STANFORD ENERGY SYSTEM INNOVATIONS

Steam to Hot Water in 33 Months

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Adam Dell: Stanford University

Damon Ellis: Whiting-Turner Contracting

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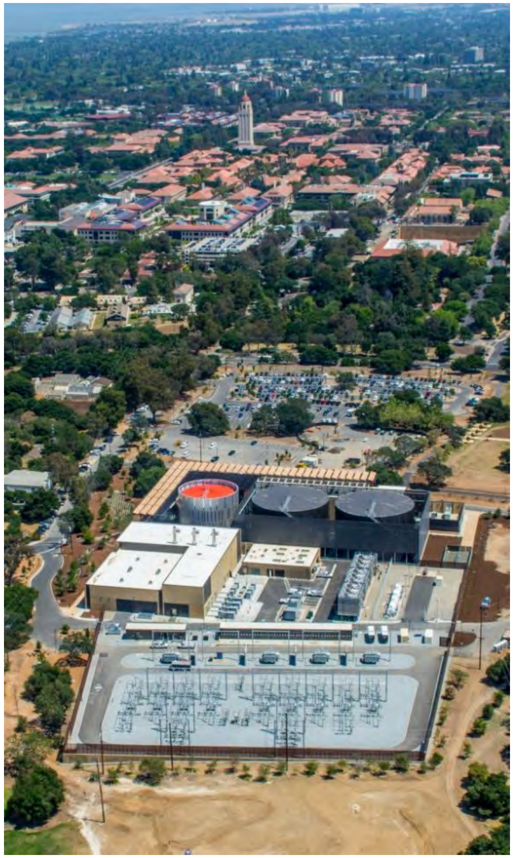
Meeting Agenda

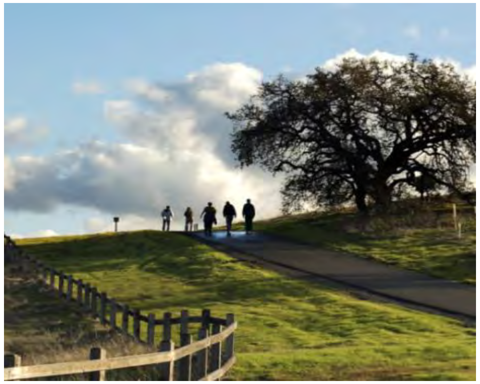
- Introduction / Project Overview
- Underground Construction
  - Design / Installation
  - Leak Detection
  - Water Treatment
  - Schedule Flexibility
- Building Conversions
  - Design
  - Installation
  - Improve Summer Delta T
  - Improve Winter Delta T
- Questions?

Project Overview

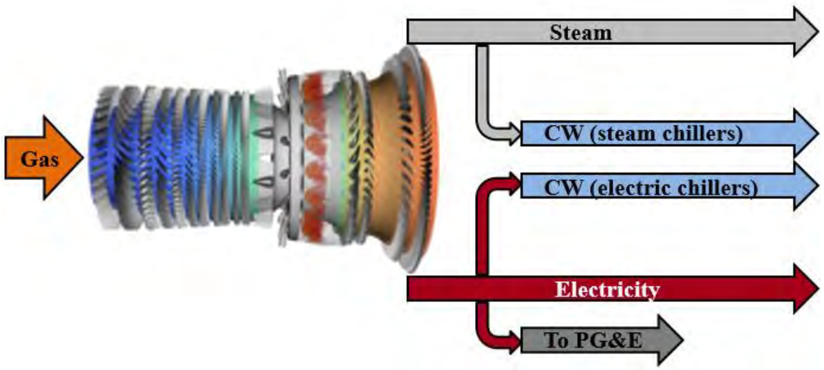
Stanford Energy System Innovations (SESI) is the sustainable energy program designed to meet the energy needs of Stanford campus through at least 2050. After four years of planning and three years of construction and implementation, SESI came online in late March 2015 via a new Central Energy Facility.

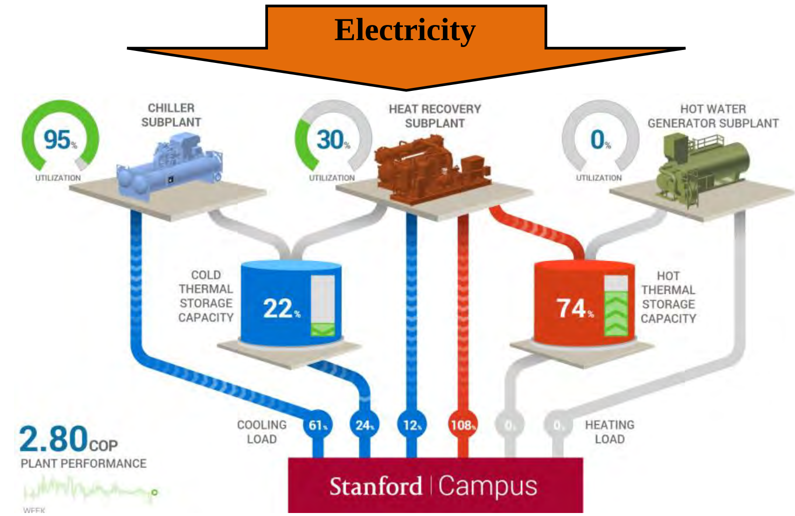
The Stanford Campus transitioned from a natural-gas cogeneration plant to a heat recovery system, including replacing 22 miles of underground piping and retrofitting 155 buildings – all while the campus remained operational.





Project Overview: Conversion from Cogeneration to Heat Recovery





- System at end of useful life when contract expired in 2015
- 1980's technology, was at 50% overall efficiency
- Used 100% natural gas - produced 90% of campus carbon emissions
- Used 25% of campus potable water

- Reduce campus greenhouse gas emissions by **68%** (and growing)
- Reduce potable water use **15%**
- Will save **$459** million compared to cogeneration over next 35 years
- Allows for expansion of campus
- Creates foundation for green energy portfolio

Project Overview: Cost & Schedule Overview

Central Energy Facility

- $260M construction cost*
- 3 year construction duration
- Five transformers provide 20mva; total electrical capacity of 100mva
- Two 5M gallon cold water tanks; 90k ton-hour capacity
- One 2M gallon hot water tank; 600mmbtu capacity
- Three heat recovery chillers with 2,500 ton capacity
- Three backup chillers with 3,000 ton capacity, and nine cooling towers with 9,000 GPM capacity
- Three gas powered hot water generators with 1,800 HP

Piping and Building Conversions

- $210M construction cost*
- 3 year construction duration
- 22 miles of Low Temperature Hot Water Piping
- 5 miles of electrical duct bank
- 154 buildings converted from steam to LTHW
- Steam plant constructed for process steam needs; 24,000 lb/hr

*funded via cash and debt (open market – bonds and commercial paper). Cost recovery via utility rates per federal OMB guidelines

LTHW Piping – Design / Installation

Proven System

- Established design specifications
- Obtained OSHPD alternate material approval
- Based on heat recovery chiller specification (170° supply, 130° return)
- Minimum 12psi dp at furthest lines
- Sized based on campus and hospital capital plans for year 2050
- Based on above, pipe size ranged from 24″ to 4″. Most laterals were 4″-6″, most mains were 8″-12″

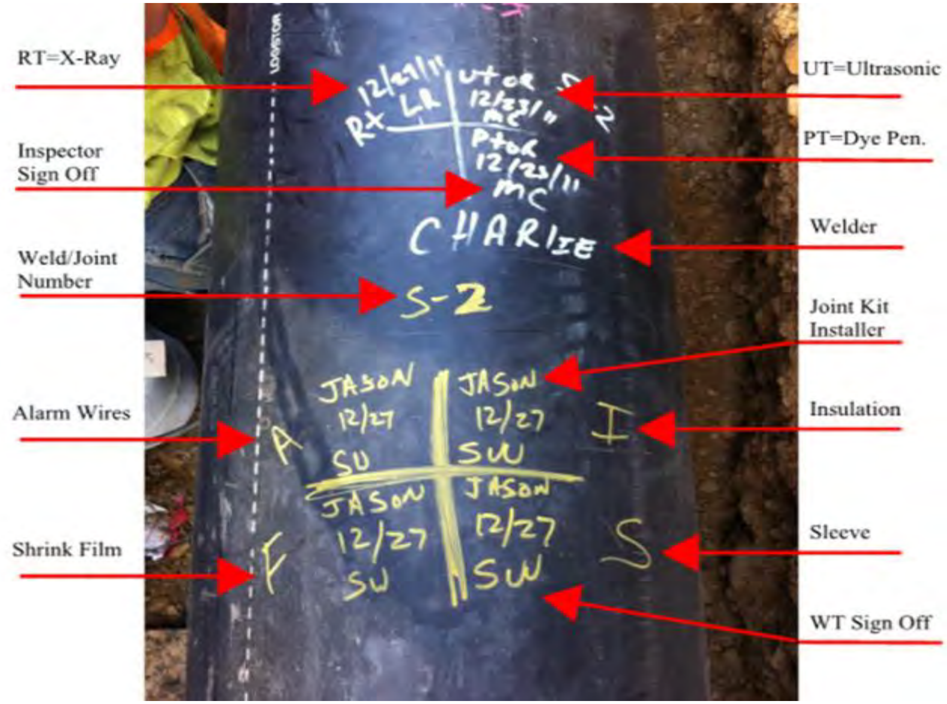
Easier Installation

- Shallow Bury: eliminated vaults, anchors & expansion joints. **<u>Decreased cost and schedule</u>.**
- Self-Restrained
- Direct Bury Valves

