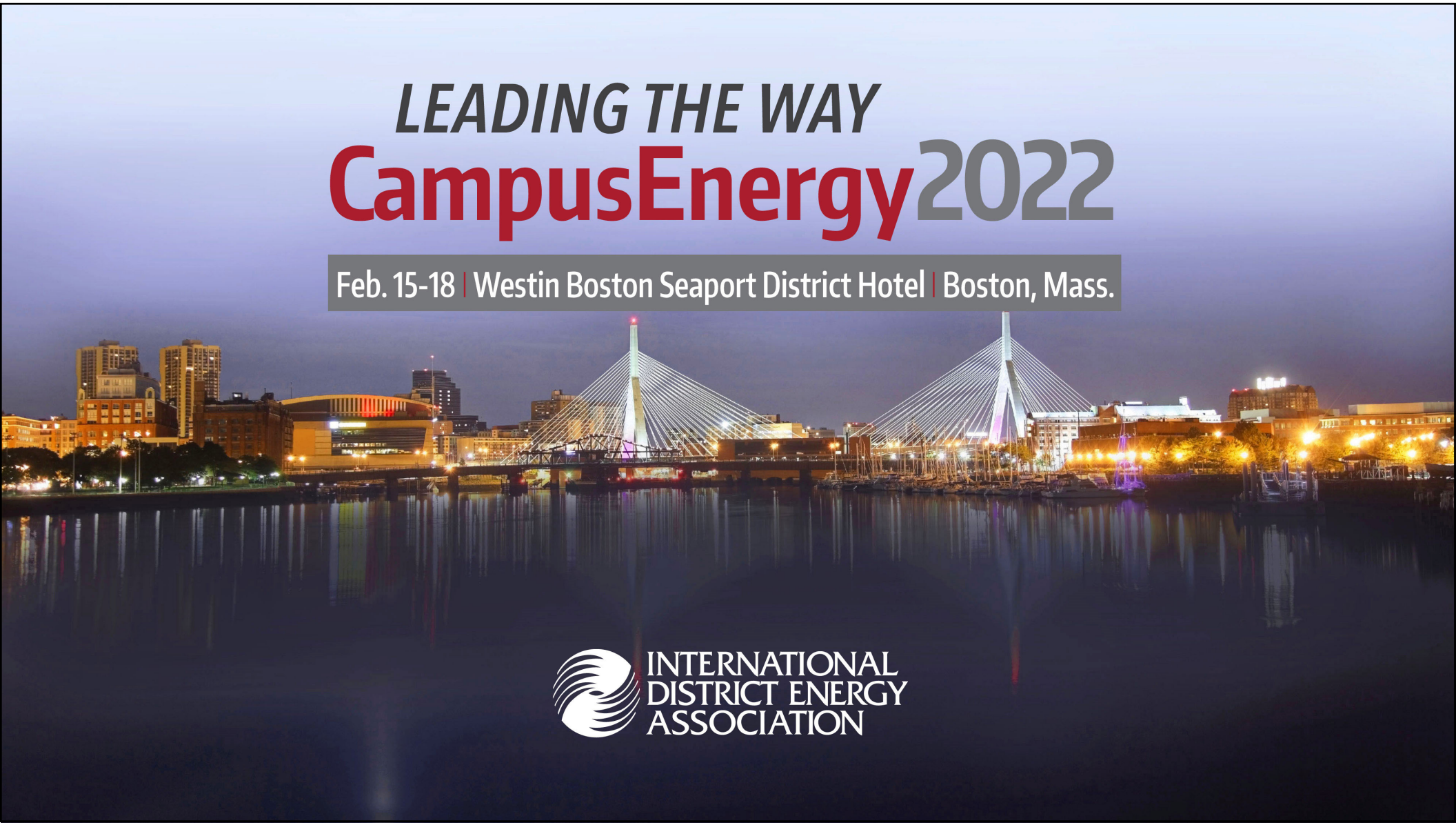
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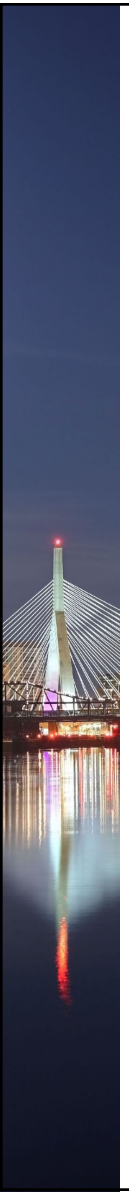

An Owner's Long-Term Experience with Multiple TES Installations

Dennis Bass

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The University of Texas at Austin

