Stanford
ENERGY SYSTEM
INNOVATIONS

GENERAL INFORMATION

(UPDATED DECEMBER 8, 2014)

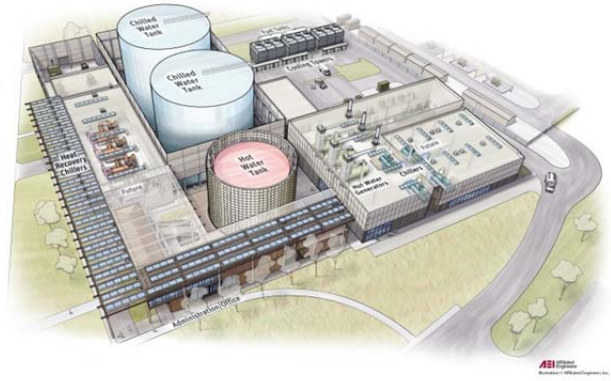
Stanford University

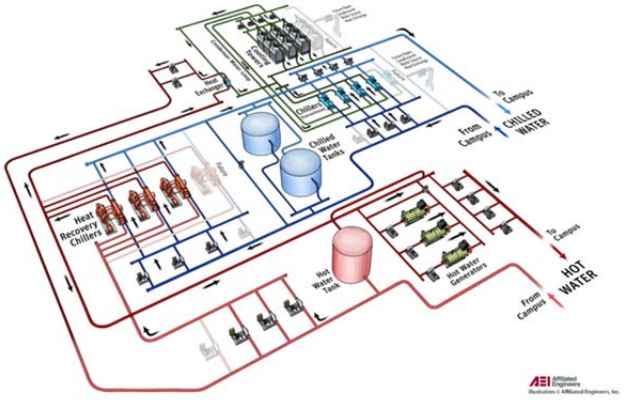
Stanford Energy System Innovations

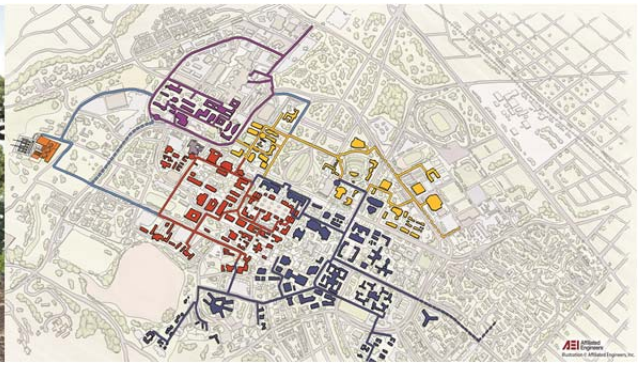
Introduction

The Stanford Energy System Innovations (SESI) project is a $485 million major transformation of the campus district energy system. The transformation is from gas fired combined heat and power with steam distribution to electrically powered combined heat and cooling with hot water distribution. When completed in April 2015, the new heat recovery system will be 50% more efficient than the existing cogeneration system on a natural gas basis; or 120% more efficient when state mandated 33% renewable power is factored in. SESI will immediately cut Stanford's Category I and II GHG emissions in half; save 15% of Stanford's drinking water supply; and save $300 million (20%) over the next 35 years compared to the existing system.

