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Energy Storage for Land-Challenged Campus Facilities

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The Problem – Space for TES

- **Summer cooling loads are largest contributor to peak electric demand***
- **The electricity market is transitioning to renewable energy generation**
  - Tariffs are changing and demand charges are increasing to encourage consumers to have **electric load flexibility** to maximize renewable energy utilization and provide dispatchability
- **Affordable load flexibility solutions need space and many college campuses are land challenged**

* July 2016. Fighting Air Conditioning's Peak Demand With Thermal Energy Storage. Forbes.

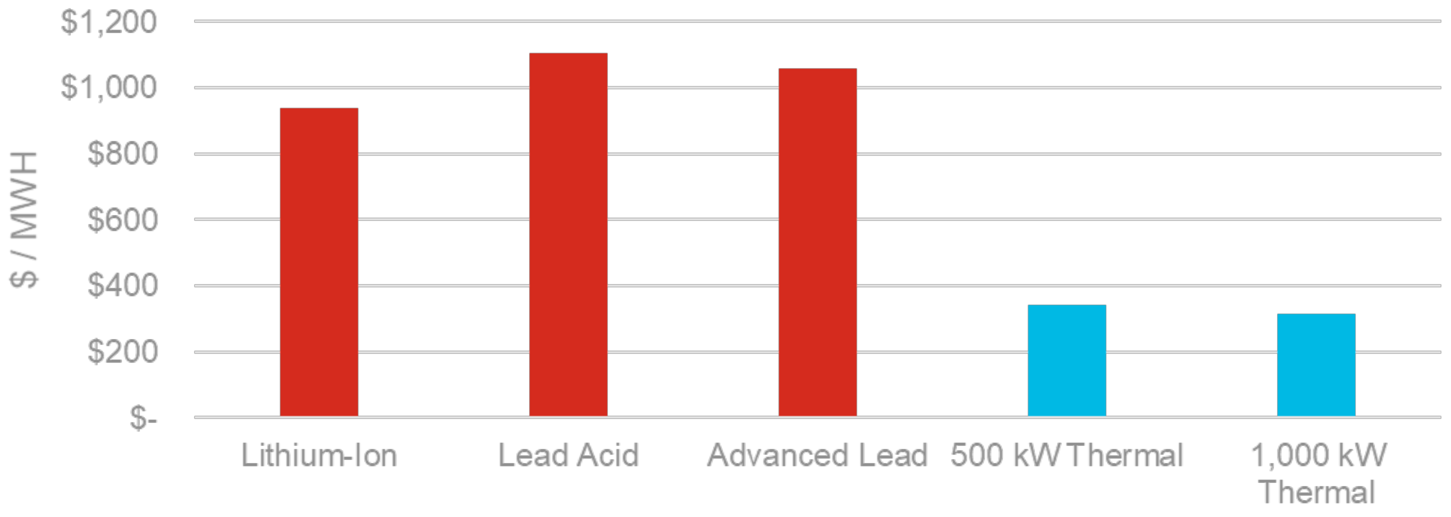
Load Flexibility Solutions

- **Batteries**
- **Co-generation**
- **Fly-wheels**
- **Thermal Energy Storage**
  - More affordable energy storage type*
  - Can be designed for specific charging and discharging durations
  - Simple maintenance
  - Long life
  - Proven in hundreds of installations

Source: Ingersoll Rand

Thermal energy storage is 1/3 the cost of chemical battery systems for C&I

Levelized Technology Cost for BTM Applications[1,2]



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

- 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

Water Thermal Energy Storage

Advantages

- Potentially use existing chillers
- More efficient charging
- Economies of scale
- Can be incorporated into fire protection system
- Anti-freezing HTF not required
- Fast Discharge Potential

Disadvantages

- Requires large space
- Little or no redundancy
- Difficult to stage growth
- Water treatment requirement
- Stranded Asset
- Complicated Partial Storage scheme
- Larger delta T to reduce costs
- Storage degrades if delta T not maintained