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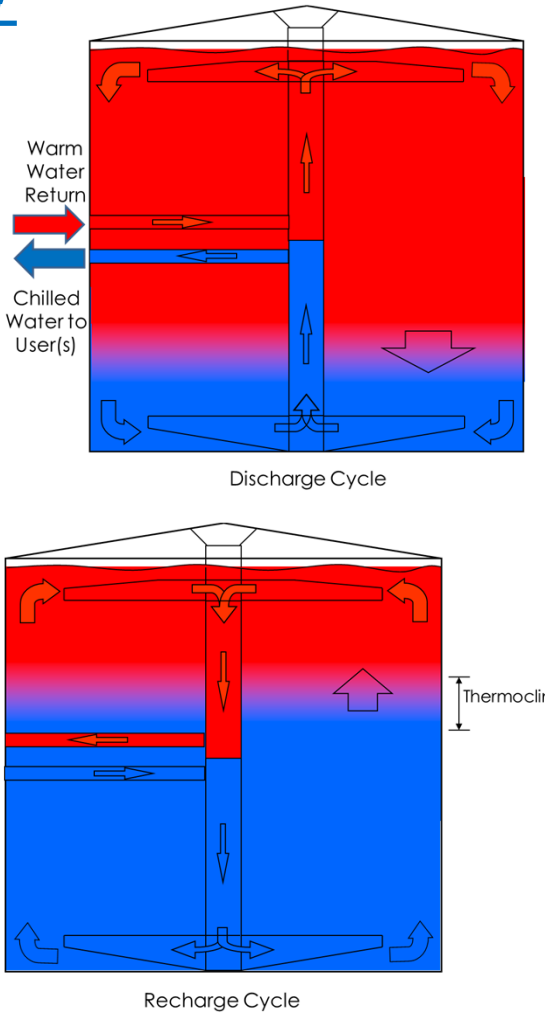
OVERVIEW

- Chilled Water Thermal Energy Storage (TES) Review
- University of Texas System TES Installations
- Chilled Water System at UT Austin Main Campus
- Why TES at the University of Texas at Austin?
- Challenges / Advantages To Installing an Additional Tank
- Benefits of Thermal Energy Storage at UT Austin

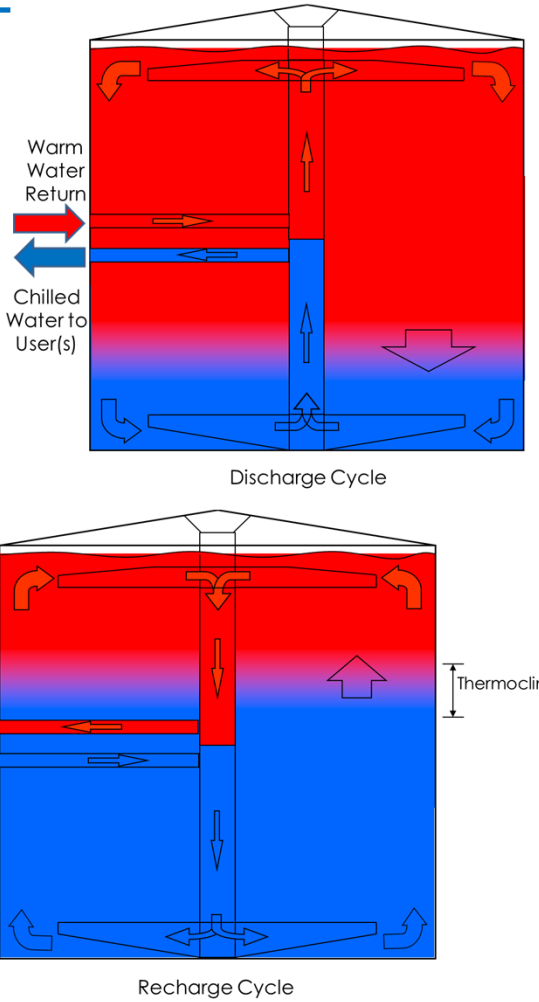
Chilled Water Thermal Energy Review

- Thermally-stratified CHW TES employs a large insulated storage tank, filled with water at all times.
- The lower portion of the tank holds a zone of cool, relatively dense (“supply”) water at about 40 °F.
- The upper portion of the tank holds a zone of warmer, less dense (“return”) water typically at 50°F to 60°F.
- Between these two zones is a narrow band containing the temperature gradient or thermocline.



