Stanford University:

Economic, Efficient, Green District Low Temperature Hot Water

IDEA Annual Conference| June 2016

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SESI Program Vision

Support Academic Mission

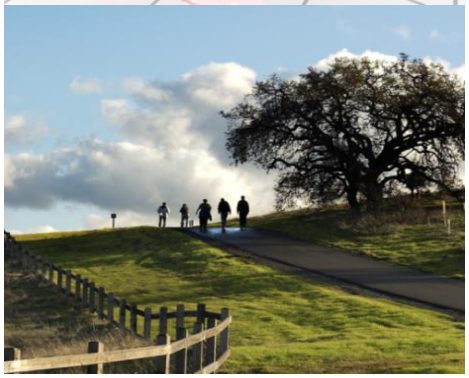
- Successor for cardinal cogeneration
- Expansion for research and academic programs

Maintain Economic Viability

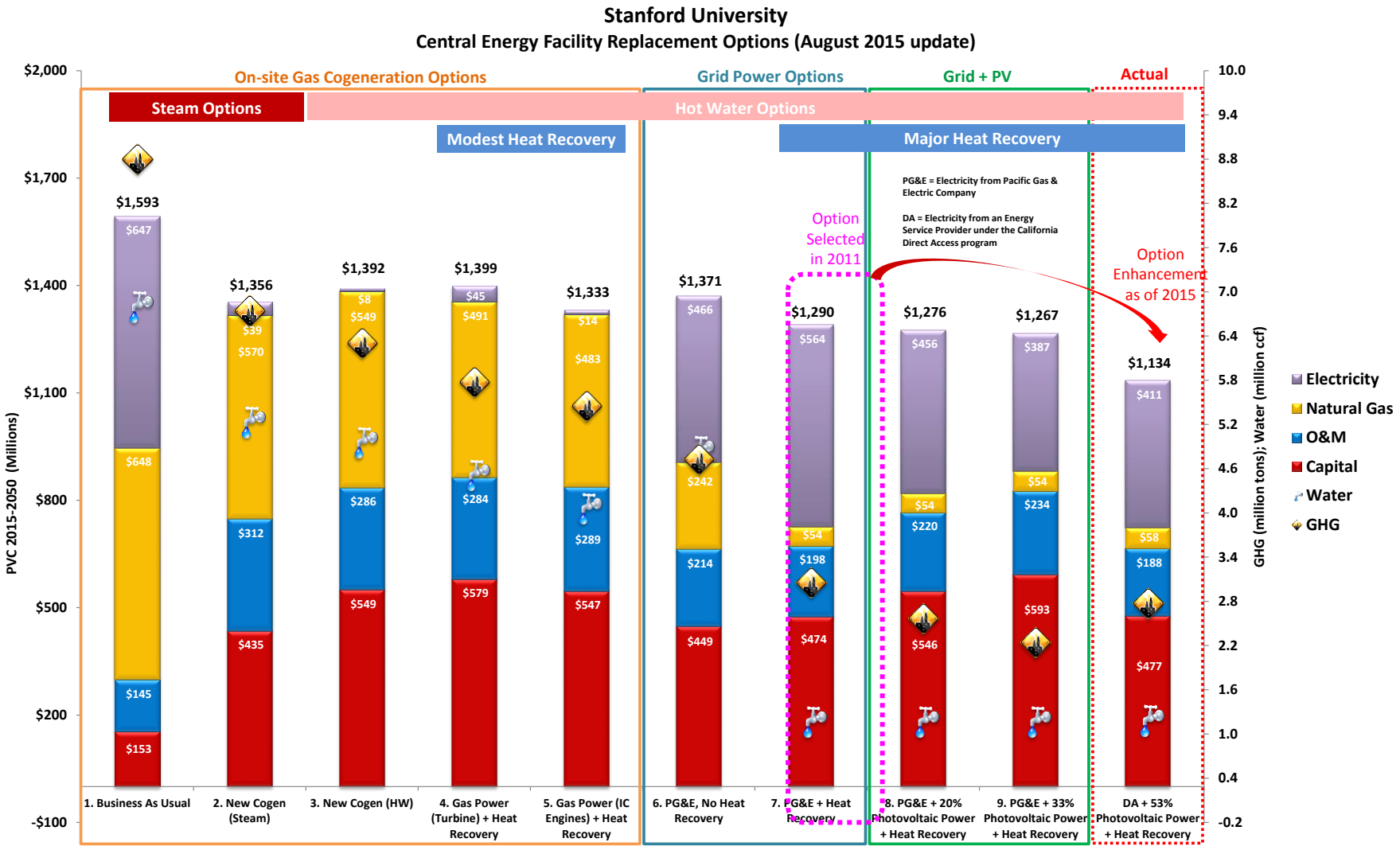
- Increase efficiency
- Protect against resource cost increase

Lead Sustainability by Example

- Reduce carbon footprint and water use
- Create foundation for green energy portfolio



Energy Options Considered in 2011 (Present Value Cost)



Stanford Energy System Innovations (SESI)

Stanford Energy System Innovations (SESI) is a new 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.

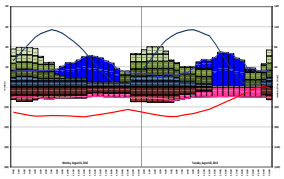
Primary Benefits

- Reduce campus greenhouse gas emissions by **68%** (and growing)
- Reduce campus drinking water use by an additional **15%**
- Save **$420** million over business as usual case over next 35 years

SESI Program Elements

Heat Recovery
(District level application)

New Thermal System
(Steam to hot water)



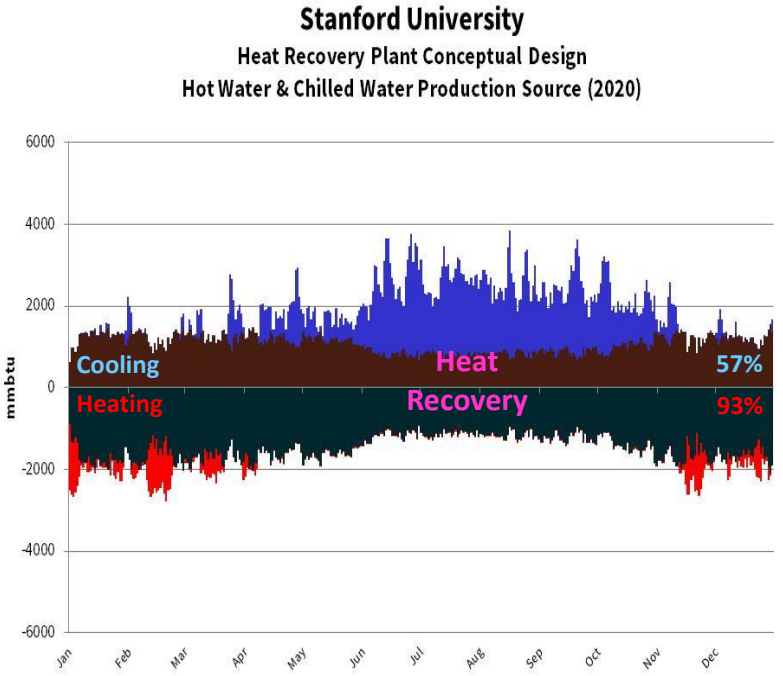
Advanced Energy Management Software
(Patented)

High-voltage Substation
(New)

Renewable Energy Portfolio
(Purchased electricity)