LTHW Piping – Design / Installation

Inspections

- Stanford had full time inspector
- Third Party inspector used for all welds, leak detection wiring, and joint kit installation.
- **<u>100% visual and 100% Ultrasonic inspections.</u>**
- 6 leaks occurred in 4,400 welds



Scheduling/Phasing

- Schedule driven by Building Conversions
- Work area was approx. 300-500 LF per crew. **<u>This will give a large enough work site to be efficient, while at the same time not impacting campus traffic.</u>**
- June 2012 – August 2014
- 22 miles of LTHW piping

LTHW Piping – Design / Installation

Material Availability

- Plan for long lead times
- Stanford bulk ordered with 25% drawings **(not recommended).**
- **Plan for 16-20 week lead time for pipe and valves.**
- Need location for inventory

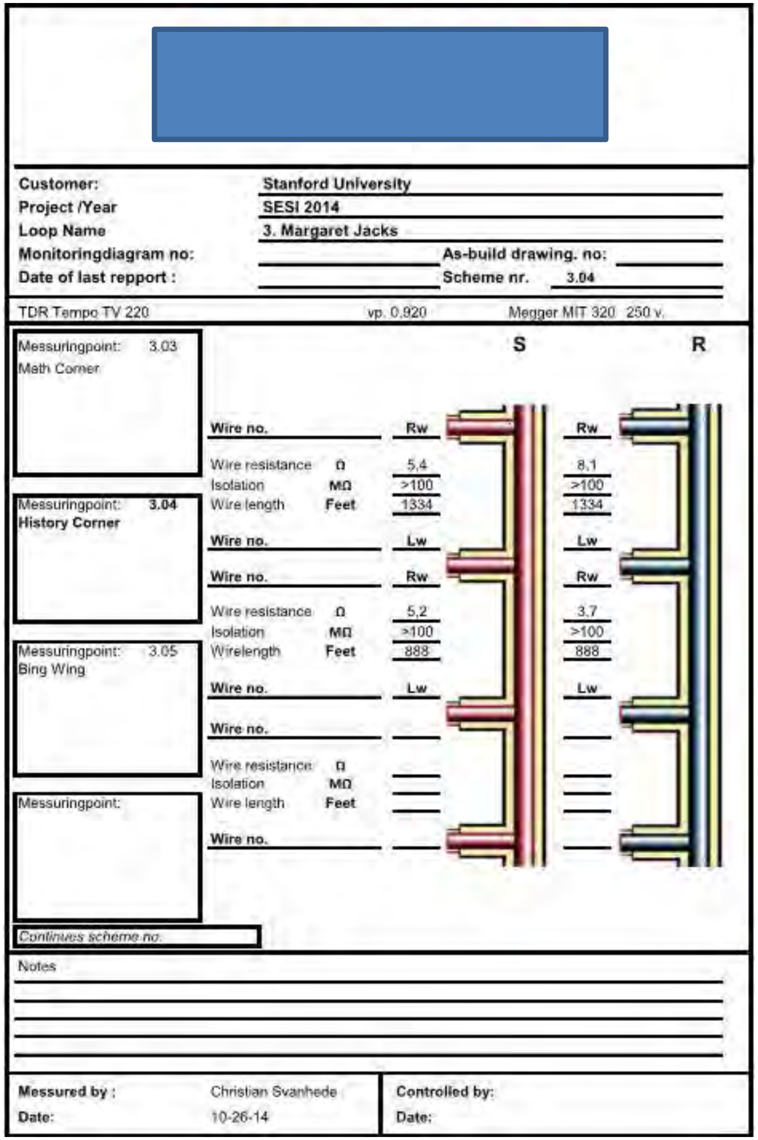
Performing work on new LTHW system

- Inspections insured that installed pipe was kept clean. However strainers needed to be cleaned out after connection to new plant.
- Stanford crews need to be trained on how to install/modify LTHW pipe system

LTHW Piping – Leak Detection

Leak Detection System

- System was used to find leaks during startup.
- Bad wiring connections were found using system, and repairs made.
- System is now complete and operational.
- We have a few sections on campus that are not tied into leak detection system – these will require manual testing.
- Vendor requires training and certification for installers.
- **Hold detailed installation meeting with leak detection vendor prior to installation of pipe. Proper installation of leak detection wiring from the beginning will help throughout construction (for identifying leaks) and make for a more efficient commissioning process.**



Customer: Stanford University
Project /Year: SESI 2014
Loop Name: 3. Margaret Jacks
Monitoringdiagram no:
As-build drawing. no:
Date of last repport :
Scheme nr. 3.04

TDR Tempo TV 220 vp. 0.920 Megger MIT 320 250 v.

Messuringpoint		S	R
Messuringpoint: 3.03 Math Corner	Wire no.	Rw	Rw
	Wire resistance Ω	5.4	8.1
	Isolation MΩ	>100	>100
Messuringpoint: 3.04 History Corner	Wire length Feet	1334	1334
	Wire no.	Lw	Lw
	Wire no.	Rw	Rw
	Wire resistance Ω	5.2	3.7
	Isolation MΩ	>100	>100
Messuringpoint: 3.05 Bing Wing	Wirelength Feet	888	888
	Wire no.	Lw	Lw
	Wire no.		
	Wire resistance Ω		
	Isolation MΩ		
Messuringpoint:	Wire length Feet		
	Wire no.		

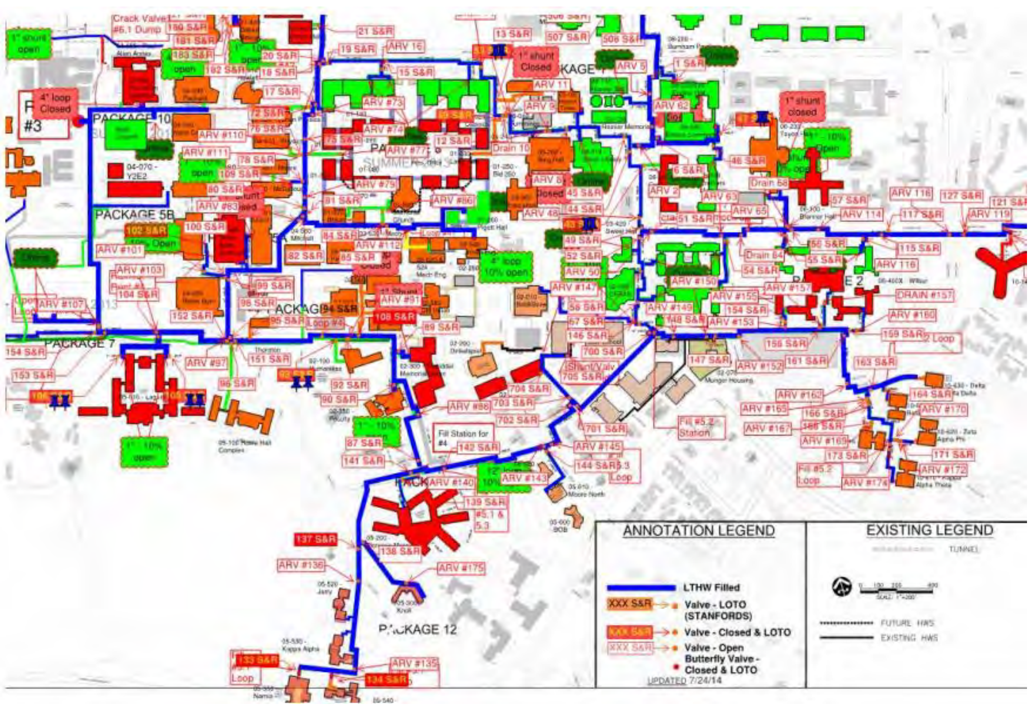
Continues scheme no.