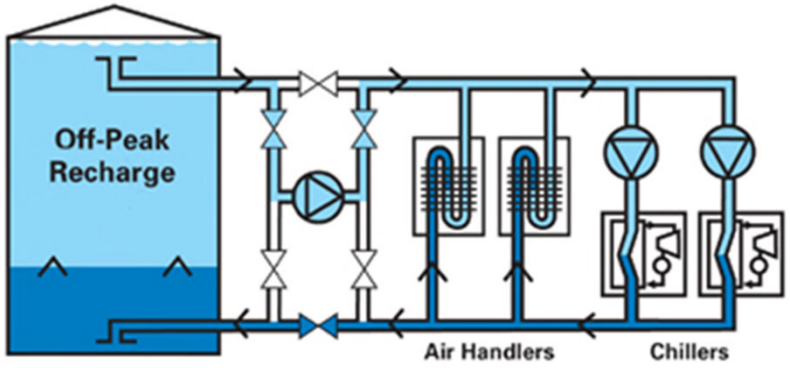
Chilled Water Thermal Energy Review

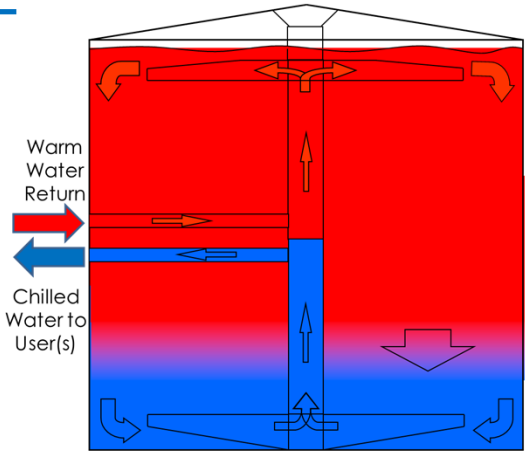
- The two distinct temperature zones are kept from mixing through the use of flow diffusers at the top and bottom of the tank which slow the incoming and outgoing flow of water in the tank, to a degree that the density differences between the two water zones is adequate to maintain their separation.
- During off-peak periods of low cooling loads or low electric grid power demand (usually at nighttime), warm water is removed from the upper zone of the tank, cooled in a chiller plant, and returned to the lower zone of the tank, causing the thermocline to rise as the TES tank is charged until the tank is 100% cool water.



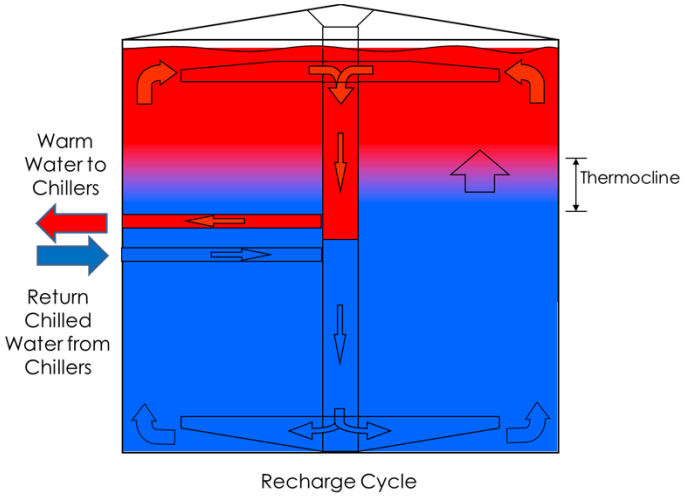
Chilled Water Thermal Energy Review

- During on-peak periods of high cooling loads or high electric grid power demand (usually in daytime), cool water is removed from the lower zone of the tank, sent to the cooling loads, and returned to the upper zone of the tank, causing the thermocline to fall as the TES tank is discharged until the tank is about 100% warm water.
- No moving parts or heat exchangers in the tank—just pumps and valves outside the tank.





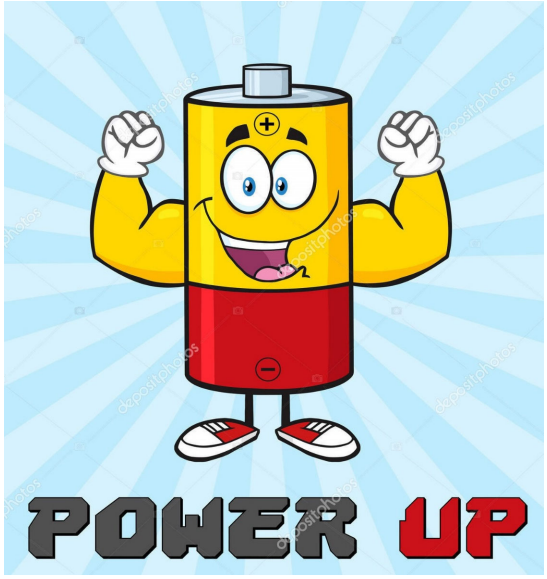
Discharge Cycle



Recharge Cycle

Chilled Water Thermal Energy Review

- TES is a rechargeable “battery” for your chilled water system.
- Use the stored chilled water when needed to meet cooling loads.
- Recharge the chilled water tank during off peak electrical usage.