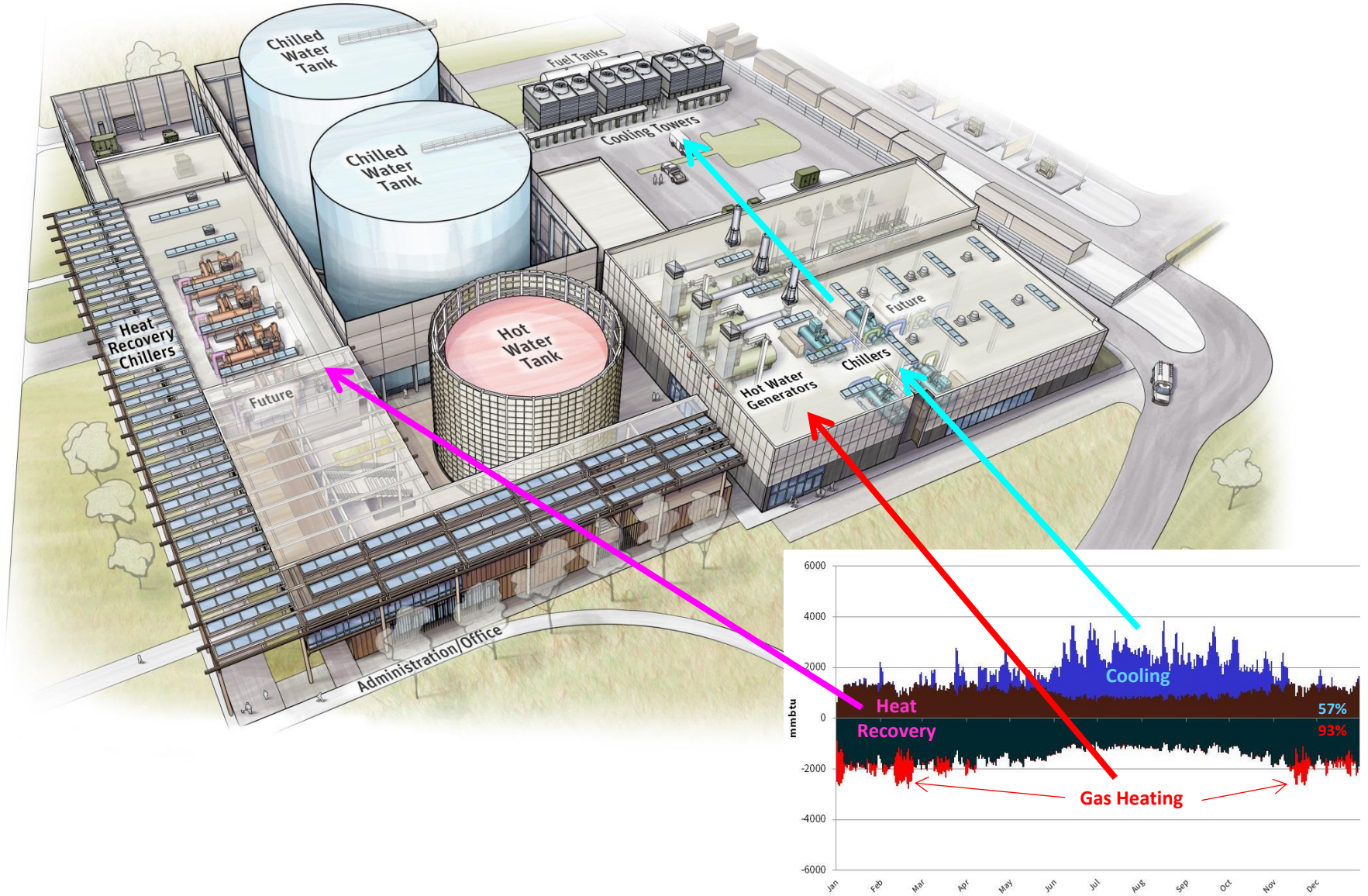
Benefits - Energy savings, water savings, increased system efficiency, flexibility to adapt to new energy generation technologies, increased safety, reduced operations and maintenance cost, and improved services reliability.

Innovation: District Level Heat Recovery



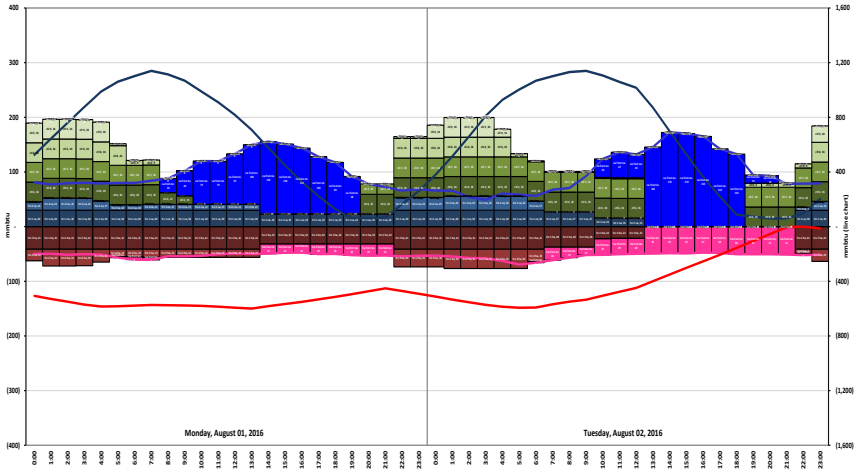
- Large scale deployment of heat recovery
- Combining best heating and cooling technologies in Europe and North America

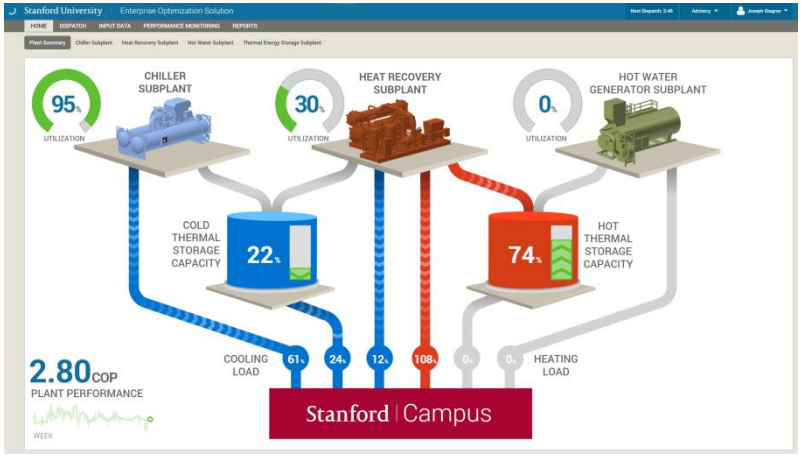
SESI's New Central Energy Facility



Innovation: Advanced Planning & System Operation

Central Energy Plant Optimization Model (CEPOM)/Enterprise Optimization Solution (EOS)