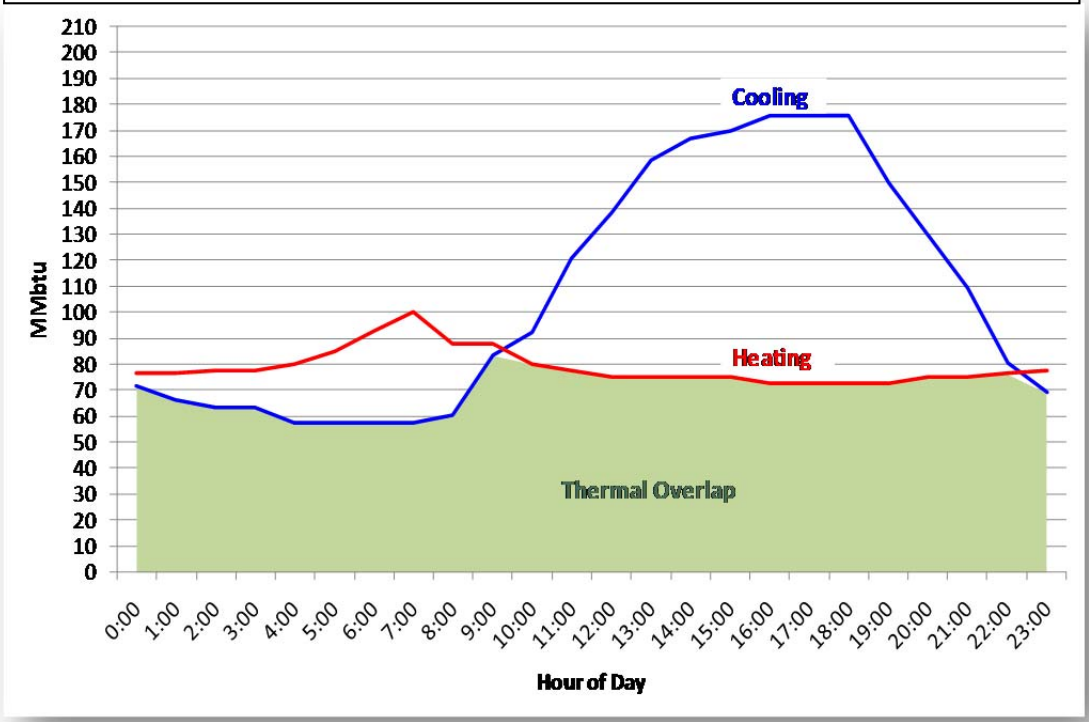
The heart of SESI is heat recovery- capturing waste heat from the district chilling system to produce hot water for the district heating system. This is depicted in the following charts of daily (summer example) and annual heating and cooling loads.