Notes

Messured by : Christian Svanhede
Date: 10-26-14
Controlled by:
Date:

European Water Treatment

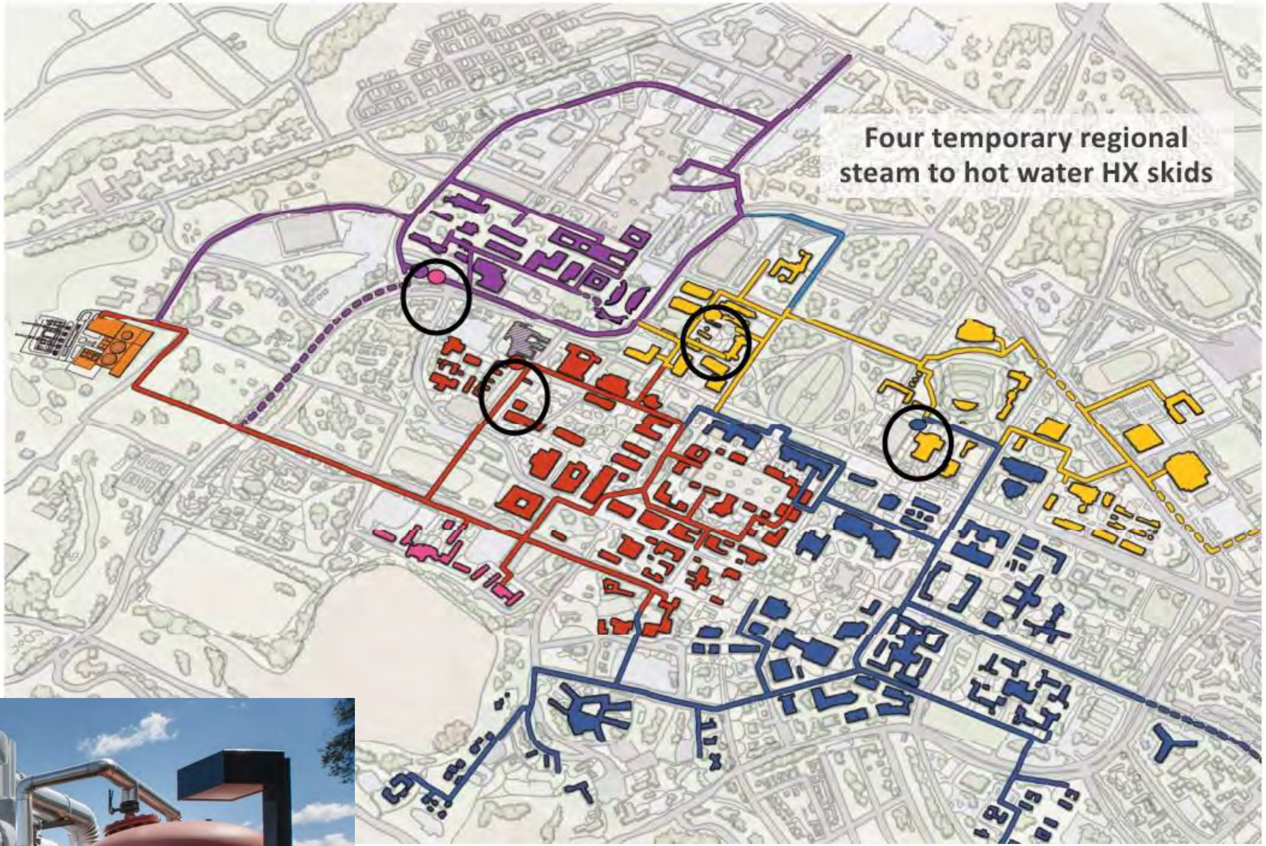
- Pipe requires "European treated water". A fill skid was used to remove oxygen and adjust pH. Additionally side steam water treatment was installed at one of the regional heat exchangers.
- Oxygen was not fully removed until the water was heated.



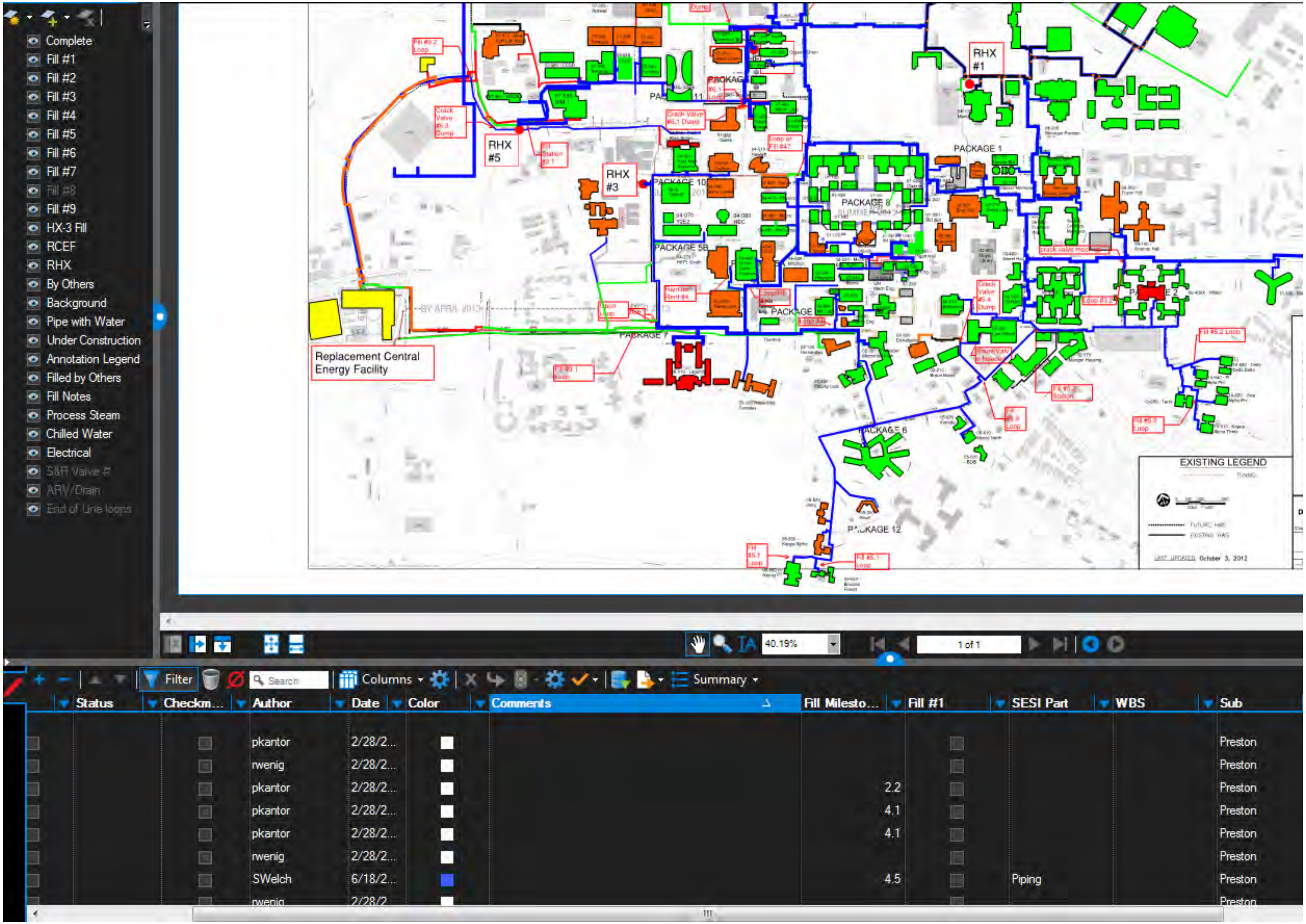
LTHW Piping - Schedule Flexibility

<u>Implement regional heat exchangers to allow for phased conversions.</u>

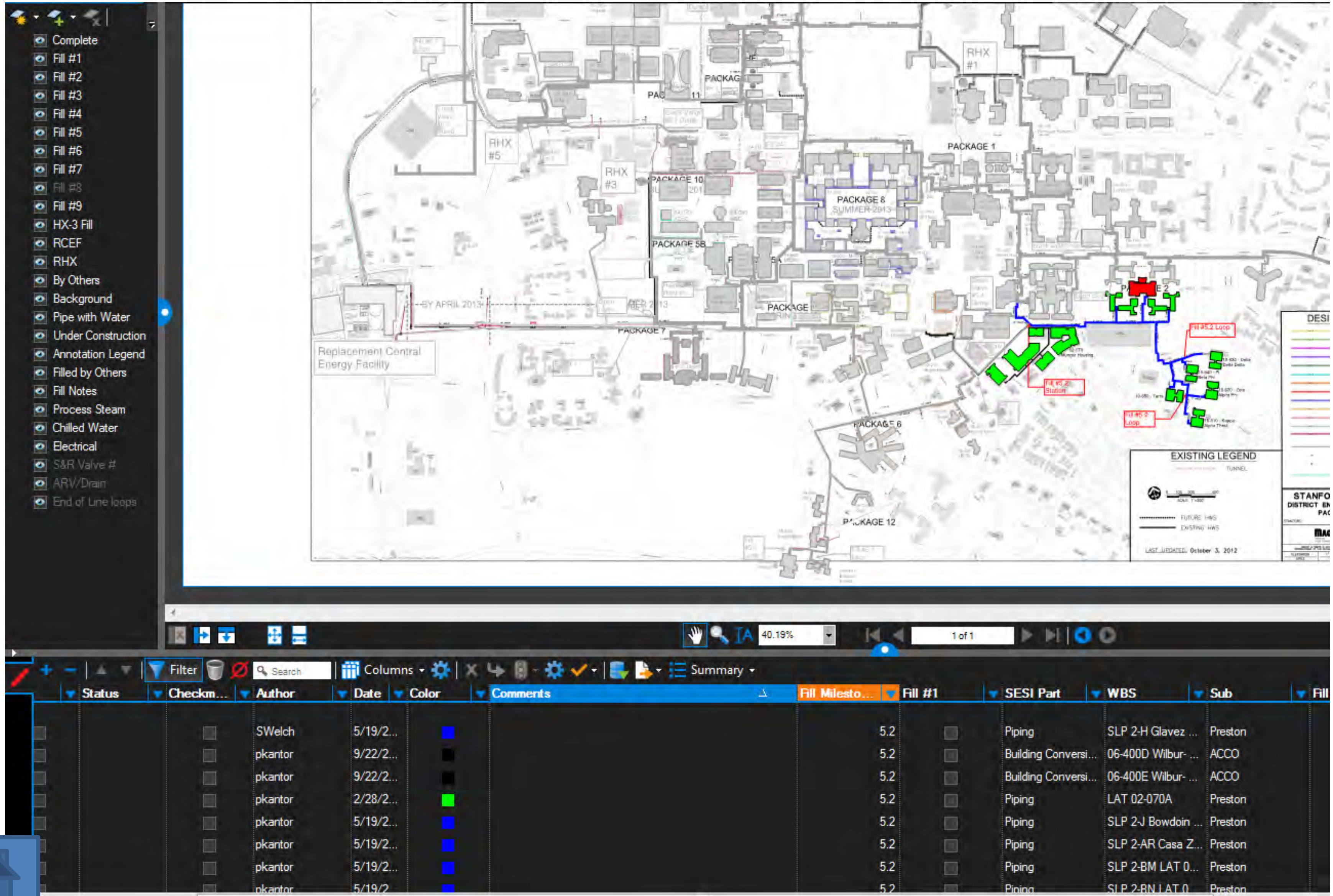
SESI built 4 temporary regional heat exchange substations to convert steam to LTHW