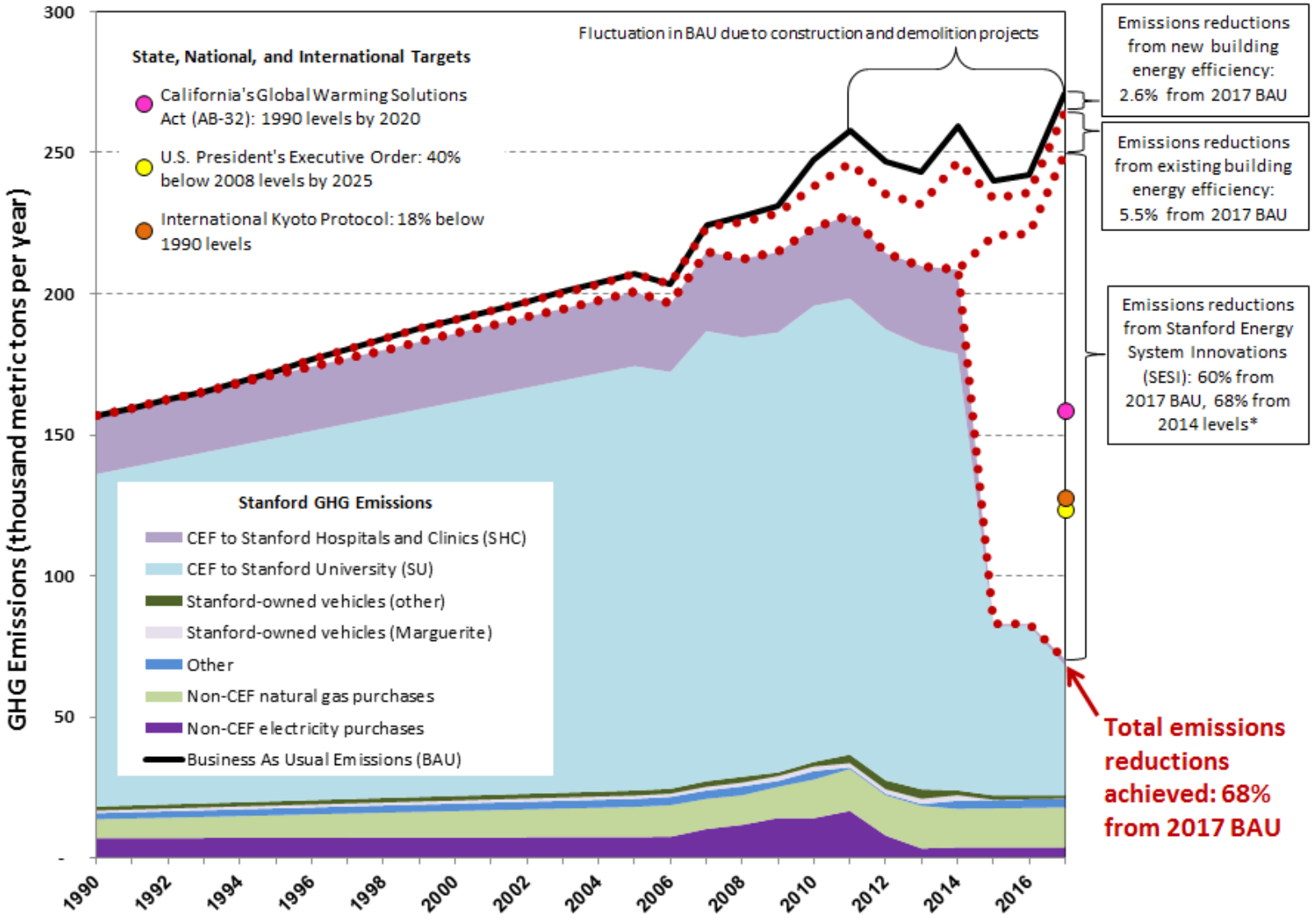


CEPOM/EOS is a patented 'model predictive control' forward looking energy modeling and plant dispatch program using over 1,220 variables including projected energy prices, load forecasts, and energy plant equipment and thermal storage capabilities to develop optimal hourly energy system operating plans.

Regularly updated annual (8,760 hours) versions of these plans (Planning Tool) are used for long range system planning, annual budget development and management, long term system efficiency monitoring, and other strategic planning and management processes.

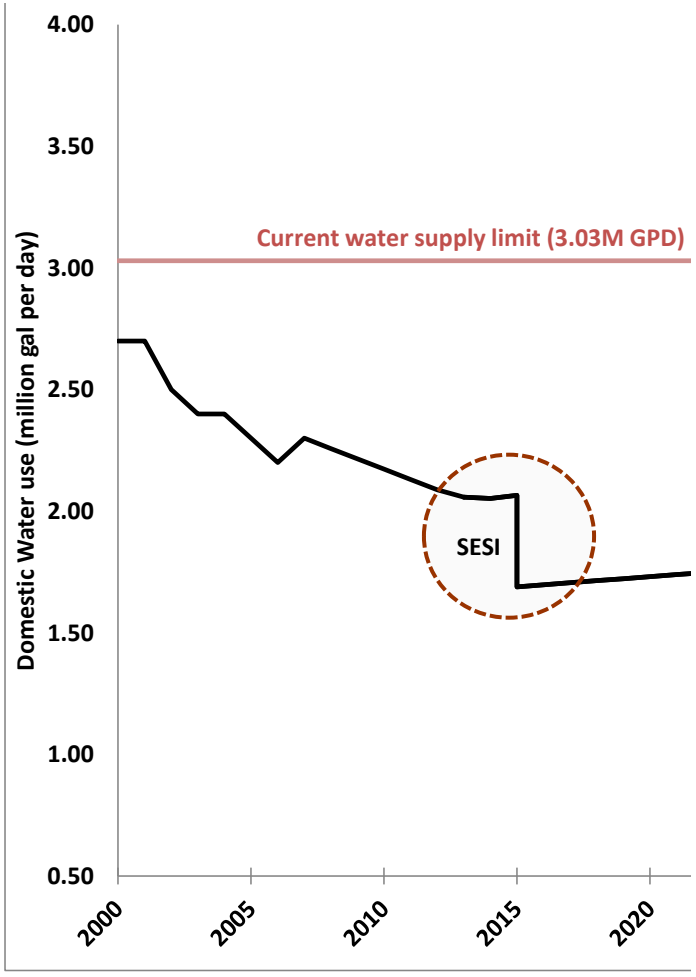
Regularly updated (minimum of every 15 minutes) one week (168 hours) look ahead versions of these plans (Operational Tool) are used to direct actual system operation through either advisory or automatic plant control.

68% Greenhouse Gas Emissions Reduction (and Growing)



*17,000 metric tons transfered to separate SHC inventory, due to SU no longer supplying that heating load with its CEF. This transfer is not included in percent emission reduction calculations.

15% Potable Water Savings



History of Conservation

Since 2000, Stanford has already reduced its potable water consumption by 21% though building retrofits and conservation efforts.

With SESI, Stanford will save an additional 15%

Stanford's water savings will increase to 36% in just the past 15 years.

Global Potential for Heat Recovery

- Heat recovery opportunity exists across all built environment regardless of climate
- Heat pumping from ground, water, or air can augment heat recovery from existing processes