Univ. of Texas Campuses—TES Installations

In Service		CHW TES		Approximate Electrical Equivalents	
Year	UT Campus	Capacity (ton-hrs)	Peak Discharge (tons)	Power (MW)	Storage (MWh)
1999	El Paso	30,000	4,340	3.5	24.0
2002	Pan Am - Edinburg	10,000	1,430	1.1	7.5
2011	Austin (1st Tank)	30,000	10,500	7.4	21.0
2012	Pickle - Austin	10,500	2,500	1.8	7.4
2016	Austin (2nd Tank)	39,000	10,010	7.0	27.3
2016	Med – Galveston #1	16,000	4,410	2.9	10.4
2016	Med – Galveston #2	16,000	4,410	2.9	10.4
Total	7 TES Installations	151,500	37,600	26.6	108.0

Univ. of Texas – El Paso

- CHW TES in-service since 1999
- Rated 30,000 Ton-hrs @ CHWS/R of 40/53 °F
- Above-ground welded steel tank
- 108’D x 55.25’H (~3.8 million gals)
- Reduces peak by ~4,340 Tons (~3.5 MW)
- Equivalent electric storage of ~24.0 MWh

Univ. of Texas Pan American– Edinburg

- CHW TES in-service since 2002
- Rated 10,000 Ton-hrs
- Above-/ below-grade concrete tank
  10’ below grade + 10’ with a berm
- 77’D x 40’H (~1.4 million gals)
- Reduces peak by ~1,430 Tons (~1.1 MW)
- Equivalent electric storage of ~7.5 MWh

Univ. of Texas – Austin (first of two tanks)

- CHW TES in-service since 2011
- Rated 30,000 Ton-hrs @ CHWS/R of 40/52 °F
- Above-ground welded steel tank
- 104.5’D x 67.5’H (~4.3 million gals)
- Reduces peak by ~10,500 Tons (~7.4 MW)
- Equivalent electric storage of ~21.0 MWh

Univ. of Texas – Austin, Pickle Research Campus

- CHW TES in-service since 2012
- Rated 10,500 Ton-hrs @ CHWS/R of 42/58 °F
- Above-ground welded steel tank
- 70’D x 40’H (~1.2 million gals)
- Reduces peak by ~2,500 Tons (~1.8 MW)
- Equivalent electric storage of ~7.4 MWh
- Controlled remotely from the main UT-Austin Campus

Univ. of Texas – Austin (second of two tanks)

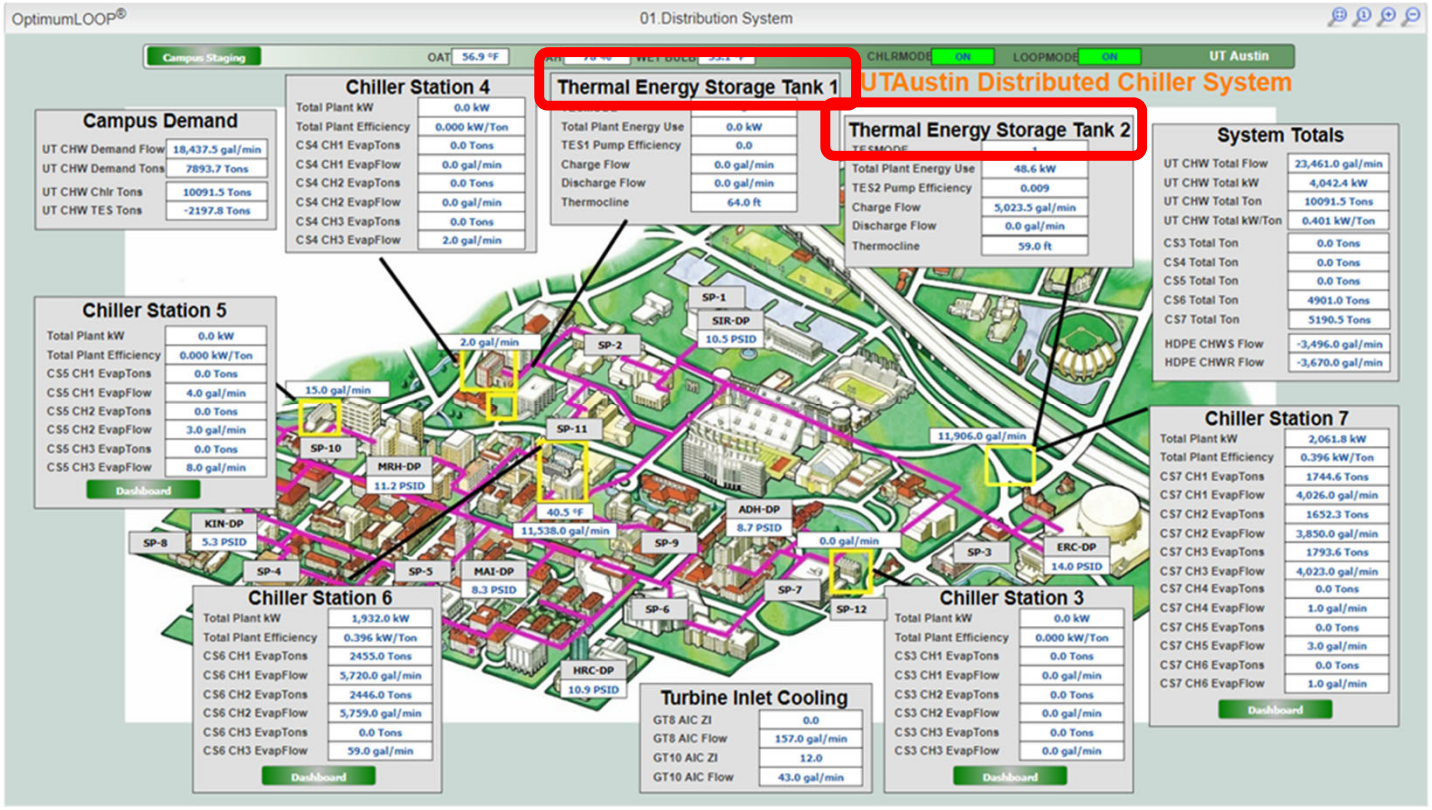
- CHW TES in-service since 2016
- Rated 39,000 Ton-hrs @ CHWS/R of 40/52 °F
- Above-ground welded steel tank
- 110’D x 80’H (~5.7 million gals)
- Reduces peak by ~10,010 Tons (~7.0 MW)
- Equivalent electric storage of ~27.3 MWh