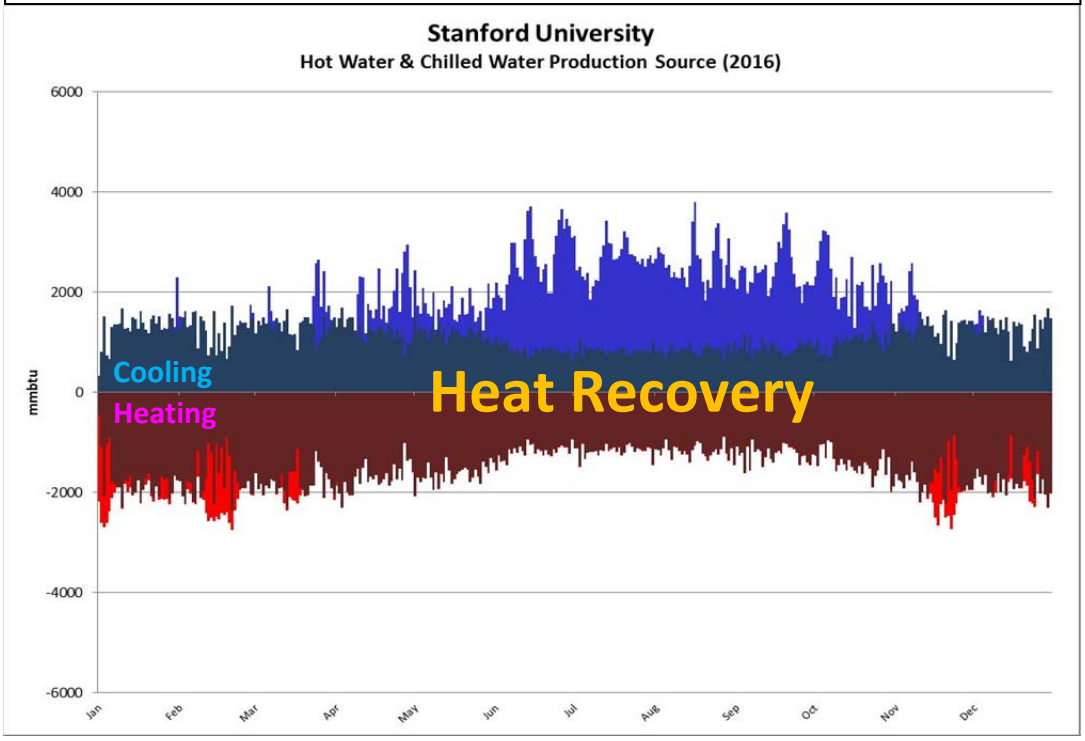




Stanford Daily Summertime Heating & Cooling Profile



Stanford Annual Heating & Cooling Profile

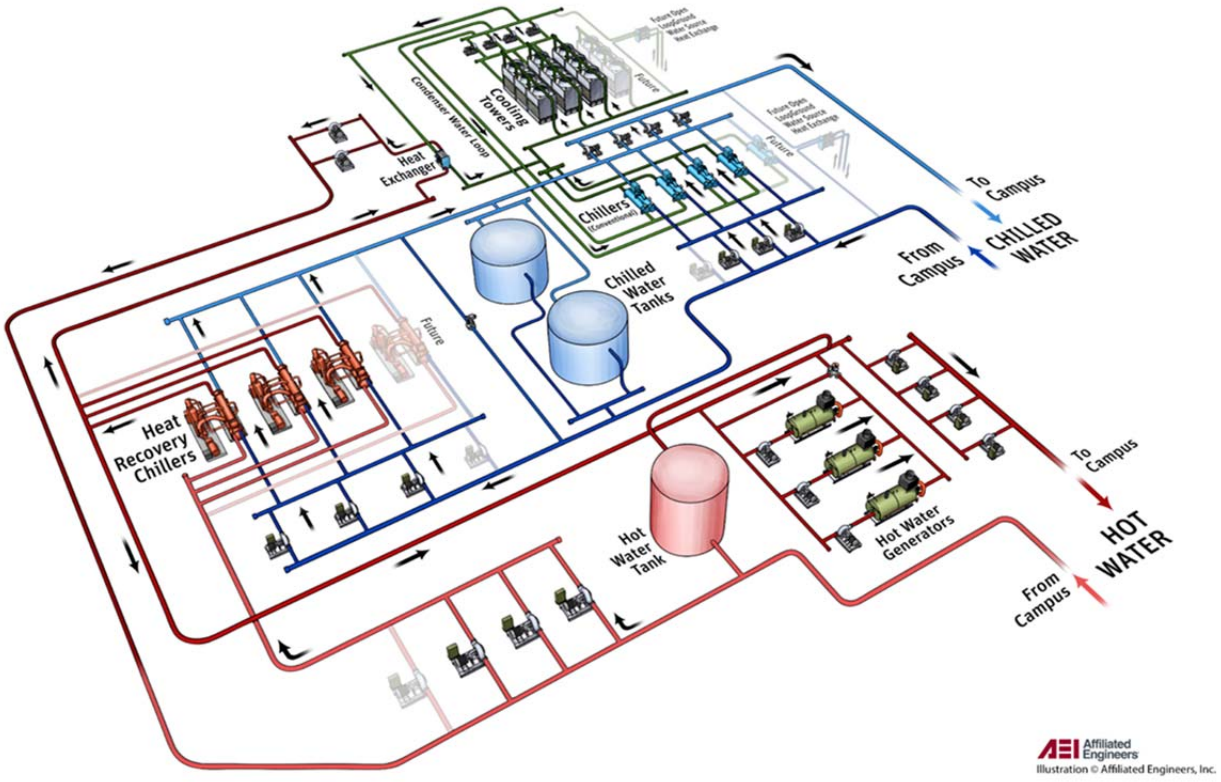


Approximately 56% of the waste heat from the chilled water system (currently being discharged out evaporative cooling towers) will be reused to meet 91% of campus heating loads through the use of industrial heat recovery chillers and conversion of the campus heat distribution system from steam to hot water. Converting from steam to hot water also reduces campus heating loads by 10% due to lower distribution line losses. SESI includes:

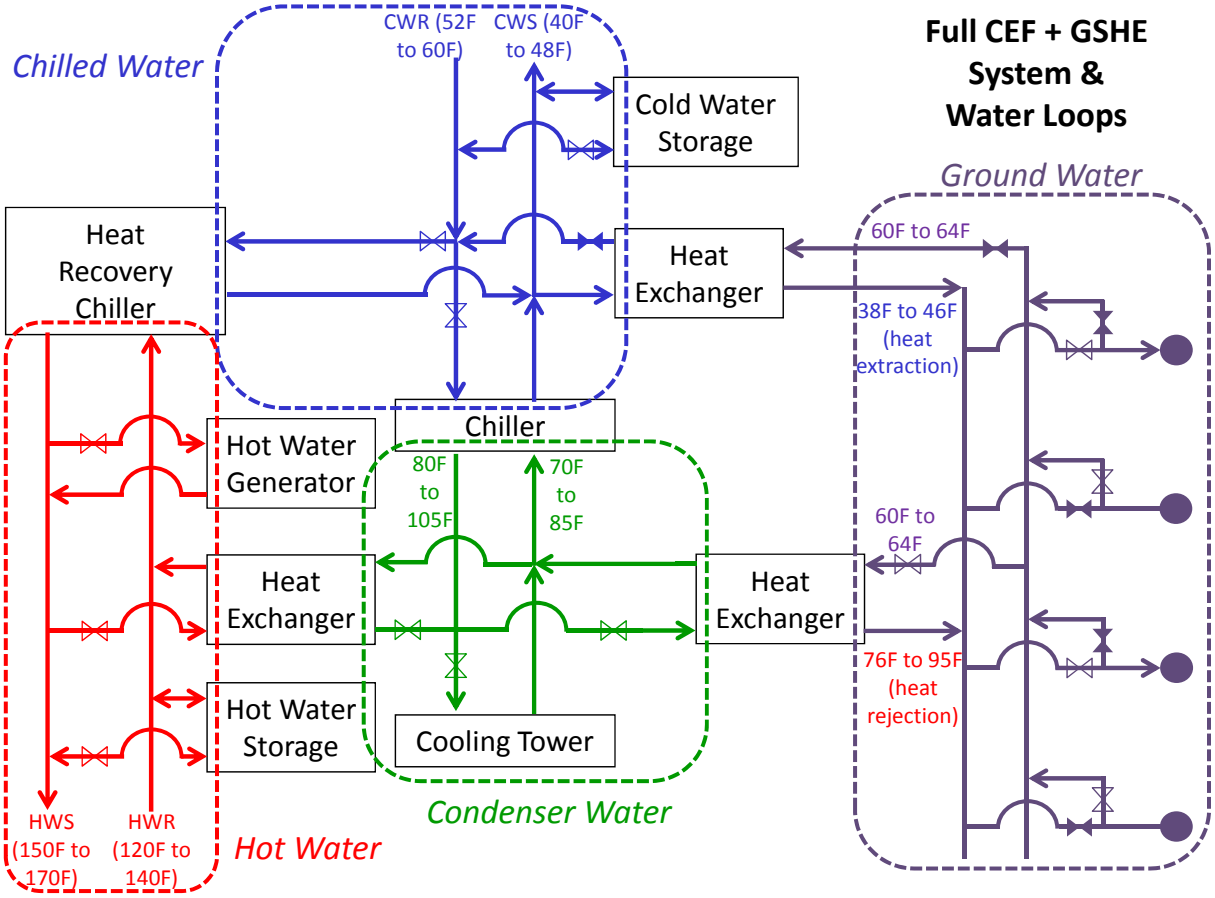
- Installation of a new electricity powered central energy facility featuring heat recovery;
- Demolition of the existing cogeneration plant;
- Installation of 20 miles of hot water distribution piping to replace the steam system;
- Conversion of 155 building connections from steam to hot water;
- Installation of a new campus high voltage substation.