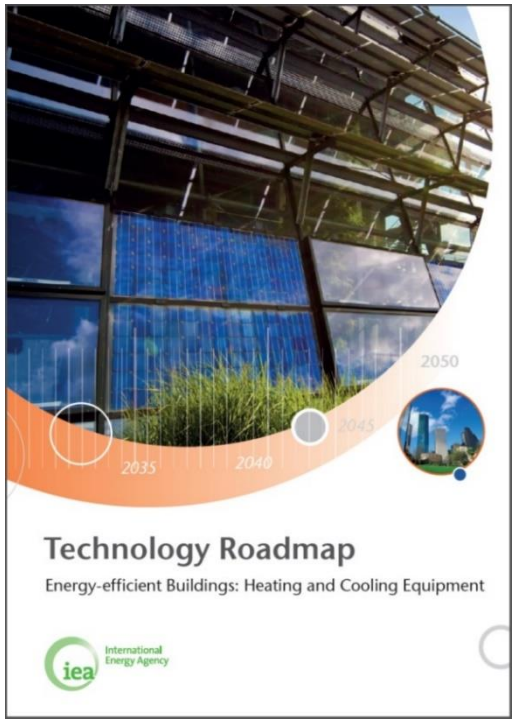
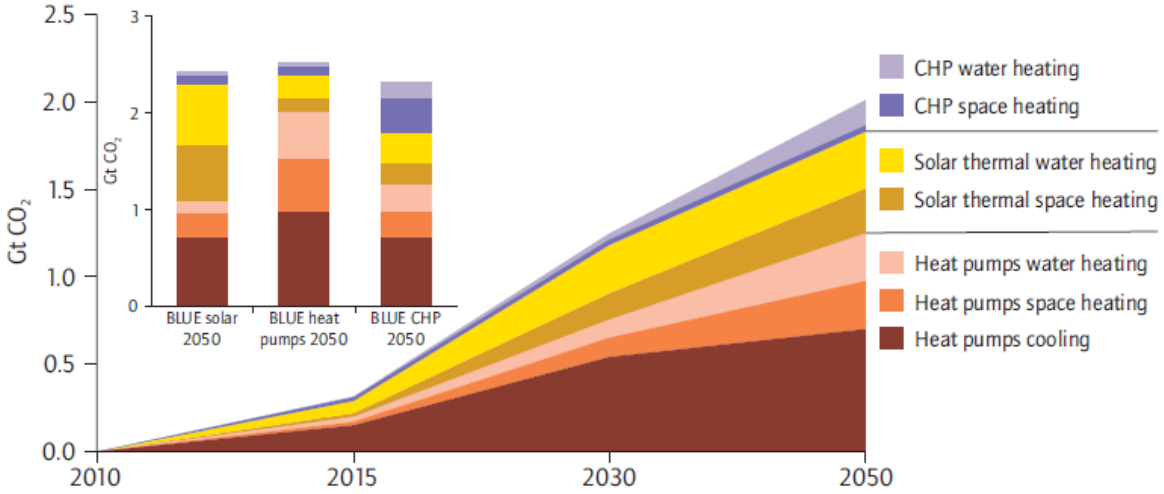


Figure 7: Heating and cooling technologies' contribution to CO_2 emissions reduction (BLUE Map and alternative scenarios)



Note: Excludes the impact of improved building shells on reducing heating and cooling loads.

KEY POINT: Energy-efficient and low/zero carbon technologies for heating and cooling save 2 Gt CO_2 by 2050.

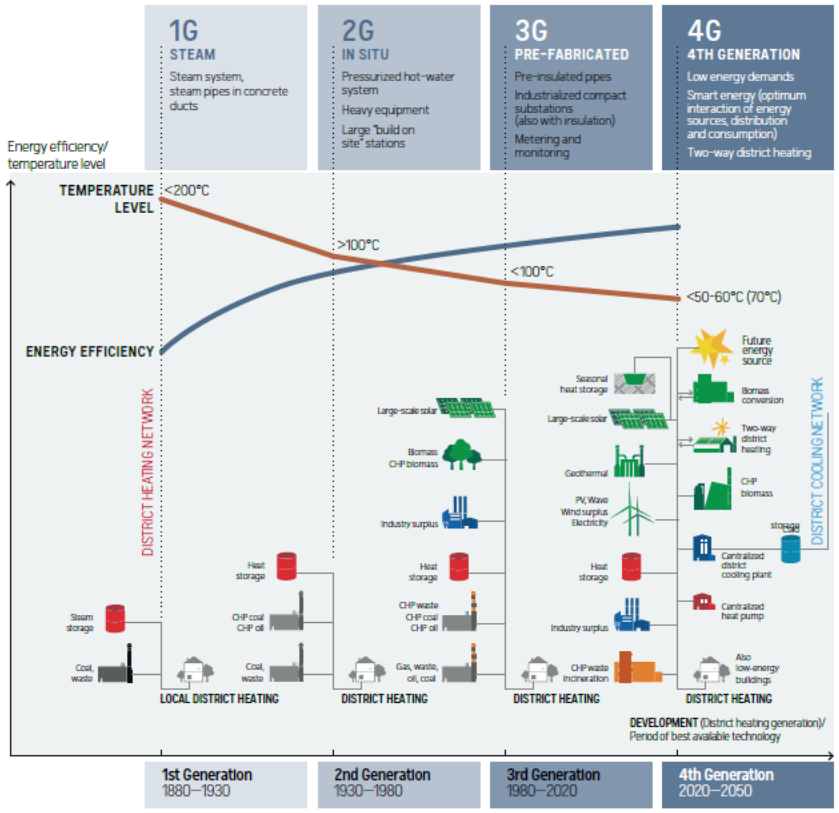
2011 International Energy Agency Report

Technology Roadmap for the Future

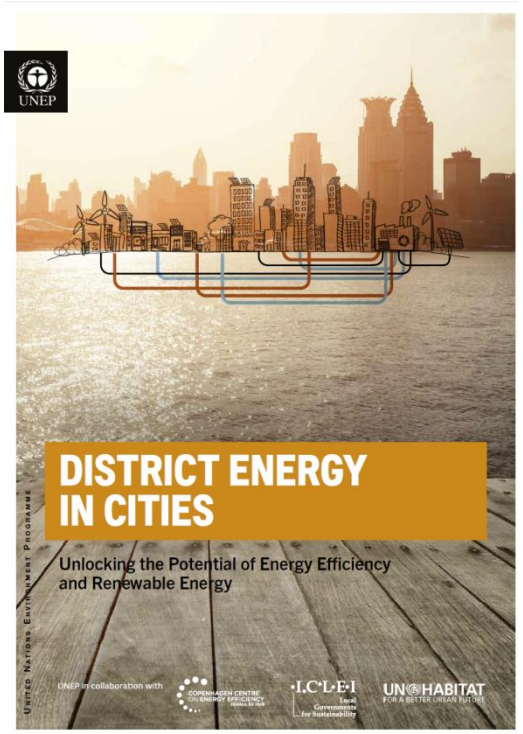
SESI 4th Generation energy system:

- Centralized heat recovery/heat pump
- Hot and cold thermal energy storage
- Low temperature
- Powered by renewable electricity

FIGURE 1.3 Historical development of district energy networks, to the modern day and into the future