Univ. of Texas Medical Branch– Galveston (two tanks)

- Two CHW TES, both in-service since 2016
- Each rated 16,000 Ton-hrs @ CHWS/R of 42/54 °F
- Two above-ground welded steel tanks
- Each 65'D x 85-87.75'H (2.1-2.2 million gals)
- Each reduces peak by ~4,410 Tons (~2.9 MW)
- Each equivalent electric storage of ~10.4 MWh

Chilled Water System at UT Austin Main Campus

- 60,600 cooling tons capacity
- 20M GSF, 2% added annually
- 10MGal Thermal Energy Storage (TES) capacity
- 38k tons, 66MW peak demand (2017)
- 33k tons, 60MW peak demand (2019)
- 0.69kW/Ton Avg. (2017)
- 0.59kW/Ton Avg. (2019)



Why TES at UT Austin?

- Avoided or postponed new chiller plant addition thus reducing capital costs.
  - First TES Tank installed in 2010, newest chiller plant operational in 2017 despite 2% annual Campus growth.
- The use of chilled water storage from the TES tanks has allowed reduced or stopped operation of older / less efficient chillers. This has resulted in reduced life cycle costs of ownership through lower required maintenance and longer life expectancy.
- TES tanks have inherent simple design with an incredible expected life from 50 to 100 years.