Following are schematics of the SESI system and renderings of the new plant now under construction.

SESI Central Energy Facility 3D Process Schematic

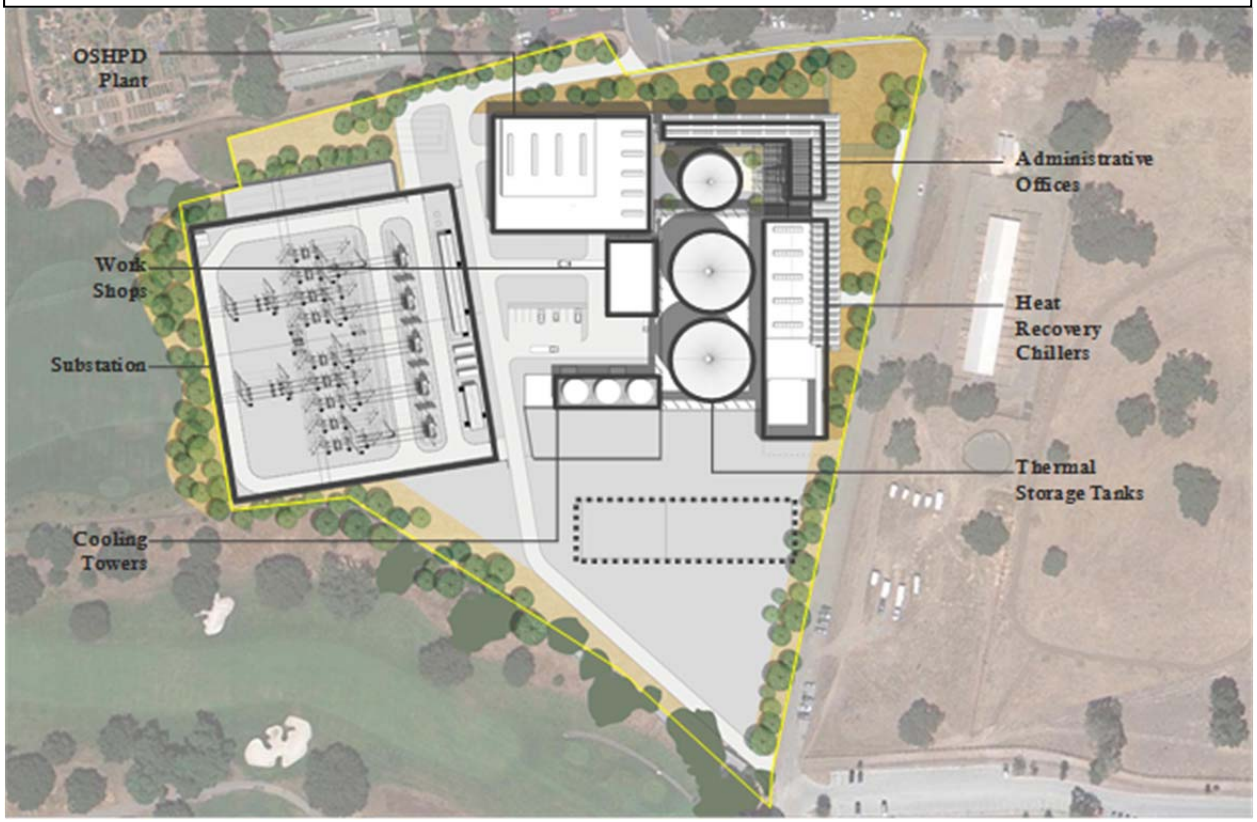


SESI Central Energy Facility Process Schematic



Stanford Replacement Central Energy Facility Renderings

Stanford Replacement Central Energy Facility Site Plan



Project Innovations

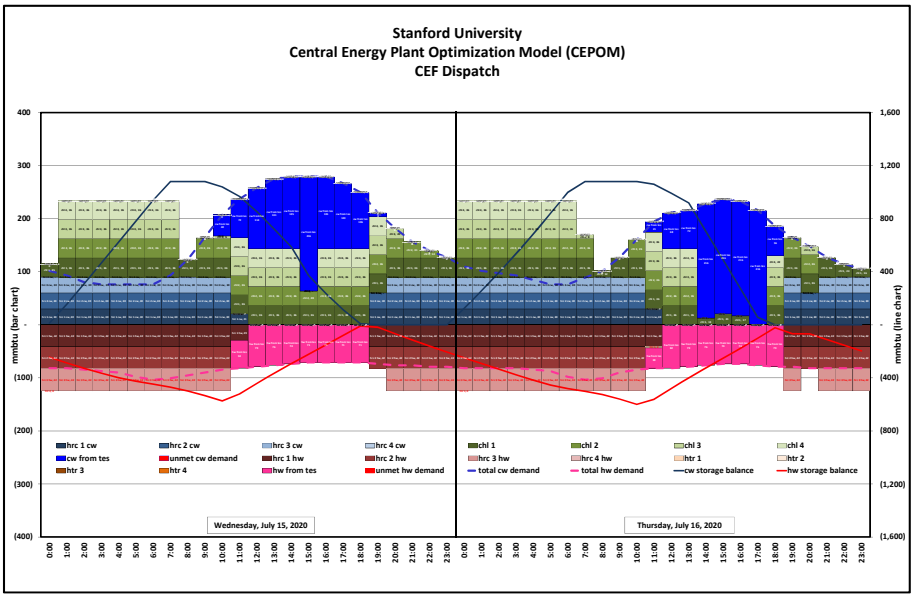
SESI is unique and innovative in design, implementation and impact. SESI advances heat recovery at a district level, achieving direct environmental improvements and cost savings at a dramatic scale, while paving a flexible and lasting path for Stanford's sustainability future.

SESI adeptly develops for the first time a highly efficient large scale district energy system based on electricity powered (full path to sustainability) combined heat and cooling rather than fossil fuel fired (questionable path to sustainability) combined heat and power, achieving gas high heating value (HHV) trigeneration efficiency greater than 100% due to the large amount of waste heat recovery. SESI utilizes both large scale hot water and cold water thermal energy storage.

SESI combines cutting edge technology from both North American and European district energy systems:

- North America
    - Overall system design (AEI- Affiliated Engineers, Inc.)
    - Architects (ZGF)
    - Structural/Geotechnical (Rutherford + Chekene)
    - Construction (Whiting Turner)
    - Heat recovery chillers & chillers (York)
    - Controls (JCI)
    - HW system design & operations consultation (District Energy St. Paul)
    - HW generators (Cleaver Brooks)
    - Peer review (Jacobs Carter Burgess, Black & Veatch, Enginomix, Navigant)
    - GSHE/Steam to Hot Water Conversion Consultation (Ball State Univ.; Univ. of British Columbia)
- Europe
    - HW system design & operations consultation (COWI Denmark, FVB Sweden)
    - HW distribution piping system (LOGSTOR Denmark)
    - HW system modeling (Termis 7T/Schneider Electric Denmark)
    - Building HW-HW heat exchangers (Alfa Laval Sweden)
    - Substation components (Siemens Italy)

Another SESI innovation is a new software program created by Stanford (US Patent 8,903,554) for optimizing the planning, design, and operation of combined heating and cooling plants with both hot and cold thermal energy storage (TES). It provides new tools for predictive load forecasting, economic dispatching, and plant optimization and automation for SESI. This new program is being further developed by outside companies to provide new tools to central energy plants of all types to improve their energy and economic efficiency.