LTHW Piping - Schedule Flexibility



LTHW Piping - Schedule Flexibility

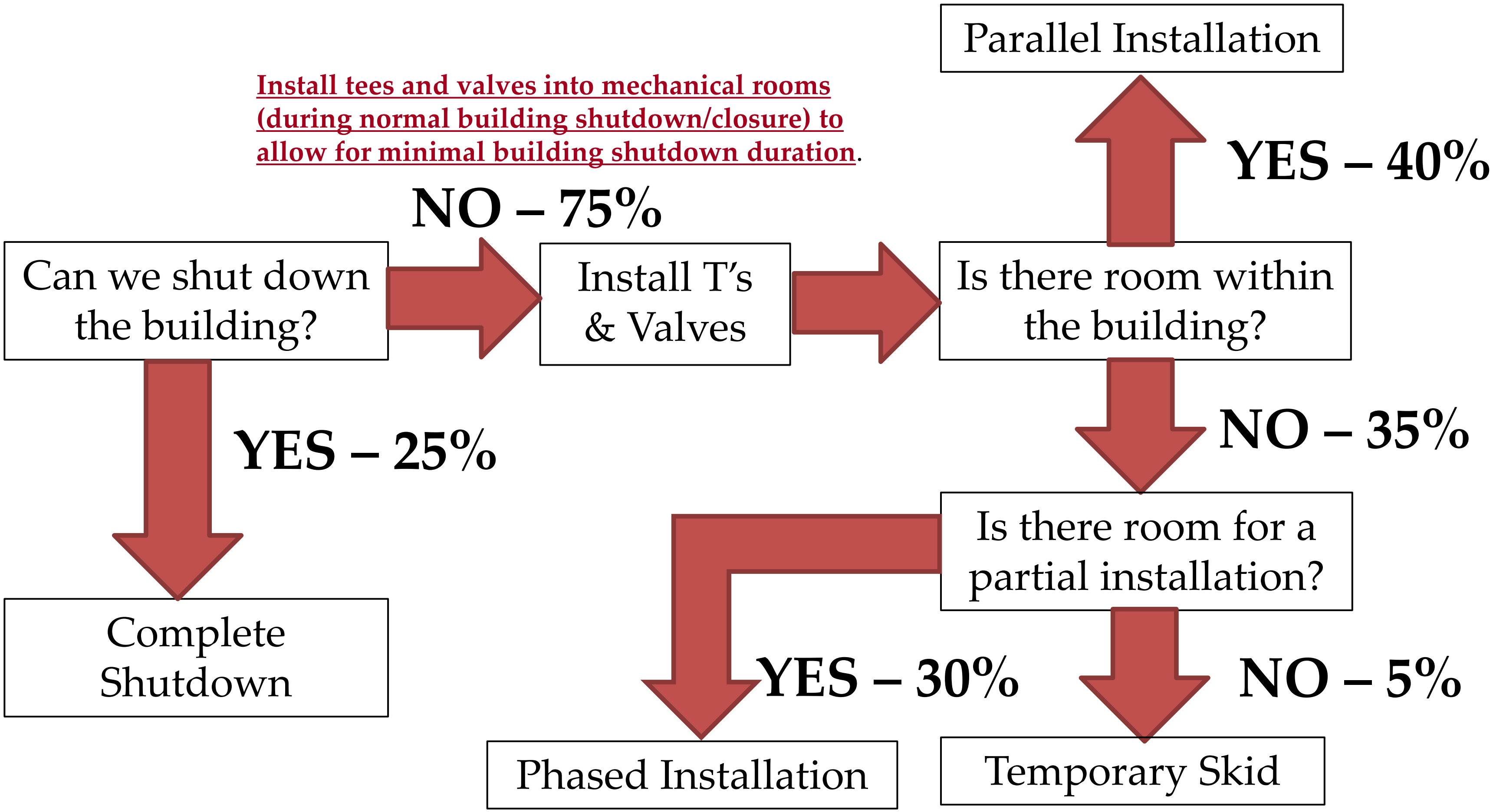


Building Conversions - Design

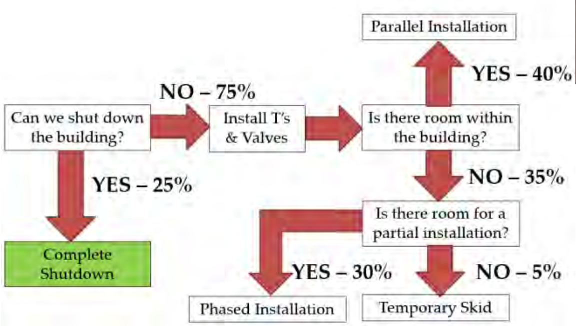
Skid Design

- Dimensions of skids important to allow:
  - **<u>Standardization</u>**
    - **<u>more efficient fabrication</u>**
    - **<u>easier integration into campus controls</u>**
    - **<u>easier fit into existing mechanical rooms</u>**
    - **<u>faster install, with reduced shutdown duration</u>**
  - Installation in existing and active buildings
- Heat Exchanger Capacity
  - **<u>Based on review of as-built documentation as well as building trend data</u>**. Important data for design: HHW flow, HHWS/R temps, HHWS/R pressure, HHW kBTU/hr, DHW demand
- Redundancy
  - We included redundant HHW pumps
  - For a few critical buildings we included redundant HX skids
- Controls
  - Need to review overall campus controls integration and needs.
  - Our solution included a meter/controller that communicates via both Modbus and BacNet

