needed on both sides of the electric meter for Renewable Energy, Net Zero Buildings and the Grid to Function Reliably

Electric Meter

Grid Side	Building Side
Pumped Hydro	Chemical Batteries
Compressed Air	Thermal Mass (passive)
Fly Wheels	Thermal Batteries (active)
Super Capacitors	

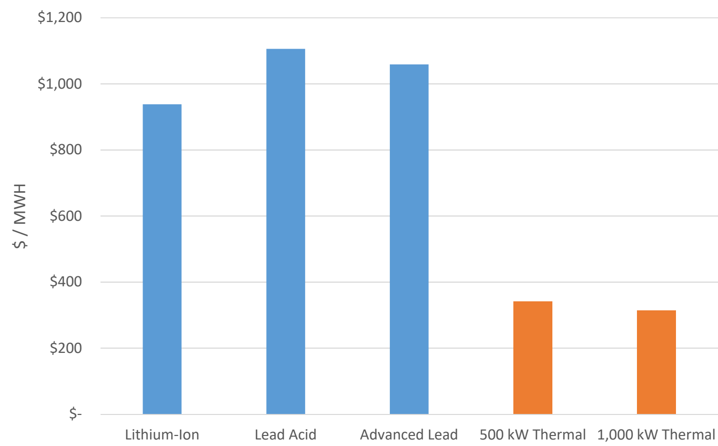
Energy Storage Options

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

Thermal Batteries are 1/3 the cost of electric battery systems for C&I

Levelized Technology Cost for BTM Applications[1,2]

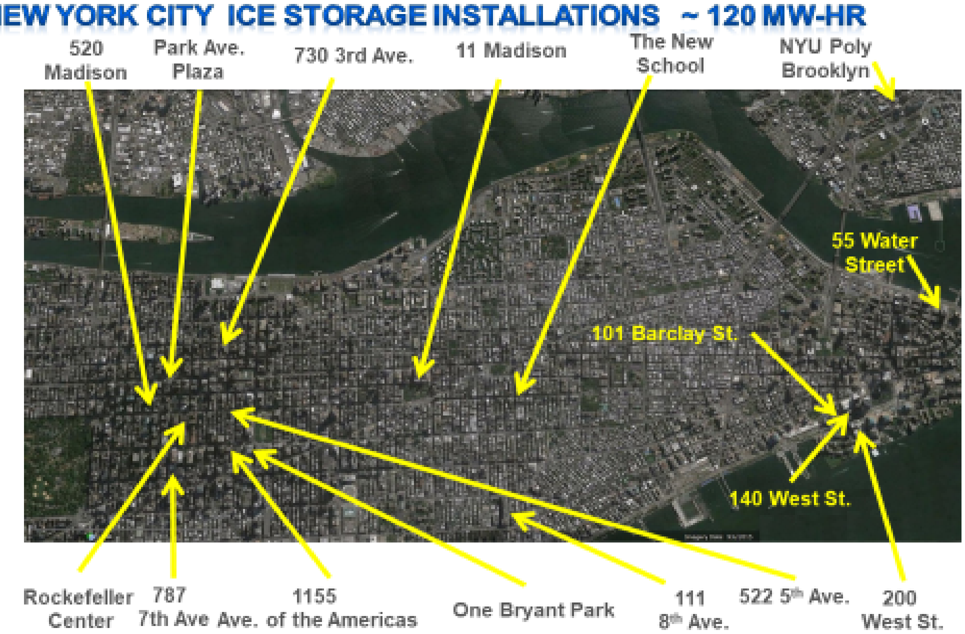


- Cost advantages
  - ✓ No inverter expense
  - ✓ Lower component costs, including balance of system; lower O&M
  - ✓ No need for capacity addition due to degradation
- Lower capital costs mean lower financing costs

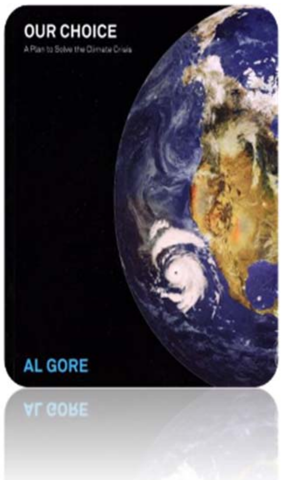
1. Costs represent average of range pulled from LCOS 3.0 for battery technologies.
2. Conservative case that includes full cost of chiller.

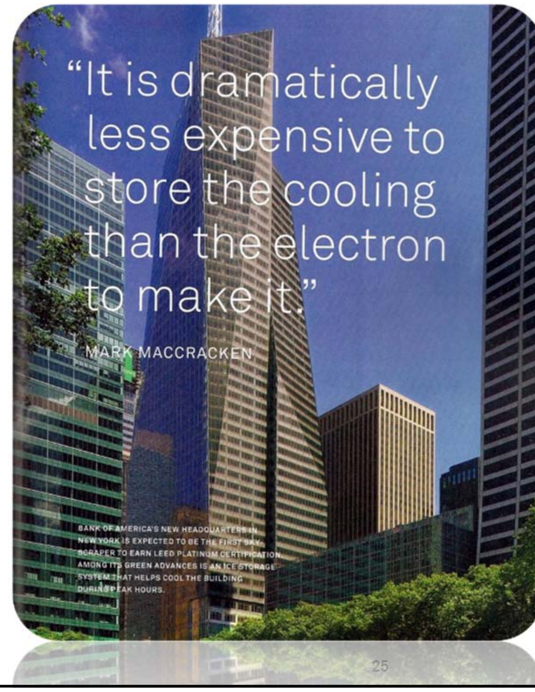
Source: Ingersoll Rand

NEW YORK CITY ICE STORAGE INSTALLATIONS ~ 120 MW-HR



Economic, Social and Environmental Benefits of Energy Storage are real





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Conclusion

The best sustainable storage solution
for the customer is to have
Thermal Batteries meet Thermal Loads
and
Electric Batteries meet Electric Loads

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