Examples of Water Energy Storage Installations

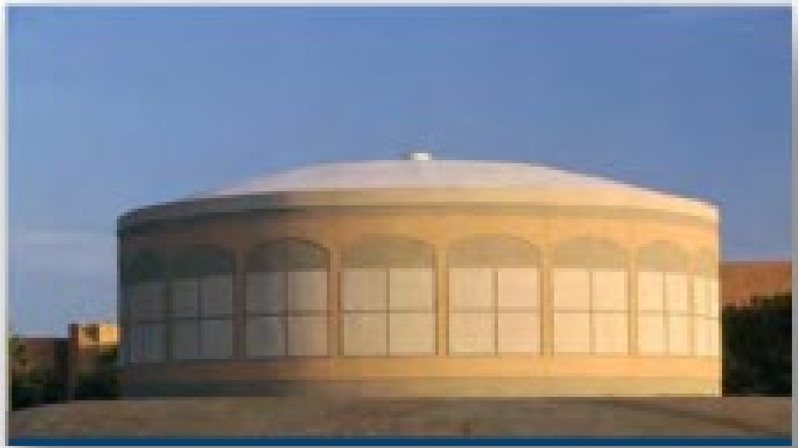


Photo courtesy of DN Tanks®

Ice Thermal Energy Storage

Advantages

- Less space required
- Modular growth possible
- Faster installation with factory assembly
- Redeployment of assets*
- Cataloged performance
- Redundancy

Disadvantages

- External piping for tank farm more extensive
- Requires Anti-freezing HTF
- Requires low temp (Ice Making Chillers)
- Vertical storage is expensive

* With some types of systems

Ice Thermal Storage

Packaged Thermal Ice Storage Tanks

Site Constructed Thermal Ice Storage Tanks

Photo courtesy CALMAC Portfolio of Trane and Baltimore Aircoil Company®

Case Study

NEW MEXICO STATE UNIVERSITY

Case study

- 1965 – Central Plant (1) 900 Ton (3200 kW) R-11 Centrifugal Chiller installation.
- 1968 – Central Plant (1) 1500 Ton (5300 kW) R-114 Centrifugal Chiller addition.
- 1975 – Central Plant (1) 1500 Ton (5300 kW) R-114 Centrifugal Chiller addition.
- **1984 – Central Plant 3 Million Gallon Chilled Water Thermal Storage.**
- 1995 – Central Plant (2) 1500 Ton (5300 kW) Double Effect LiBr Absorption Chiller addition.
- 2001 – Central Plant (3) 1500 Ton (5300 kW) R-134A Centrifugal Chiller installation. (Replaced ‘65,’68,’75 Chillers)
- 2009 – Updates to Utility Master Plan.
- 2010 – Chilled Water Distribution Capacity Improvements. (36”(900 mm) Chilled Water Mains)
- **2012 – Satellite Chiller Plant (1) 2500 Ton(8800 kW), (1) 900 Ton (3200 kW) R-123 Centrifugal Chillers with Ice Storage.**
- 2013 – Central Plant (1) 1100 Ton (3900 kW) Steam Driven Centrifugal Chiller. (Replaced 2 Absorption Chillers)