Building Conversion - Installation



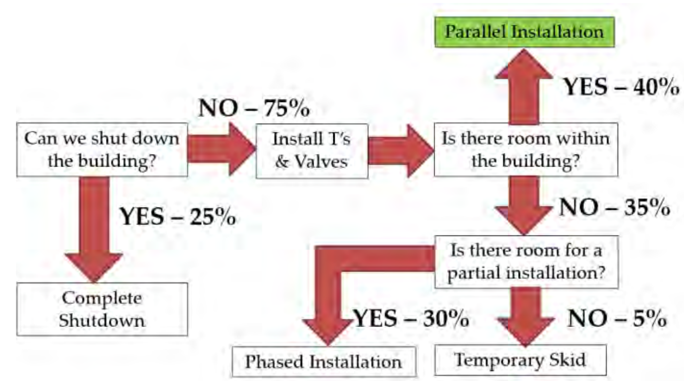
Building Conversion - Installation



Jordan Hall – Academic Building
Complete Shutdown

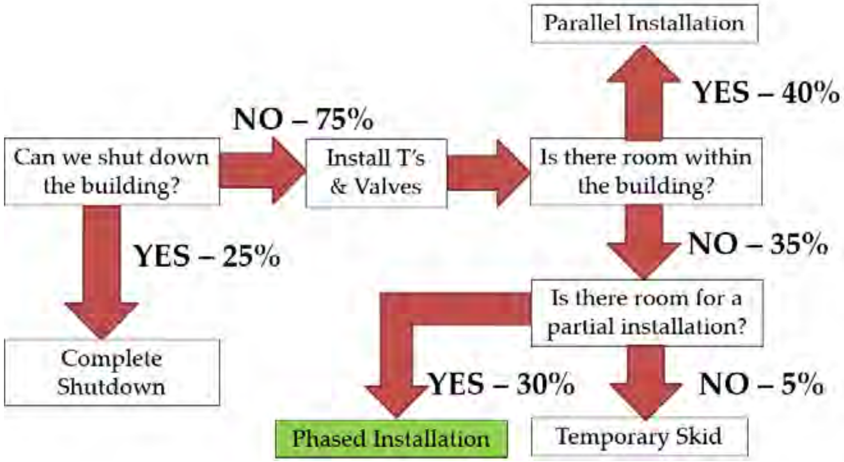
Building Conversion - Installation

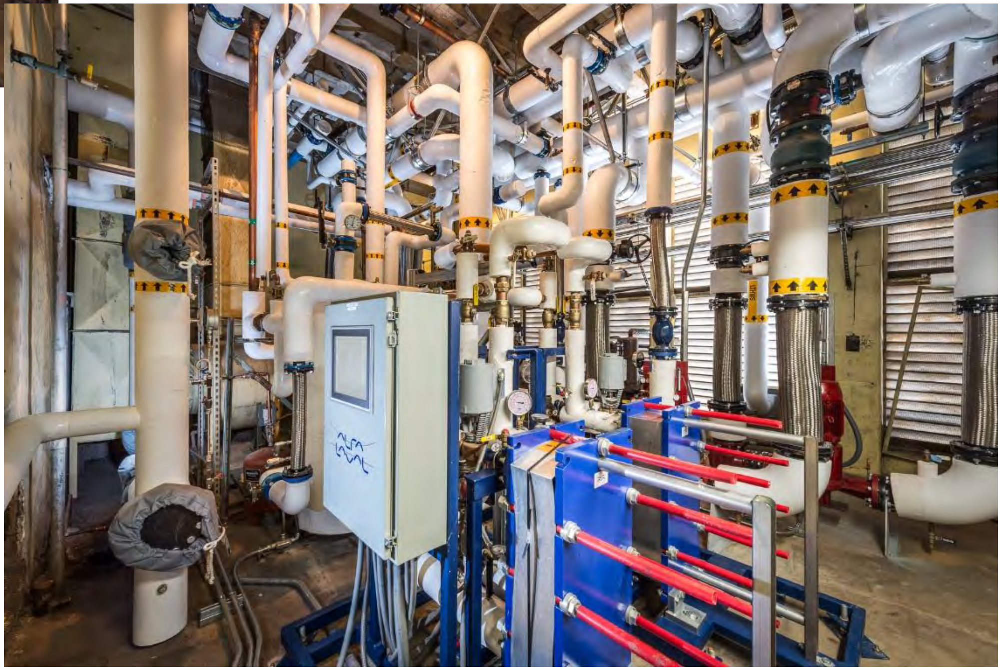
Florence Moore
Student Resident Hall
Parallel Installation



Building Conversion - Installation

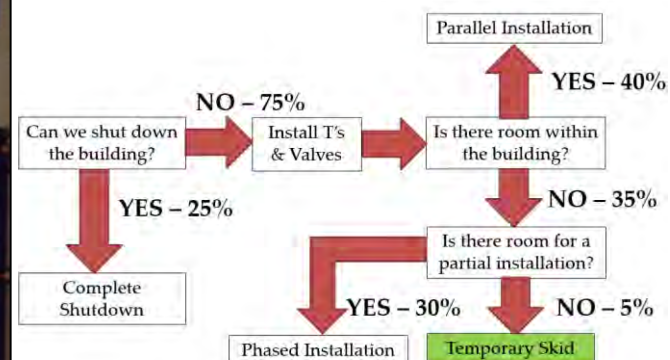
Lane
School of Medicine
Lab/Research Building
Phased Installation