Source: Aalborg University and Danfoss District Energy, 2014



2015 United Nations Report

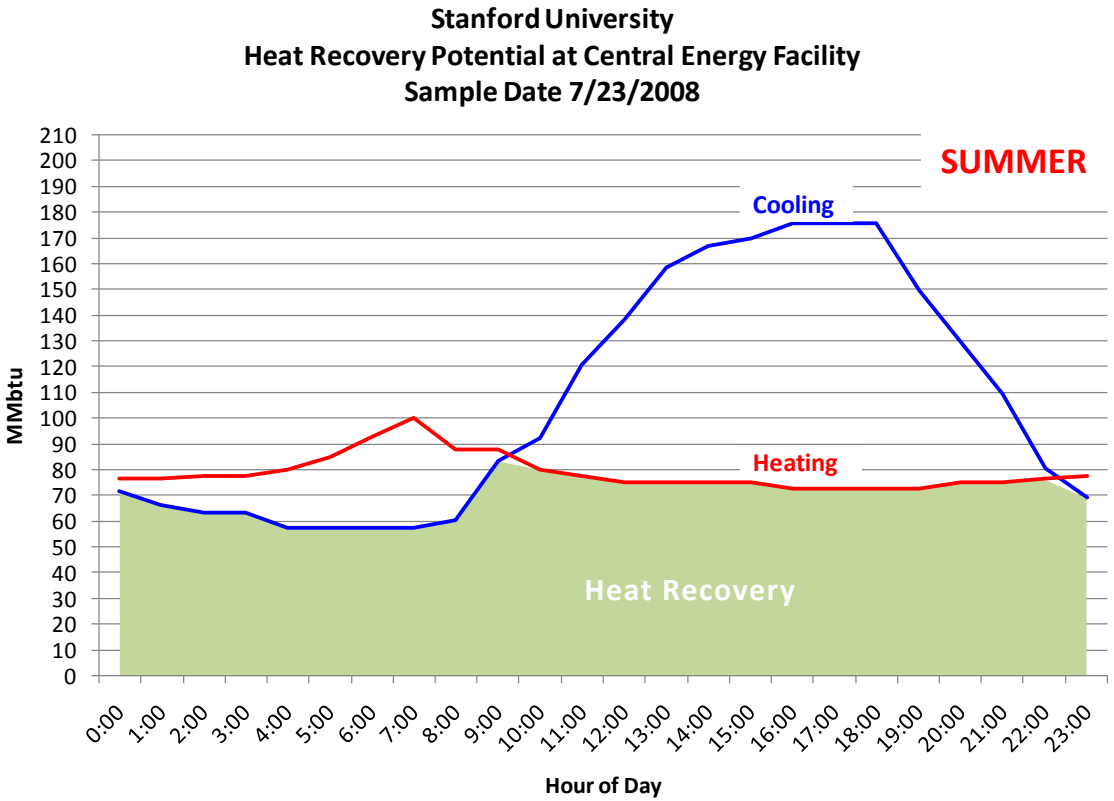
Waste Heat Discarded from Cardinal Cogeneration Plant

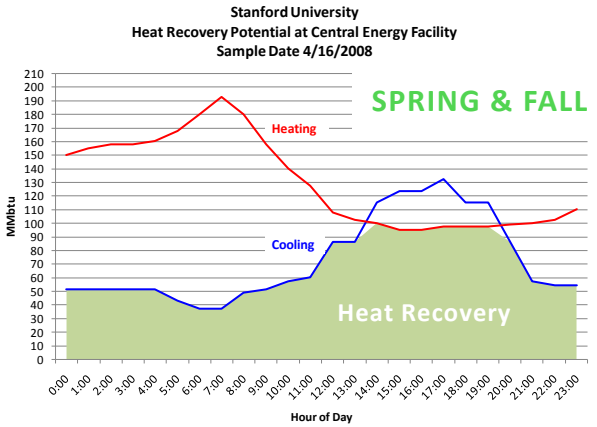
Energy can neither be created nor destroyed,
but only changed from one form to another.
- *First Law of Thermodynamics*

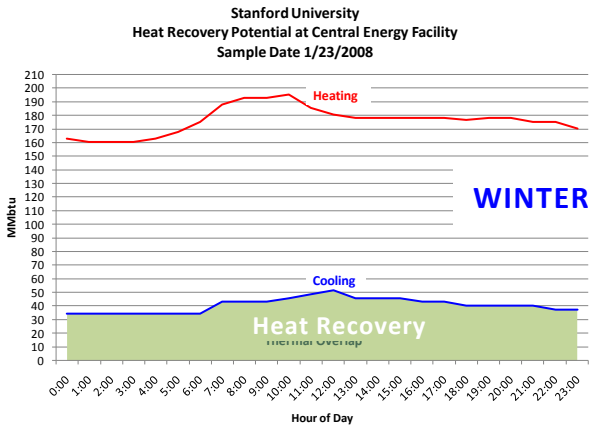
Why Heat Recovery is Possible

- We heat and cool buildings at the same time
- Cooling is just the collection of unwanted heat

Stanford can recover **65%** of the heat now discharged from the cooling system to meet **80%** of campus heating demands.







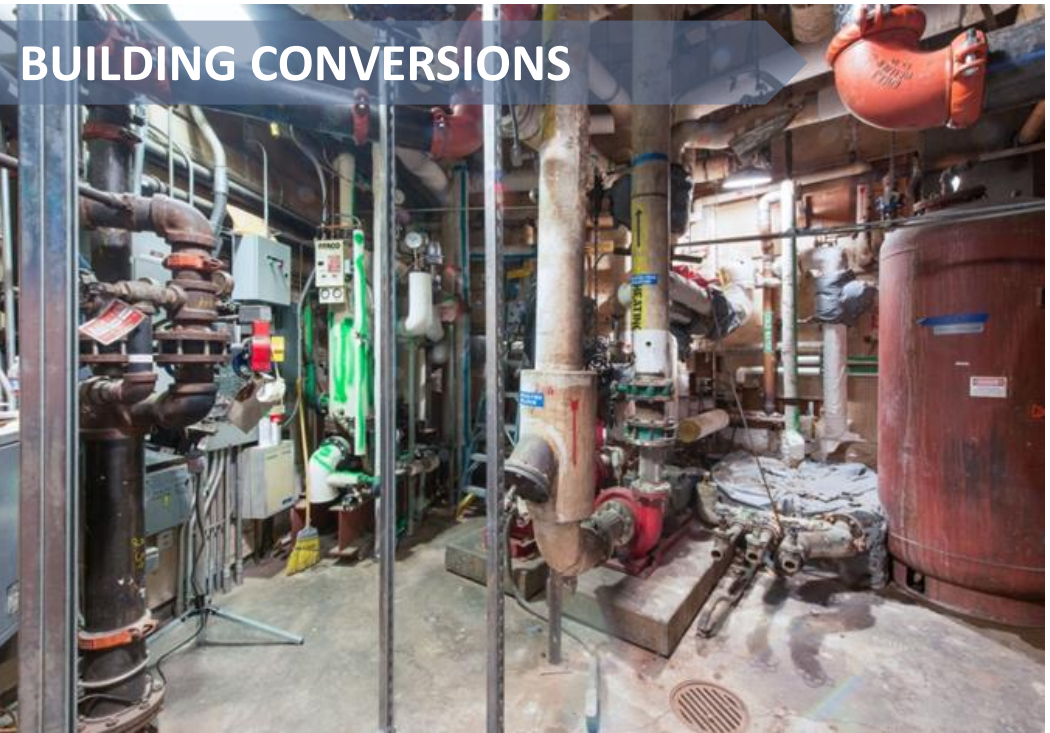
Source: Stanford University, Draft Energy & Climate Plan (April 2009)