General Arrangement- Modularity

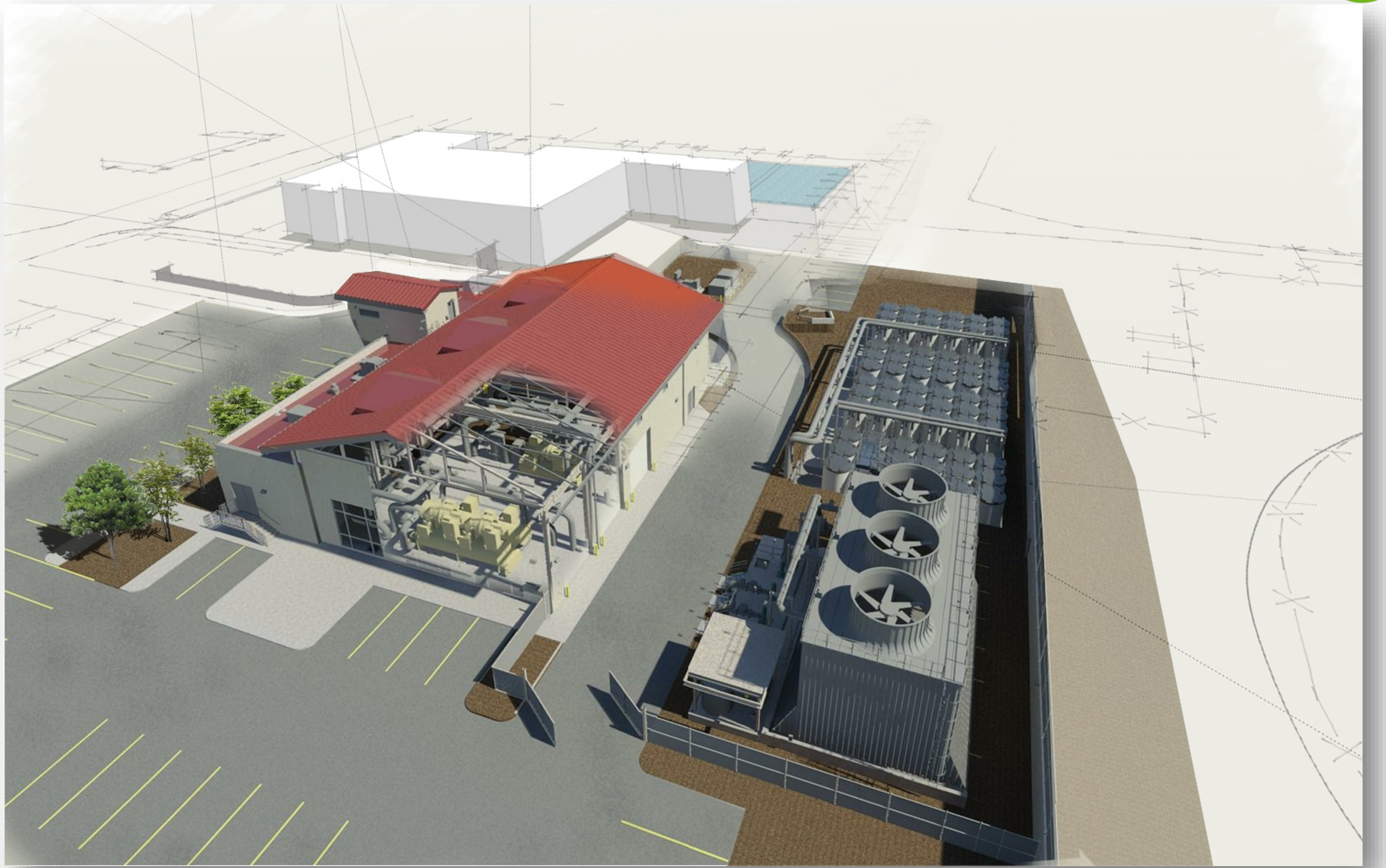


Photo courtesy of GLHN Consulting

Case study

UNIVERSITY OF ARIZONA

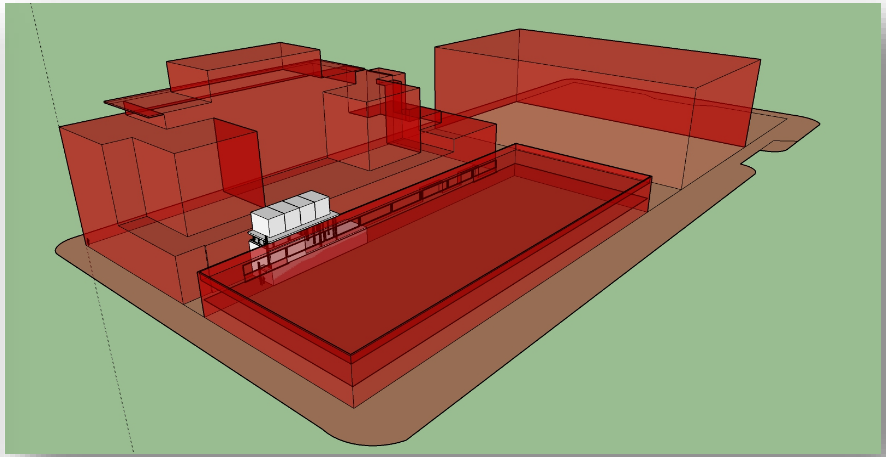
Urban Campus

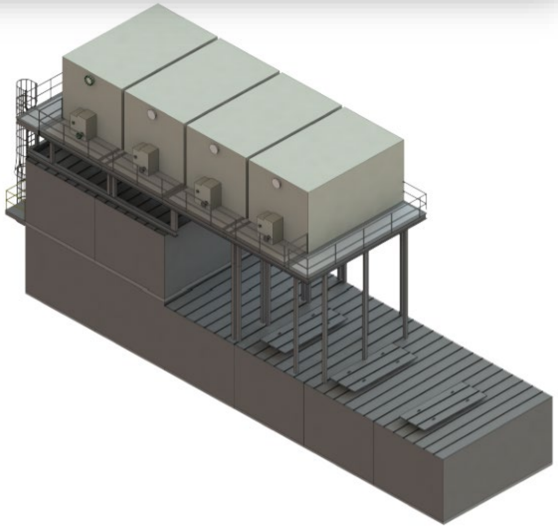
Photo courtesy of GLHN Consulting

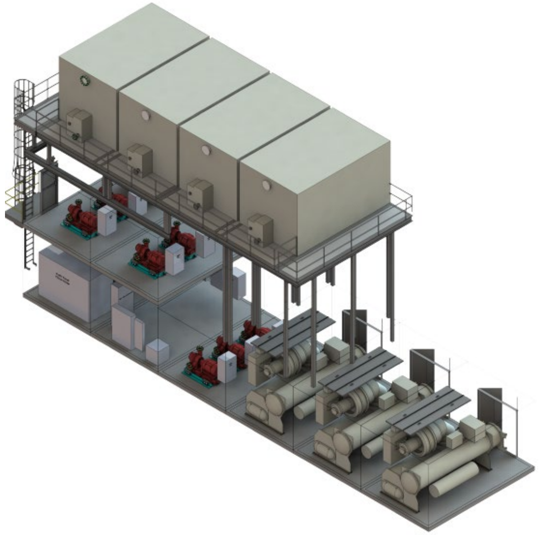
Storage Density

Photos courtesy of CALMAC® Corp.

Offsite Construction-
Package Solutions





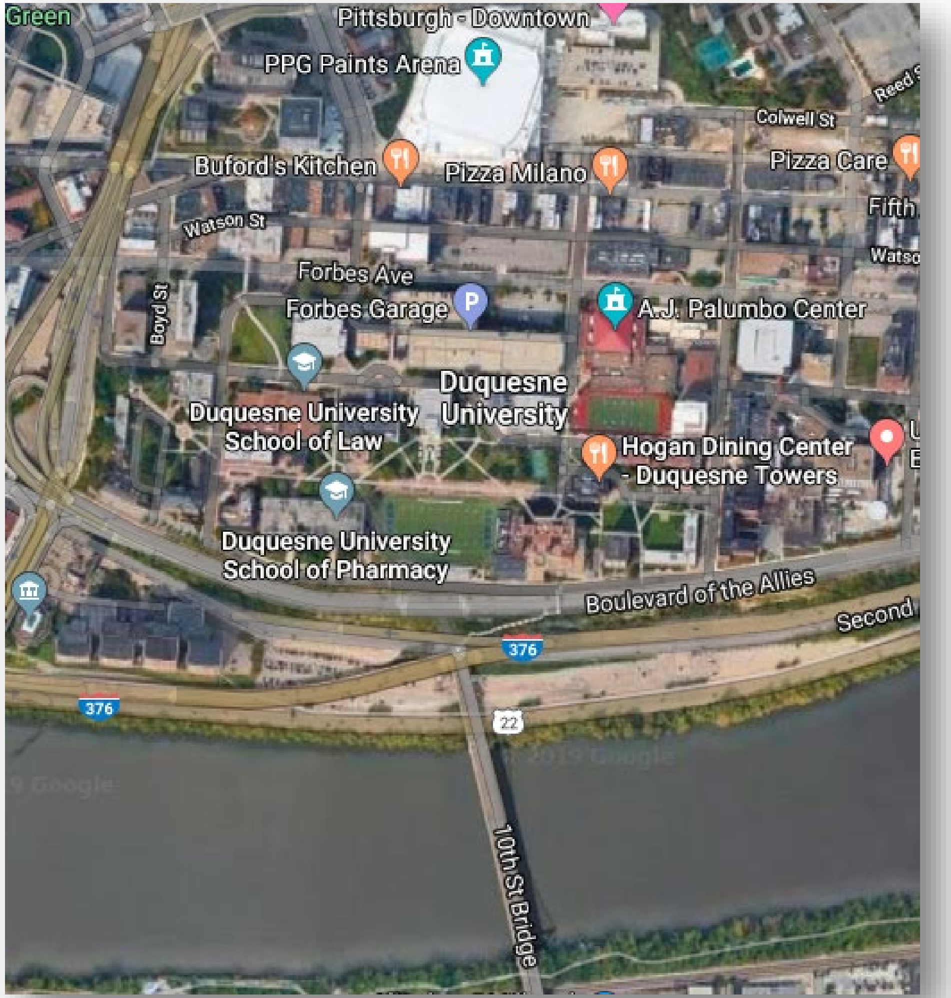


Photos courtesy of GLHN Consulting

Case study

DUQUESNE UNIVERSITY

Urban Campus- Real Estate



- Added 6,000 ton-hr. capacity without adding cooling tower for new Power Center building.
- Utilizes off peak electric rates.
- No change in condenser loop piping.
- More efficient utilization of existing equipment.

Storage density matters

Chiller plant located in parking ramp

Summary

- Land challenged campuses can apply high density TES technologies.
- TES can be modular, and factory packaged.
- Electric load flexibility can help meet future financial and sustainability goals
- Electricity demand for comfort cooling is typically very large and easy to shift with thermal energy storage.
- Careful analysis of project site and thermal energy storage technology available is key

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