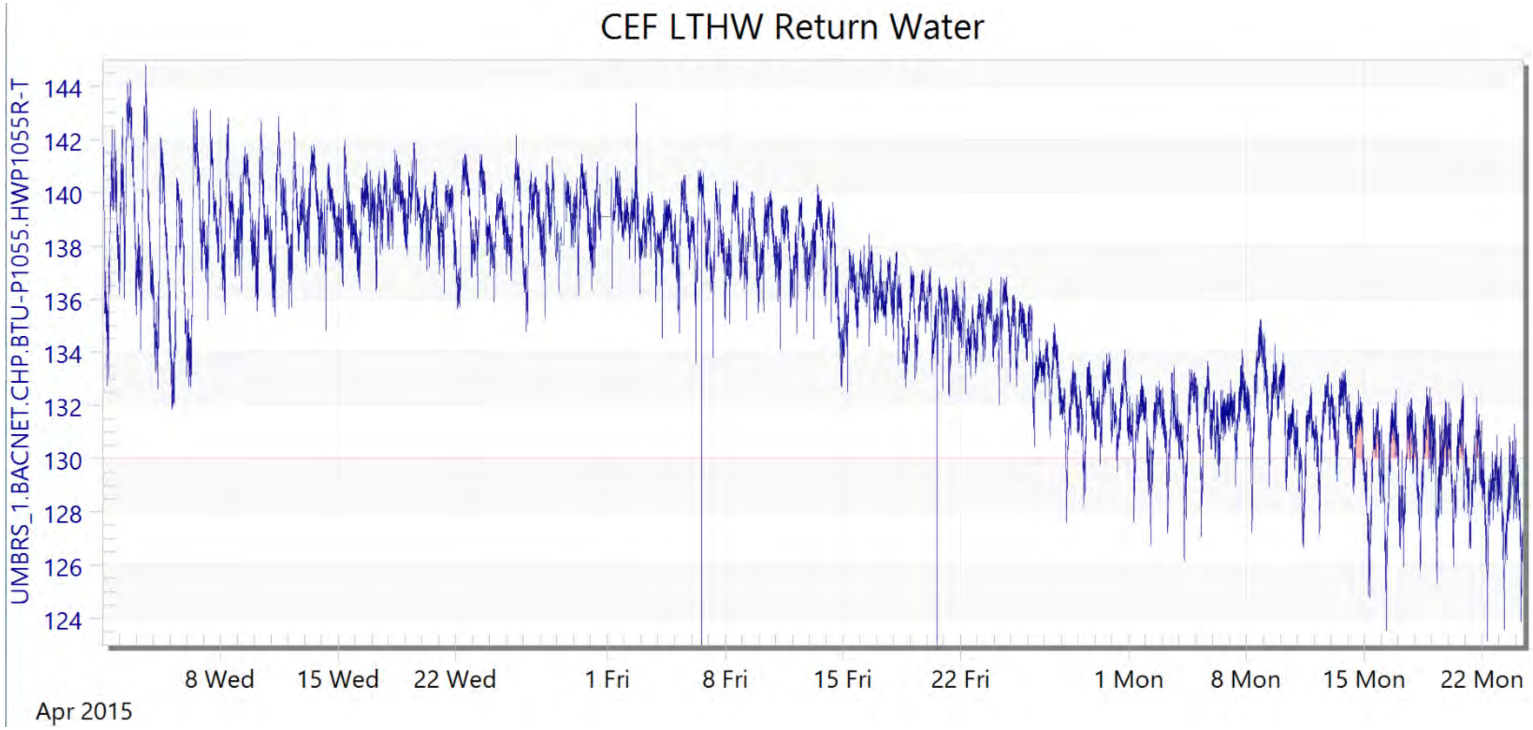


Building Conversion - Installation

Cantor Arts
Temporary Skid



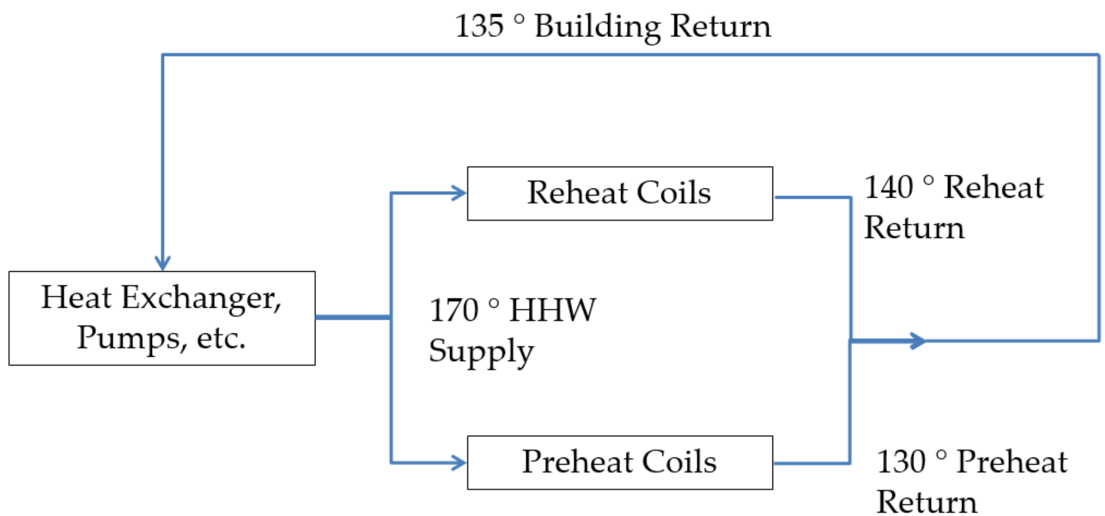
Building Conversions – Summer Delta T



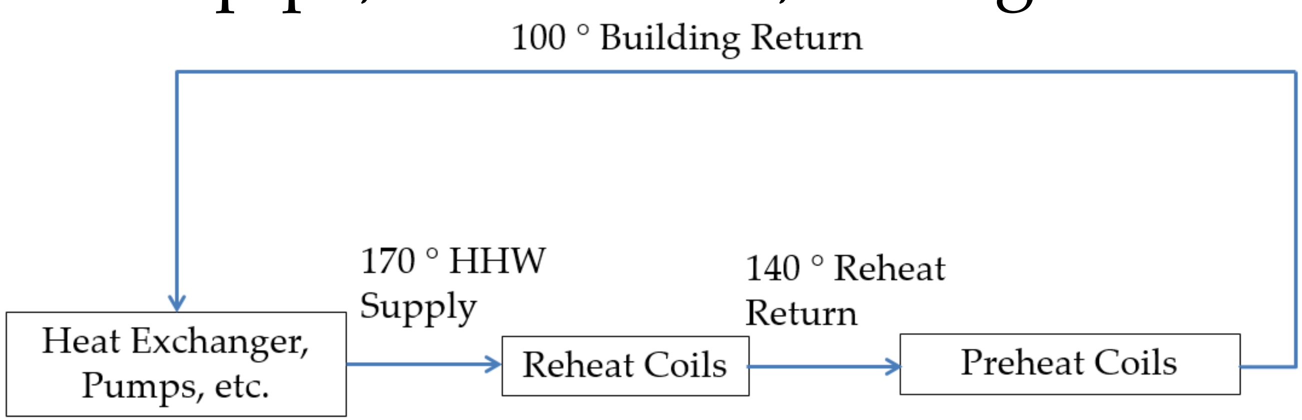
- Run building side HHW with lowest setpoints possible. Base these setpoints on either building demand or outside air temperature.
- Aggressively reset HHW setpoints. This may show rooms or zones that run cold. These areas can be improved to allow entire building to operate more efficiently.
- **<u>Eliminate/Reduce HHW bypass. This will improve LTHWR temperature.</u>**
- Review/Understand which campus buildings require the highest HHWS. These buildings will limit the LTHWS production.

Building Conversions – Winter Delta T

Locate all buildings with Preheat and Reheat Coils



Re-pipe, Add Valves, Change Coils



Question?

Underground Piping

- Design Installation
- Leak Detection
- Water Treatment
- Schedule Flexibility

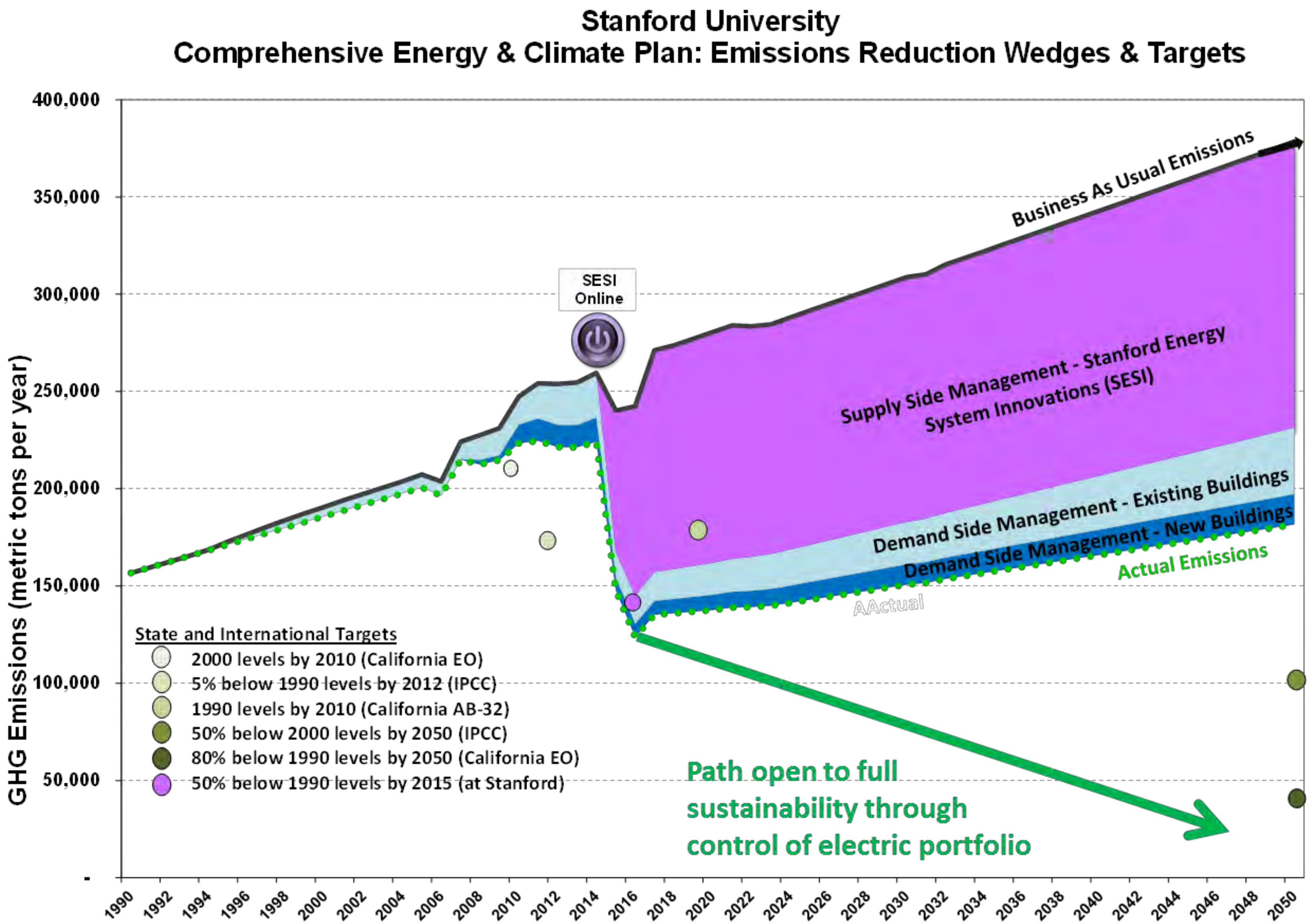
Building Conversions

- Design
- Installation
- Improve Summer Delta T
- Improve Winter Delta T

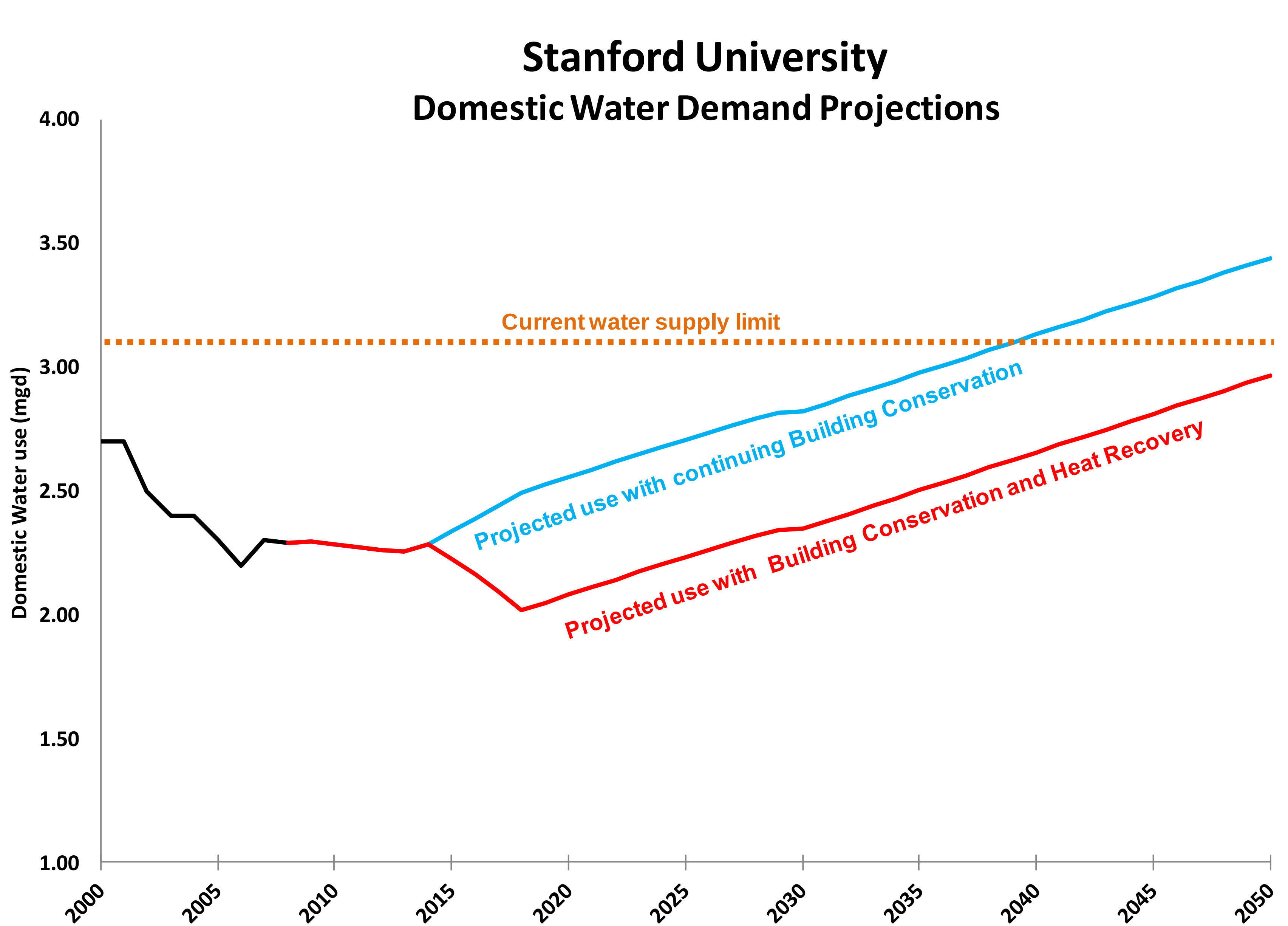
Overall System Performance

- System Performance
- Life Cycle Cost Analysis
- Heat Recovery in US Regions
- Reduced Power Consumption