Planning Aspects of the SESI Project

CENTRAL PLANT

PIPING DISTRIBUTION

BUILDING CONVERSIONS



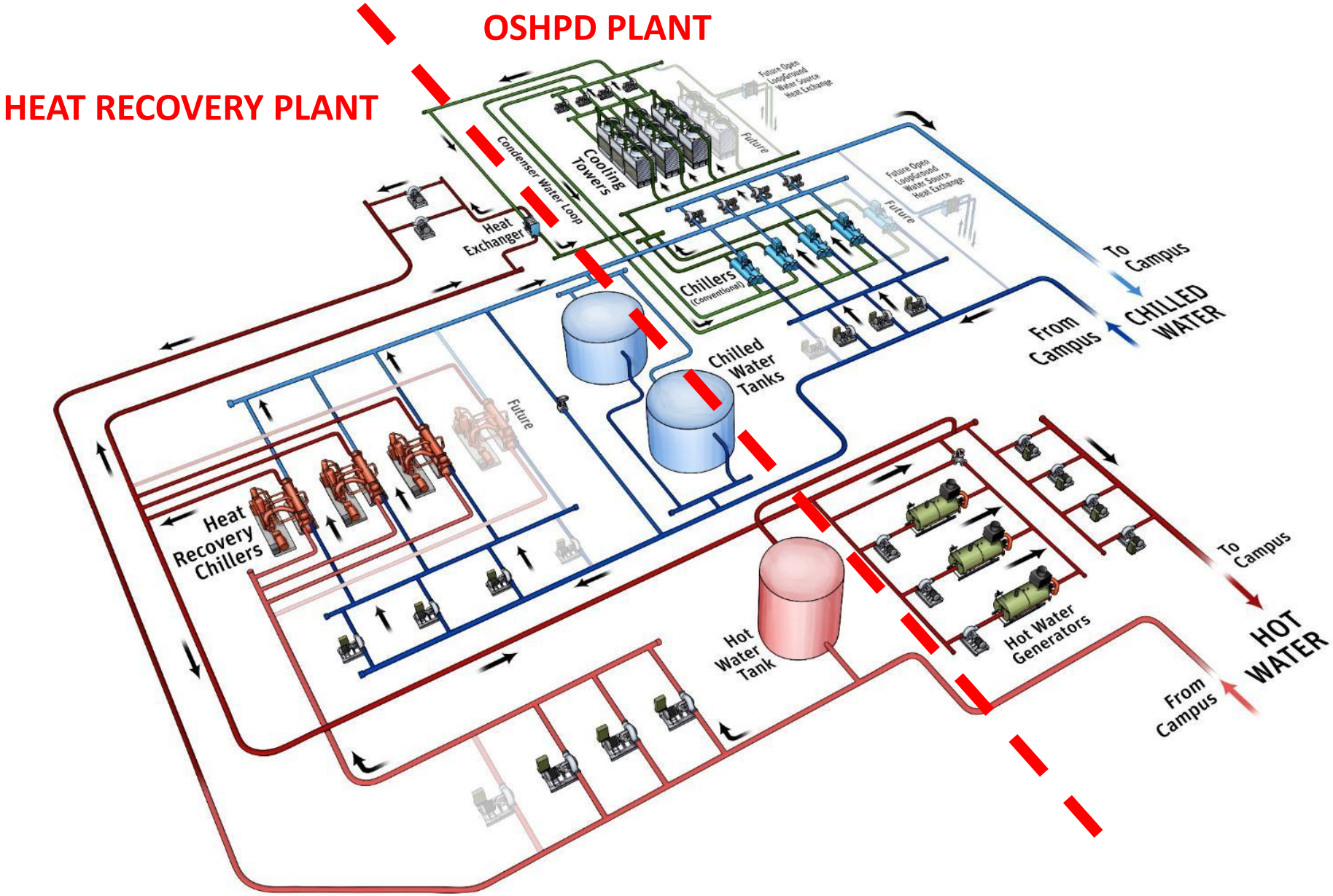
SUBSTATION

Thermal Energy Storage

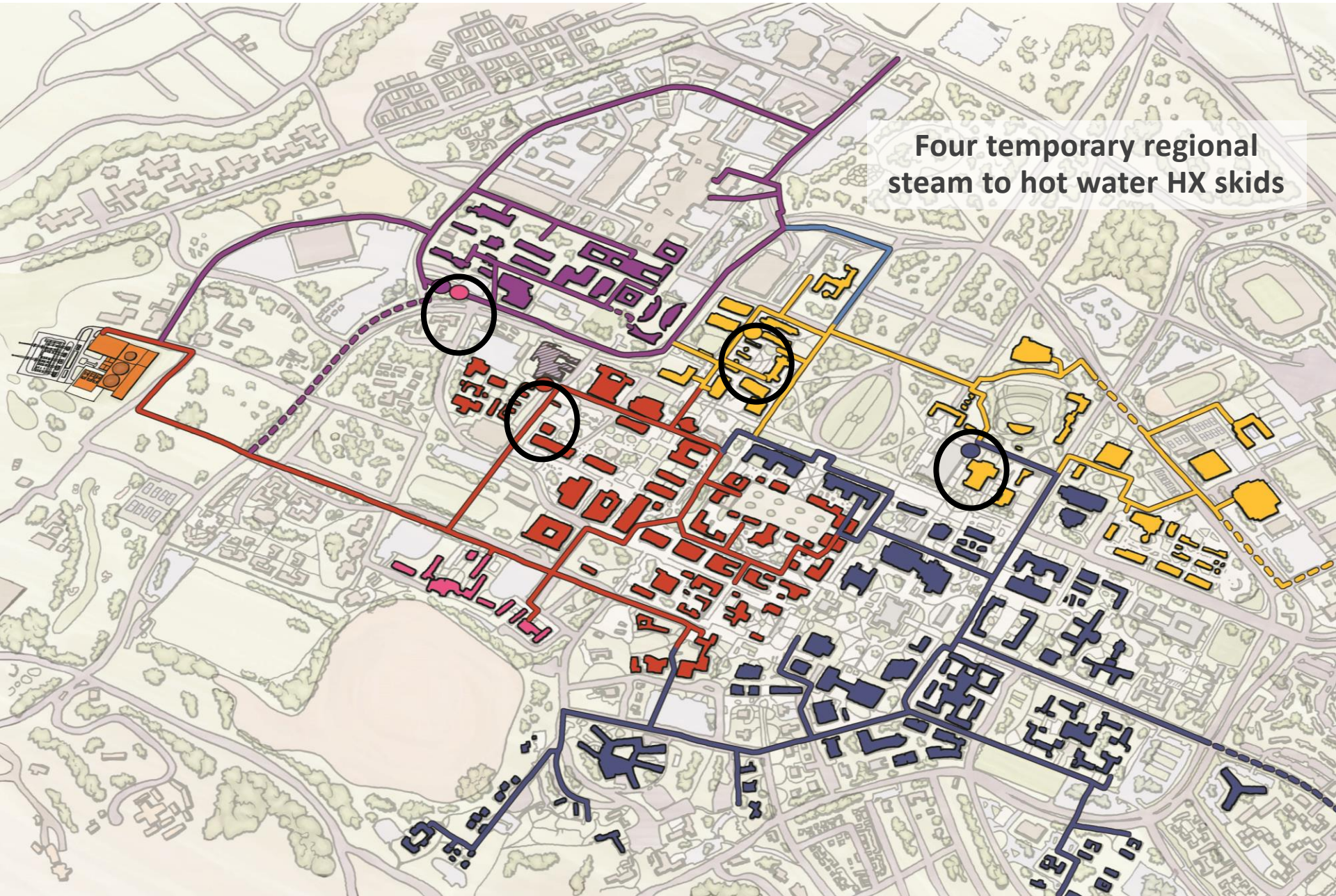
- Decoupling generation & load
- Thermal battery system