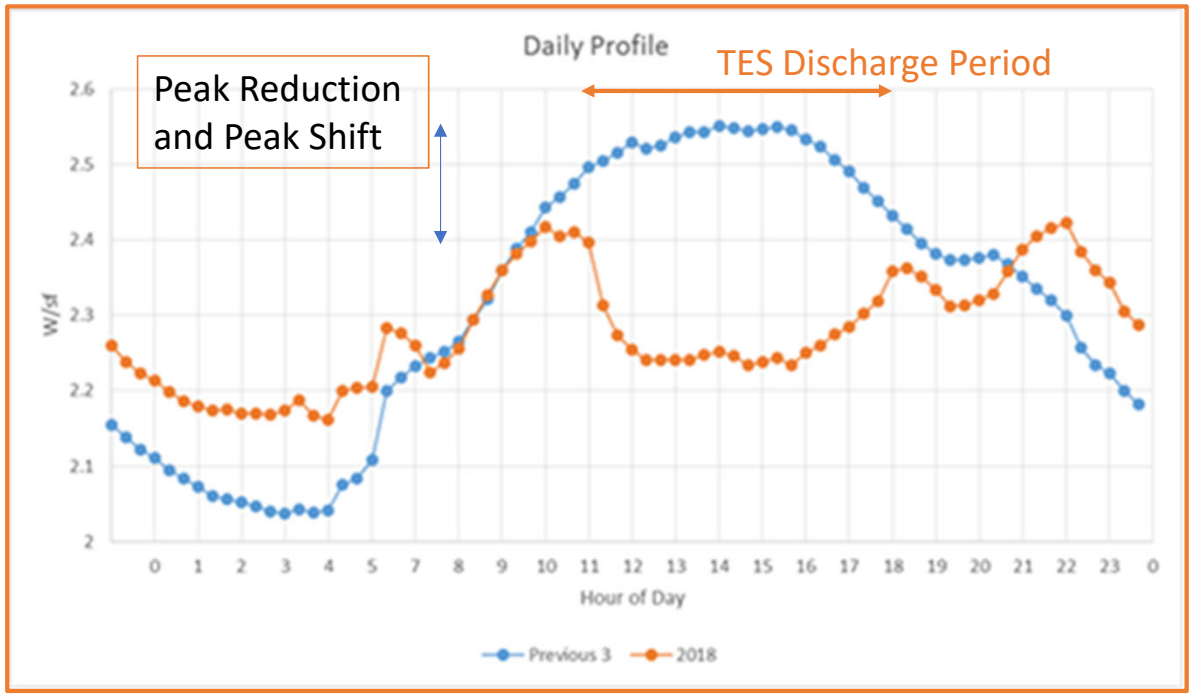
Why TES at UT Austin?

- Adds reliability, resiliency and improved operational flexibility and redundancy.
  - TES tanks can be rapidly dispatched within minutes at almost negligible electric load to the campus generation.
  - Provides availability for improved safety and comfort to medical school and campus building occupants in event of catastrophic cooling plant outage.
  - UT Austin has not experienced a campus-wide chilled water outage largely due to plant redundancies. TES improves this redundancy immensely.

Why TES at UT Austin?

- Energy Benefits–contrast between Main Campus vs. JJ Pickle Research Center(JJPRC).
  - Main Campus generates own power—chilled water storage shifts and reduces on-peak energy requirements therefore avoiding additional capital investment in power generation equipment.

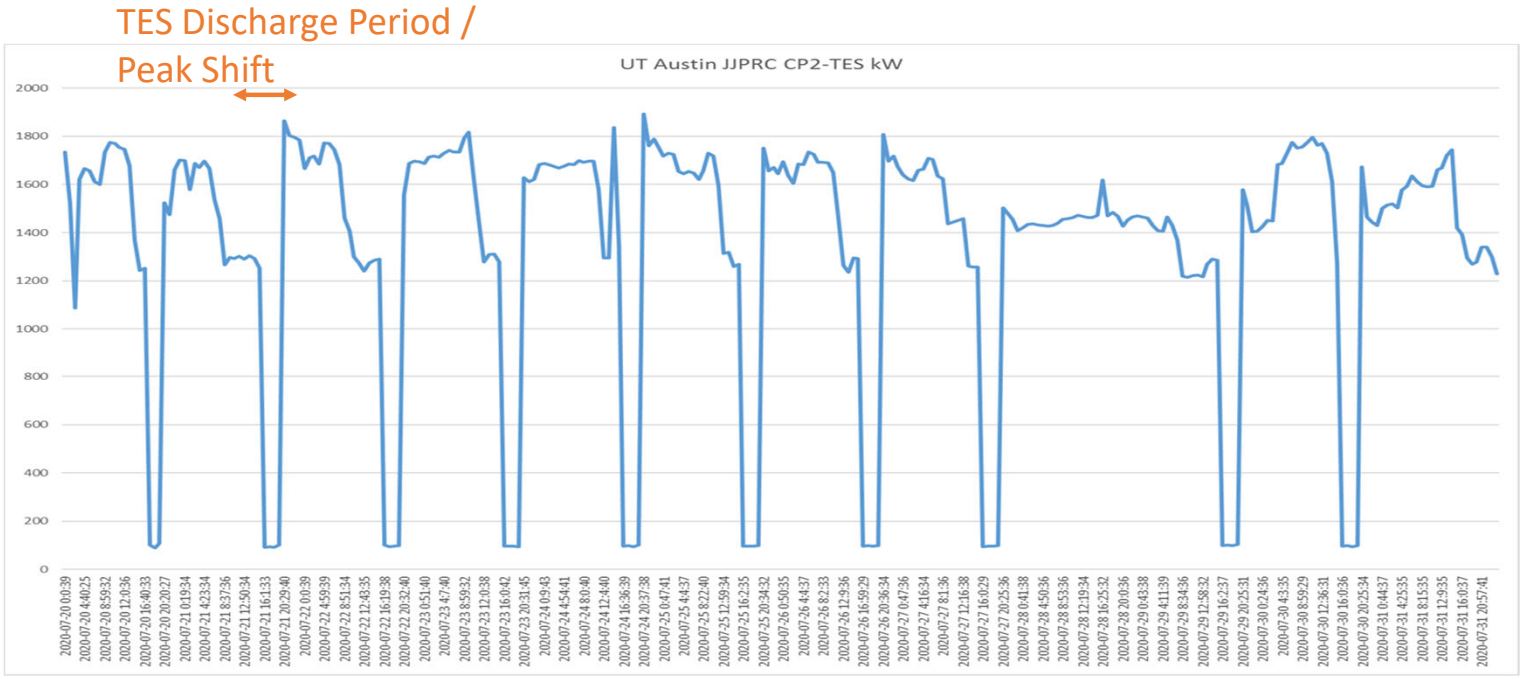
Campus MW – TES dispatching – Load Shifting