68% Greenhouse Gas Emissions Reduction (and Growing)



15% Potable Water Savings



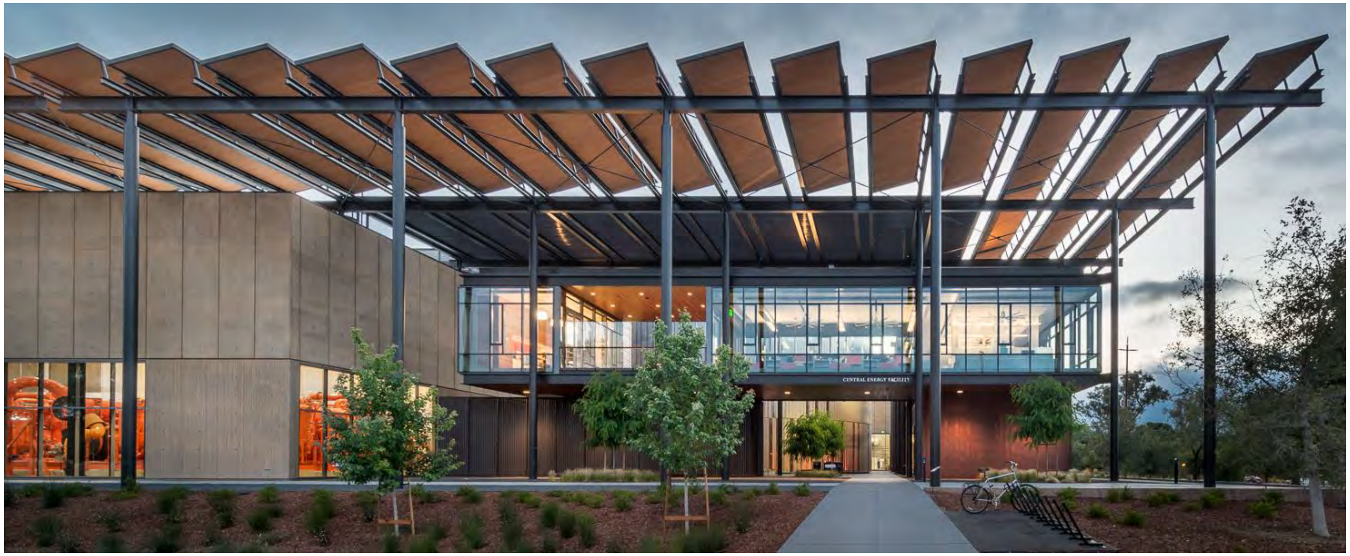
Current Plan Results – Year 1

- Plant efficiency is on track to meet estimated green house gas (68%) and water (15%) reductions.
- No gas was burned at the plant from June through mid November 2015 as planned. All campus heat came from heat recovery.
- Plant performance will be audited after a full annual cycle is complete on June 30, 2016. Estimates to date show that design assumptions are being met.

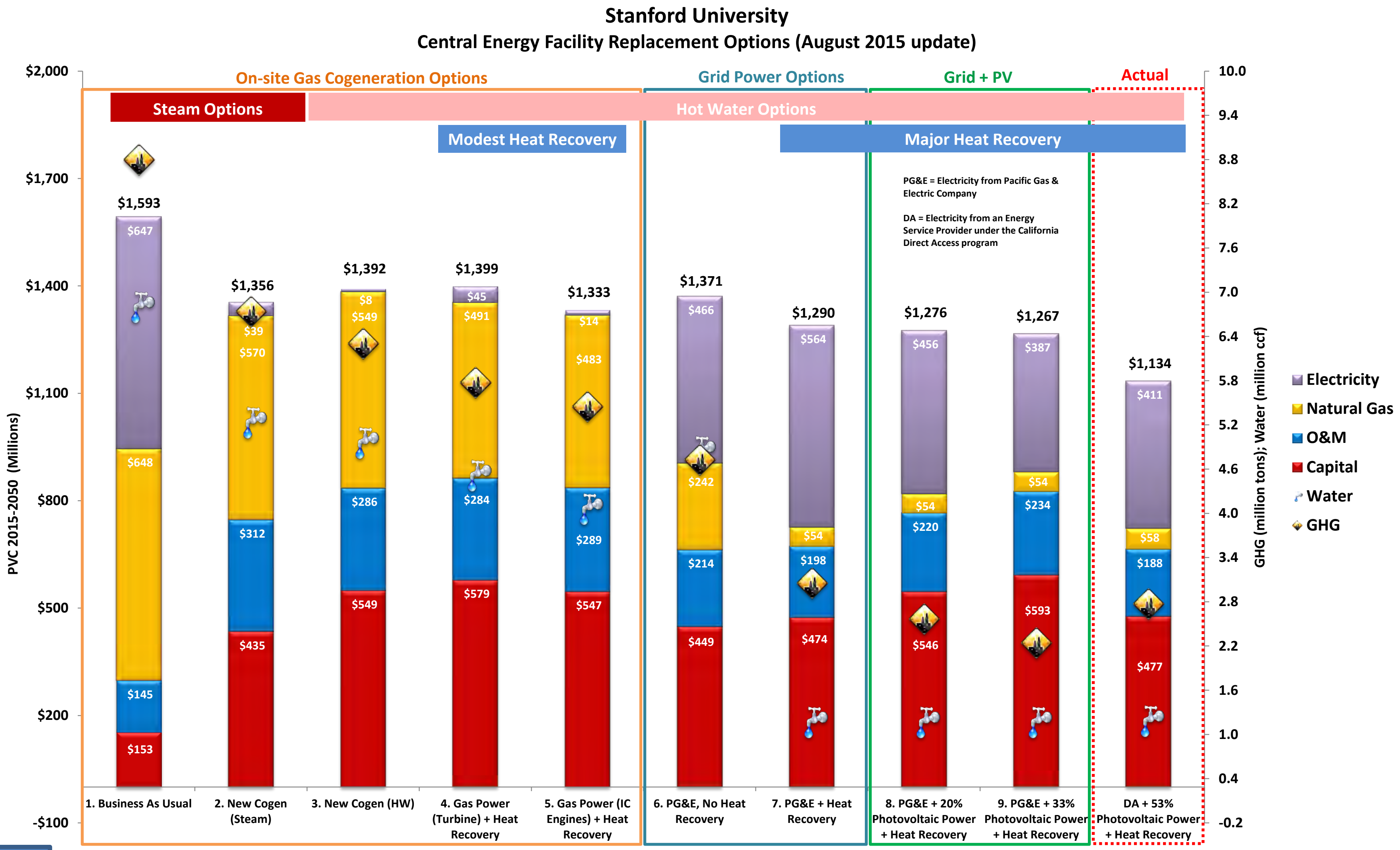
Energy Options Considered in 2011 (Present Value Cost)