Production Equipment

Final Solution: Schematic



Building Conversion & Thermal Distribution



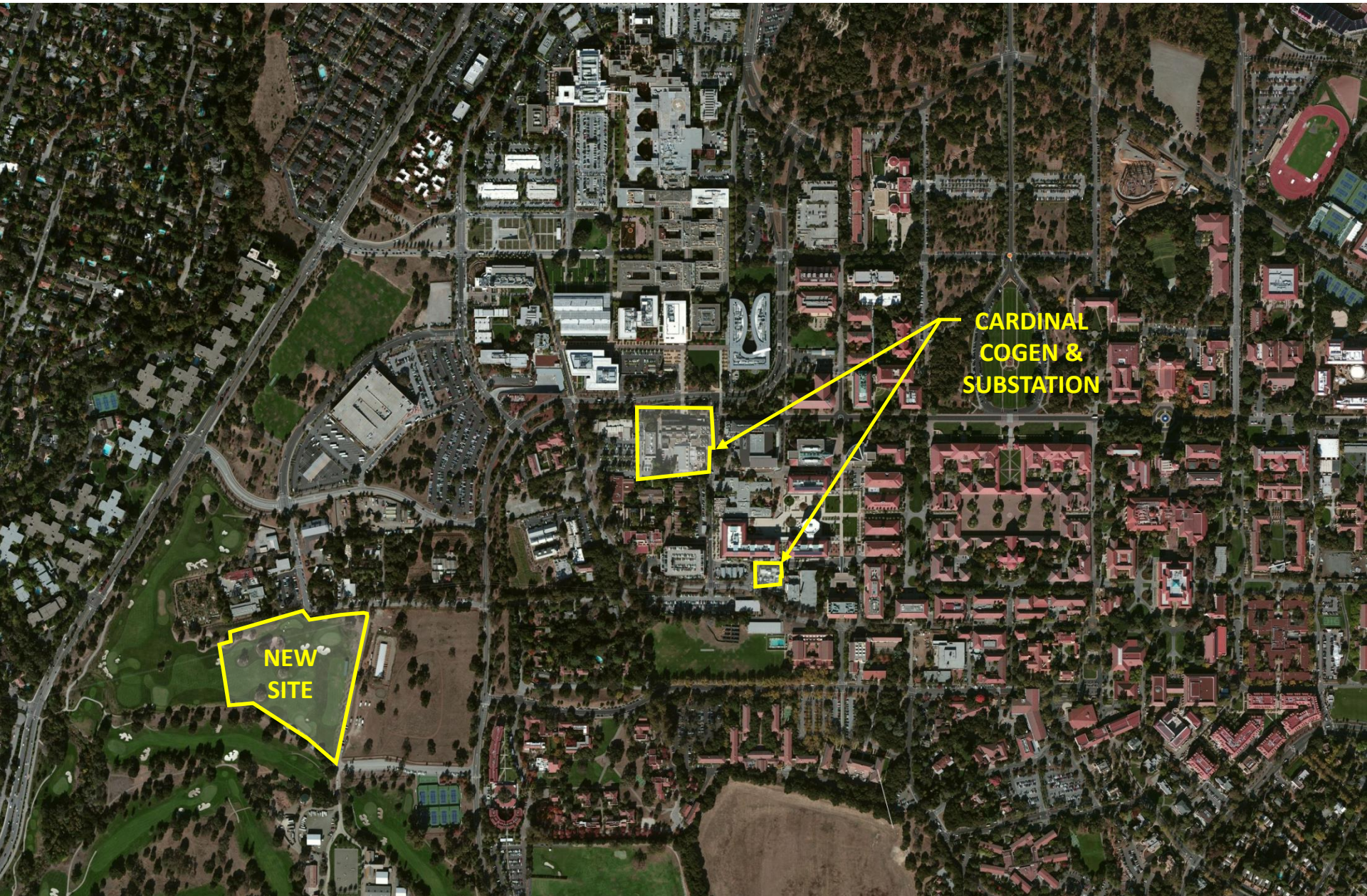
Logstor Piping & Regional HXs

- Shallow Bury
- Self-Restrained
- Direct Bury Valves
- Eliminated Vaults
- Chemical Free WT