Why TES at UT Austin?

(Continued)

- Energy Benefits–Main Campus vs. JJ Pickle Research Center(JJPRC).
  - JJPRC purchases power from Austin Energy—chilled water storage reduces on-peak energy costs shifting those loads to "off peak" usage resulting in approx. $650,000 savings. (Austin Energy one time rebate for 1.8 MW peak demand shift).

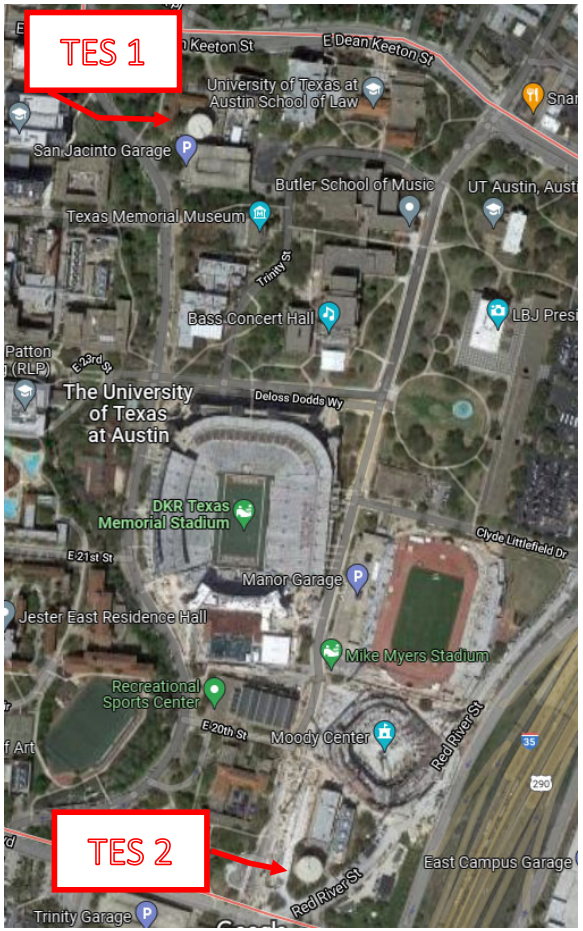


Why TES at UT Austin?

- Reduce electric “demand” costs by “flattening” thermal and electrical load profiles.
  - Operational savings from added chilled water production during night hours when wet bulb is depressed, improving efficiency.
  - Flattening has allowed us to maintain 2N+2 electrical redundancy despite unprecedented annual growth of 2% *without* need for $$$$ added generation capacity.

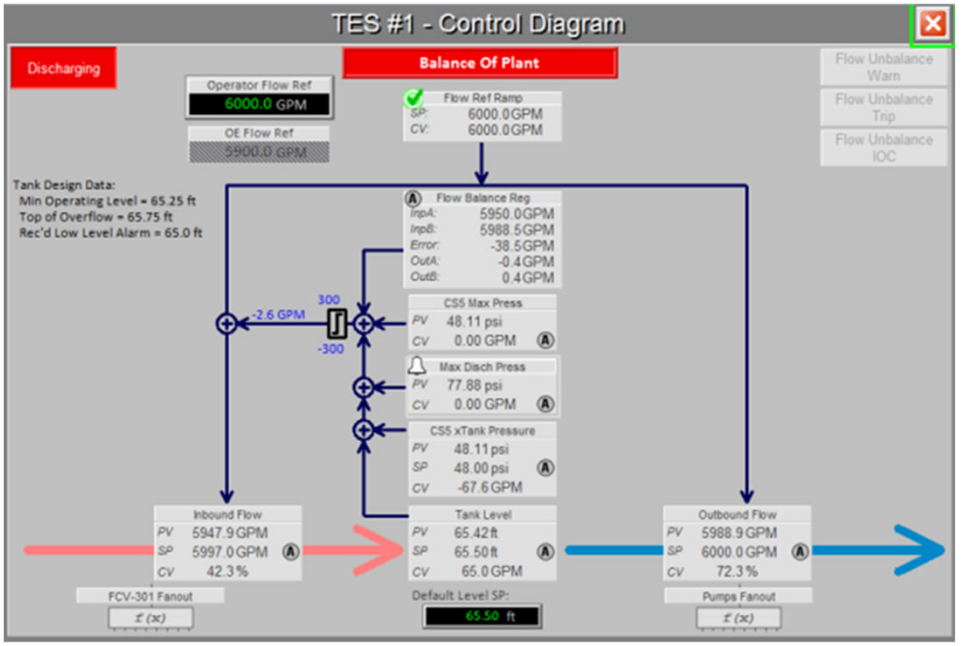
Challenges To Installing Additional Tank at UT Austin