Life Cycle Cost Analysis

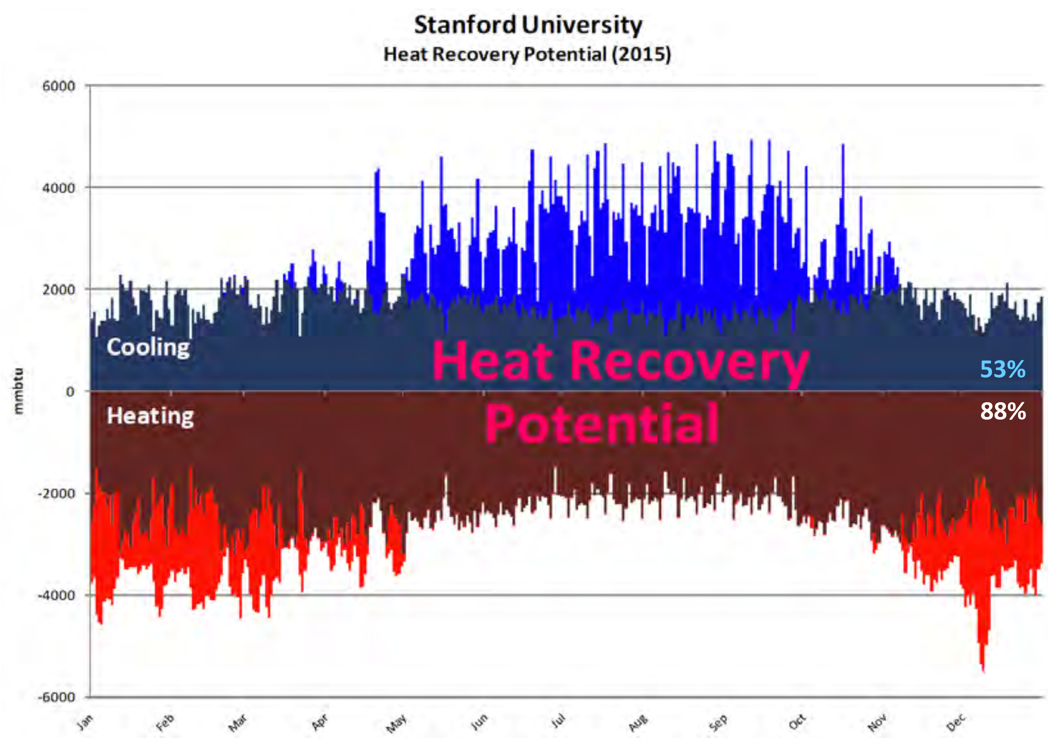
- Stanford had to select a new energy plant because the cogen contract was expiring and the plant was at the end of its useful life
- For major capital projects Stanford uses Life Cycle Cost Analysis comparing the Present Value Cost (PVC) of available options to inform the economic part of the decision making process
- In 2011 SESI provided the lowest PVC of any option and was $303 million less than continuing on with third party cogeneration. As a result of better than expected long term 25 year solar PV electricity generation contracts that PVC has been reduced by another $156M which increase the estimated life cycle savings over third party cogeneration to $459 million. See previous slide.



Project Overview: Cost Overview

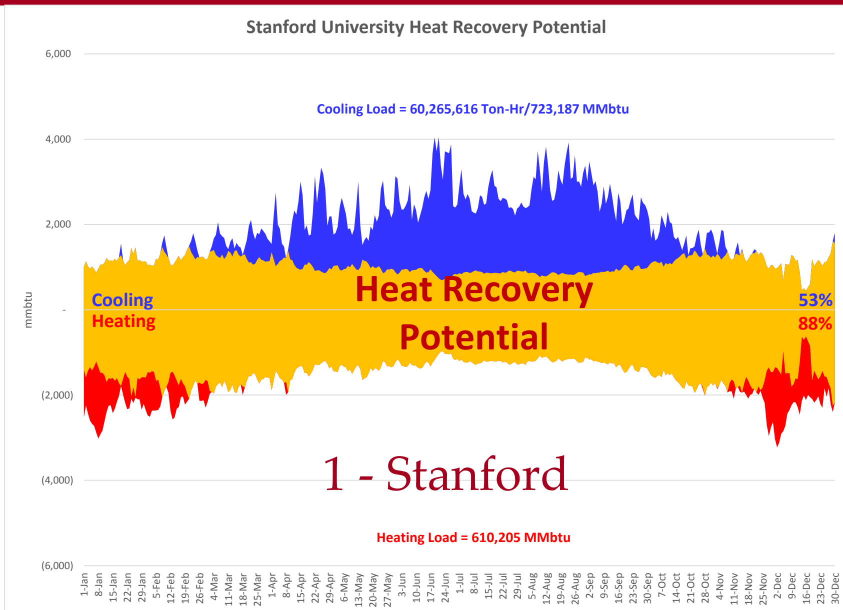


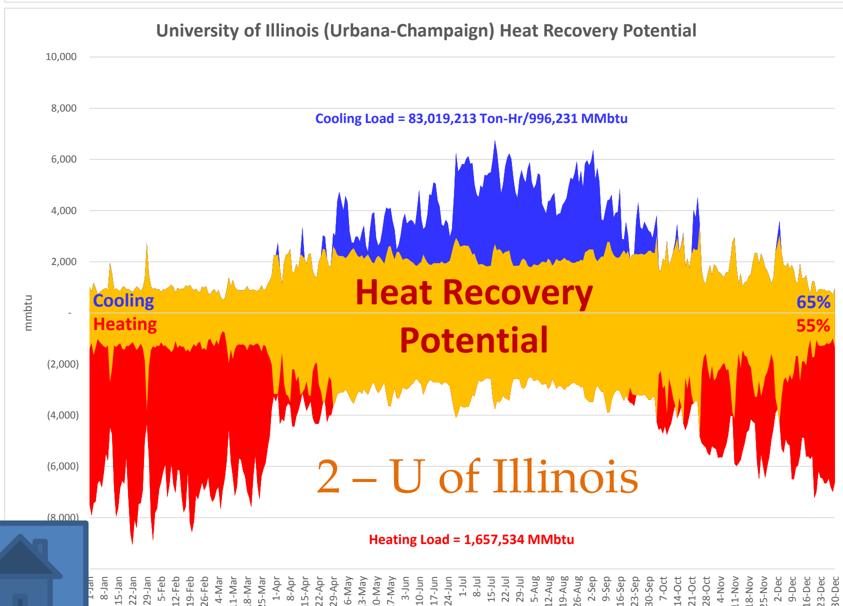
Why Heat Recovery is Possible

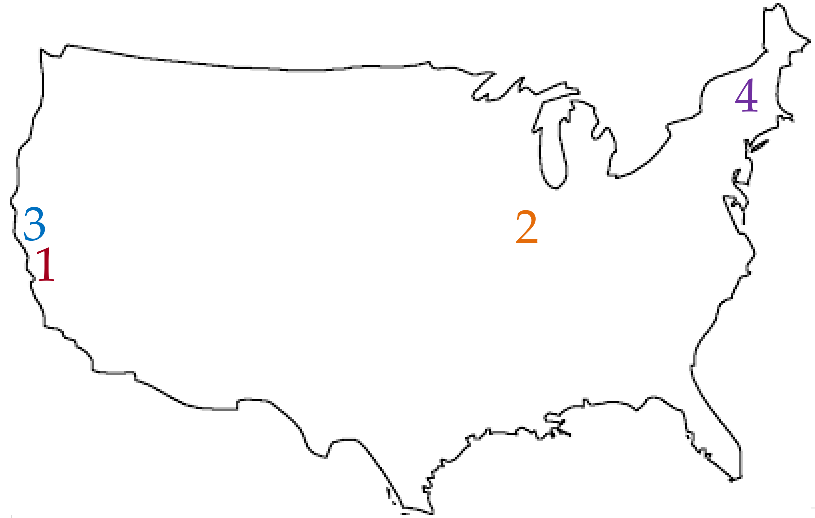


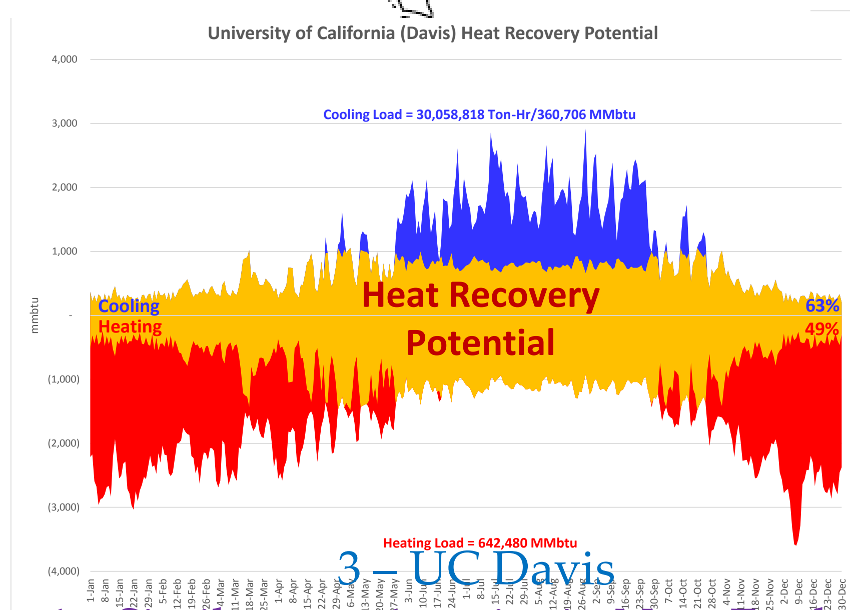
- Large scale deployment of heat recovery
- Combining best heating and cooling technologies in Europe and North America

Heat Recovery in Other US Regions









4 – Similar at university in New England (62% Cooling, 43% Heating)

Reduced Power Consumption on Campus

CEF Power

- The new SESI Central Energy Facility has been operating with a peak around 45MW in summer months, 40MW for the majority of the year.
  - Heat Recovery Chillers draw 1.3 kw/ton (3MW less than estimated)
  - The hot and cold water thermal energy storage and advanced model predictive control operating system (CEPOM/EOS) allow us to keep our control our peak production
  - The average peak of 40MW is far less than the 65MW predicted 5 years ago.