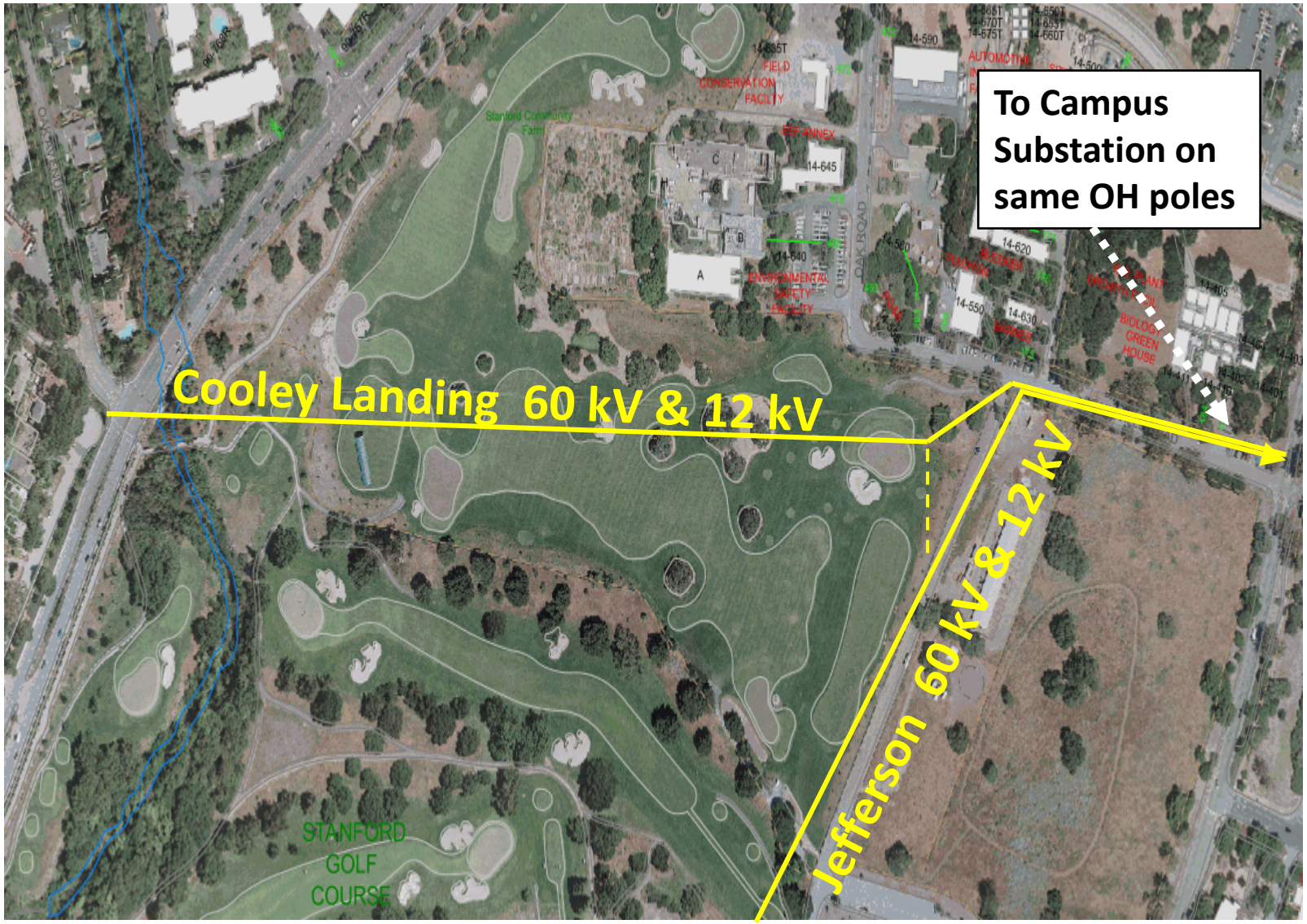
Building Distribution

After Building Conversion

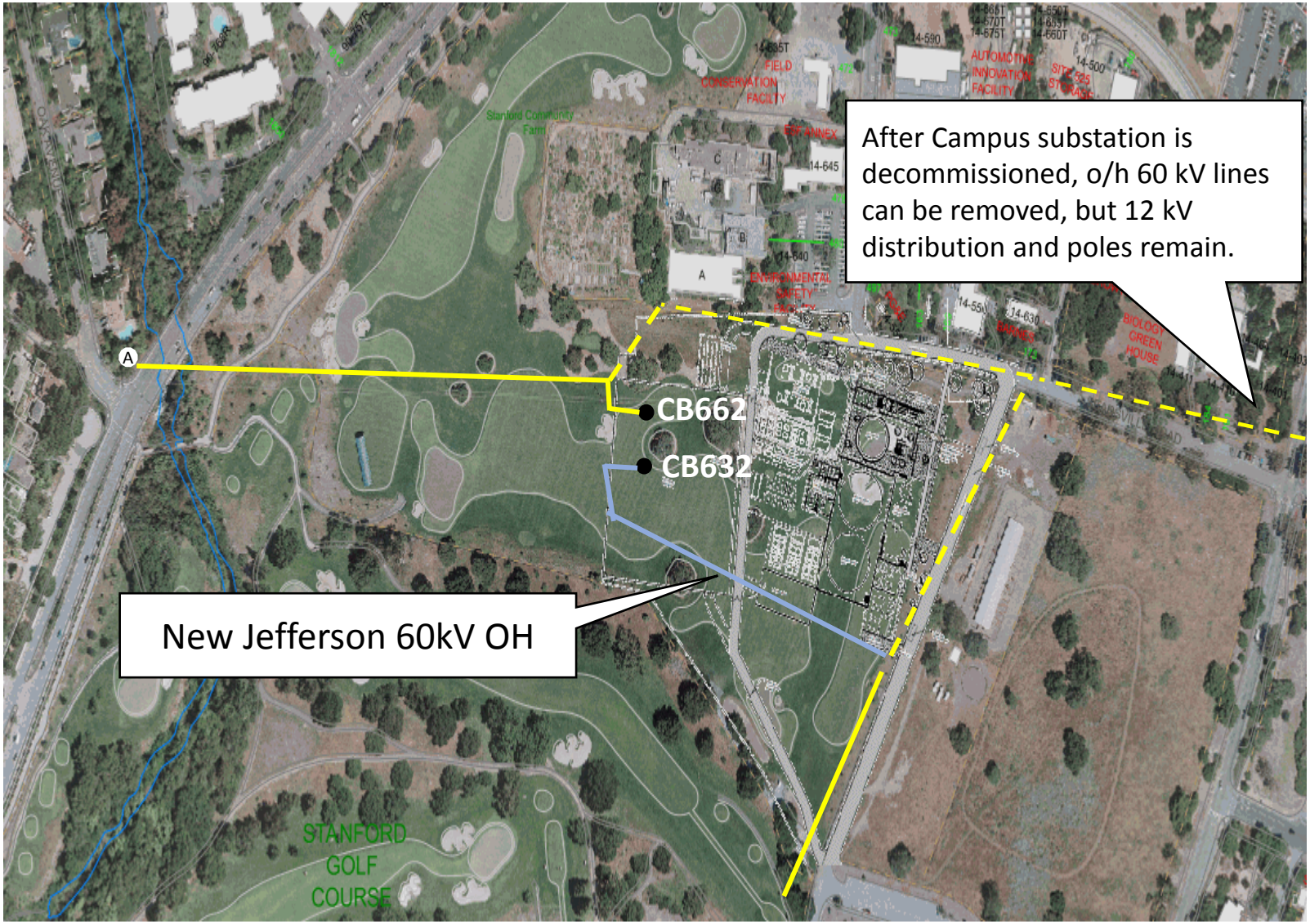
Substation Planning



Substation Planning



Substation Planning



System Performance

Insert chart on actual heating & cooling by HRC & Gas – June 2015 thru May 2016

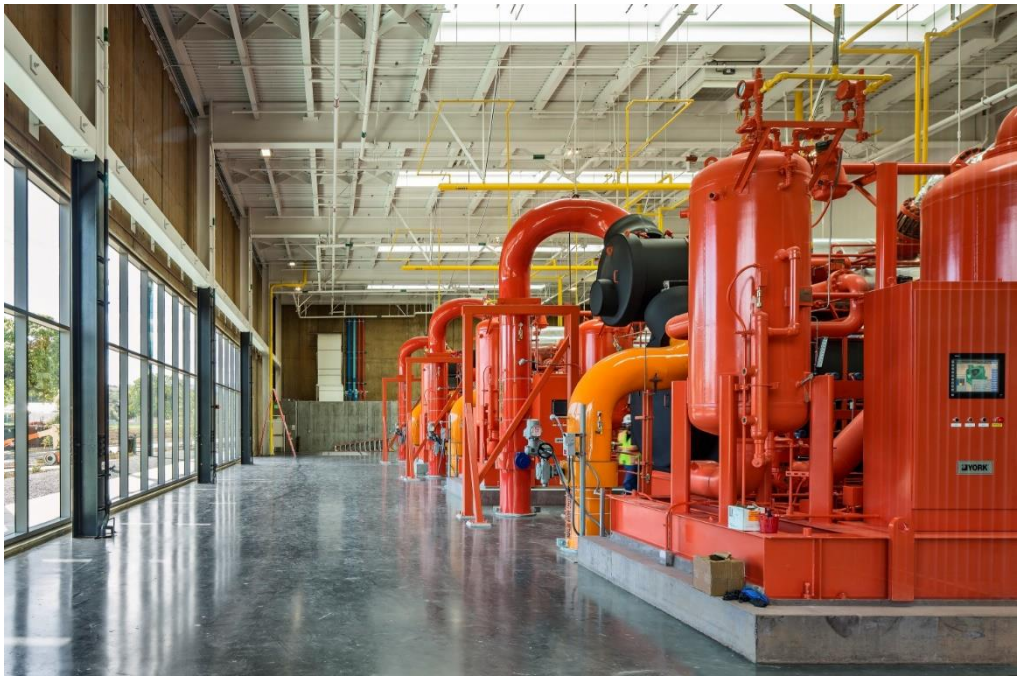
Add note of % by HR, CH & B

Add info on current vs. projected $/mmbtu of heating & cooling

System Performance

System Start-Up Challenges

- Hot Water Return Temperature & HRC
- Large Bore Pipe Mixing Issues
- Active Commissioning…
- Operator Training for Heat Recovery System



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Major Project Contributors

Stanford recognizes some of the many innovative companies and individuals from around the world that collaborated to help create SESI:

Prime Consultant/Engineer	Affiliated Engineers
Architect	ZGF Architects LLP
Structural Engineer	Rutherford + Chekene
Civil Engineer	BKF
General Contractor	Whiting-Turner
EXCAVATION	Top Grade Construction
MECHANICAL	ACCO
ELECTRICAL (PLANT)	Rosendin Electric
ELECTRICAL (SUBSTATION)	Contra Costa Electric
PIPELINES	Preston Pipelines
District Hot Water Consultation	COWI, FVB, MacKay & Somps, District Energy St. Paul
System Concept Peer Review	Affiliated Engineers, Black & Veatch, Enginomix, Jacobs Carter Burgess, Navigant
Controls Software Design	Johnson Controls
Equipment Suppliers	
HEAT RECOVERY CHILLERS/CHILLERS	York
HOT WATER GENERATORS	RF MacDonald/Cleaver Brooks
THERMAL ENERGY STORAGE TANKS	Pacific Tank
COOLING TOWERS	Baltimore Air Coil
HOT WATER DISTRIBUTION SYSTEM	Logstor
BUILDING HEAT EXCHANGERS	Alfa Laval
SUBSTATION HIGH VOLTAGE EQUIPMENT	Siemens Energy
INSTRUMENTATION & CONTROLS	Johnson Controls
PUMPS	Goulds