- Second TES tank needed to provide cooling for the medical district.
- Second tank installation at a lower elevation than first tank – pressure reducing valves were necessary.
- Major controls challenges operating two hydraulically and geographically-diverse tanks at same time.



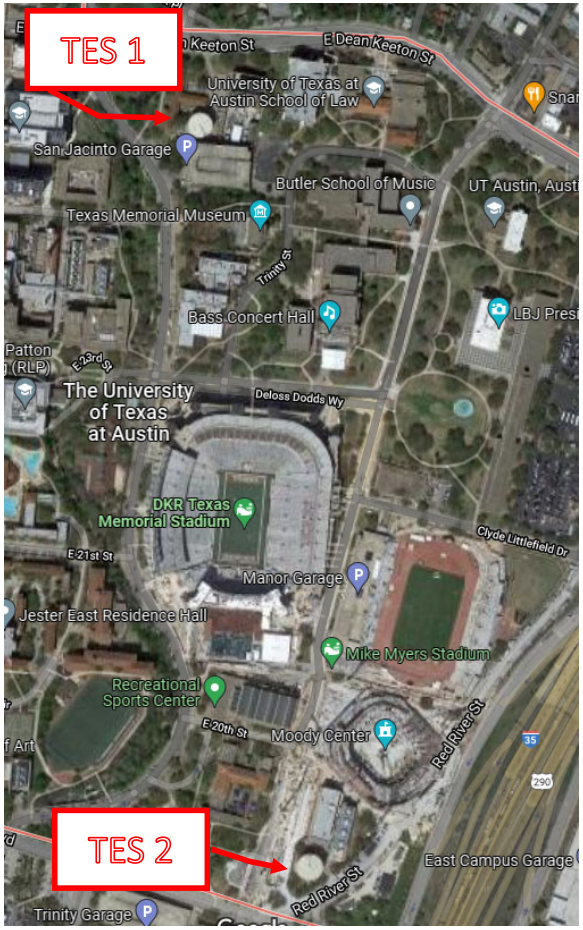
Overview Controls Philosophy With Two TES Tanks

- Push-Pull Controller
  - Pump – Outflow
  - Valves – Inflow
- Flow bias (Negative = flows out more)
  - TES tank level
  - CS5 exp. Tank pressure
- Safety Interlocks
  - Flow unbalance – time inverse function
  - CHWS pressure
  - CS5 CHWR pressure



Advantages To Installing Additional Tank at UT Austin

- Ability to “charge” from Main Campus loop if Chiller Station 7 was to go down.
- Additional TES tank adds more flexibility to the chilled water system providing more capacity as needed without adding chiller capacity. Chilled water system can be fed from either tank.



UT Austin TES—Resiliency Benefits

- Added Redundancy: TES operation can supplement outage of largest chilling station.
  - During generation outage, rapid TES discharge ramp-up can prevent triggering demand charges for AE backup contract.
- Lowers power demand from Power Generation when Campus is in islanding mode.
  - Full power demand for full TES ½ pumping is <1MW vs. ~11MW for equivalent chiller-based CHW production.
- Allows greater dependency on newer variable speed chillers.
- Finite flow variability enhances campus dP control.
- Provides an alternate water source for cooling tower condenser water during unprecedented / catastrophic events such as last year's storm Uri.

UT Austin TES—Efficiency Benefits

- Allows use of most efficient variable speed chillers.
- Reduce electrics “demand” costs by “flattening” thermal and electrical load profiles.
- More CHW production at night when WB depressed.
- Combustion turbine generators maintain higher loads near efficiency peaks – improves heat rate.
- “Lower Cost” Chilled Water for Gas Turbine Inlet Air Cooling.
- Lengthens run time for more efficient combustion turbine generator CTG-10.

QUESTIONS?

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