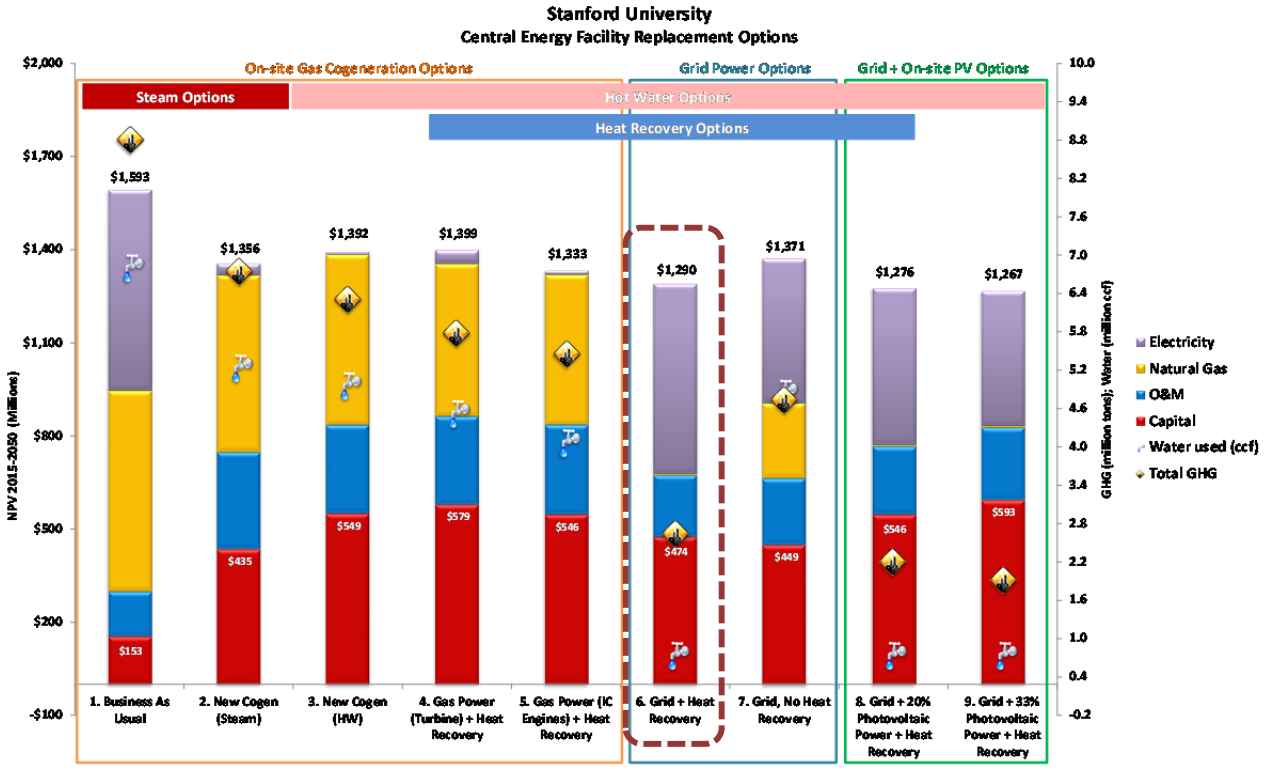


Financial Advantages

Nine major options for Stanford's next energy system were developed in detail, including:

- gas fired cogeneration and steam distribution (business as usual Third Party vs. Stanford owned & operated)
- gas fired cogeneration with hot water distribution
- hybrid cogeneration + heat recovery with hot water distribution (Turbine and IC engine options)
- heat recovery plant with hot water distribution (Grid + Heat Recovery option)
- conventional boilers and chillers central plant (Grid, No Heat Recovery option)
- Grid + Heat recovery plant with 20% to 33% on-site PV power

These options were modeled for energy and exergy efficiency, economics, and environmental impact and subjected to substantial peer review. Results are presented in the chart below which compares the life cycle cost of each option as well as the relative GHG emissions and water use. Based on these results Stanford selected the electrically powered combined heat & cooling plant with hot water distribution (option 6) as its new base energy system and is advancing study on the feasibility of adding some amount of on-site PV power to the scheme.

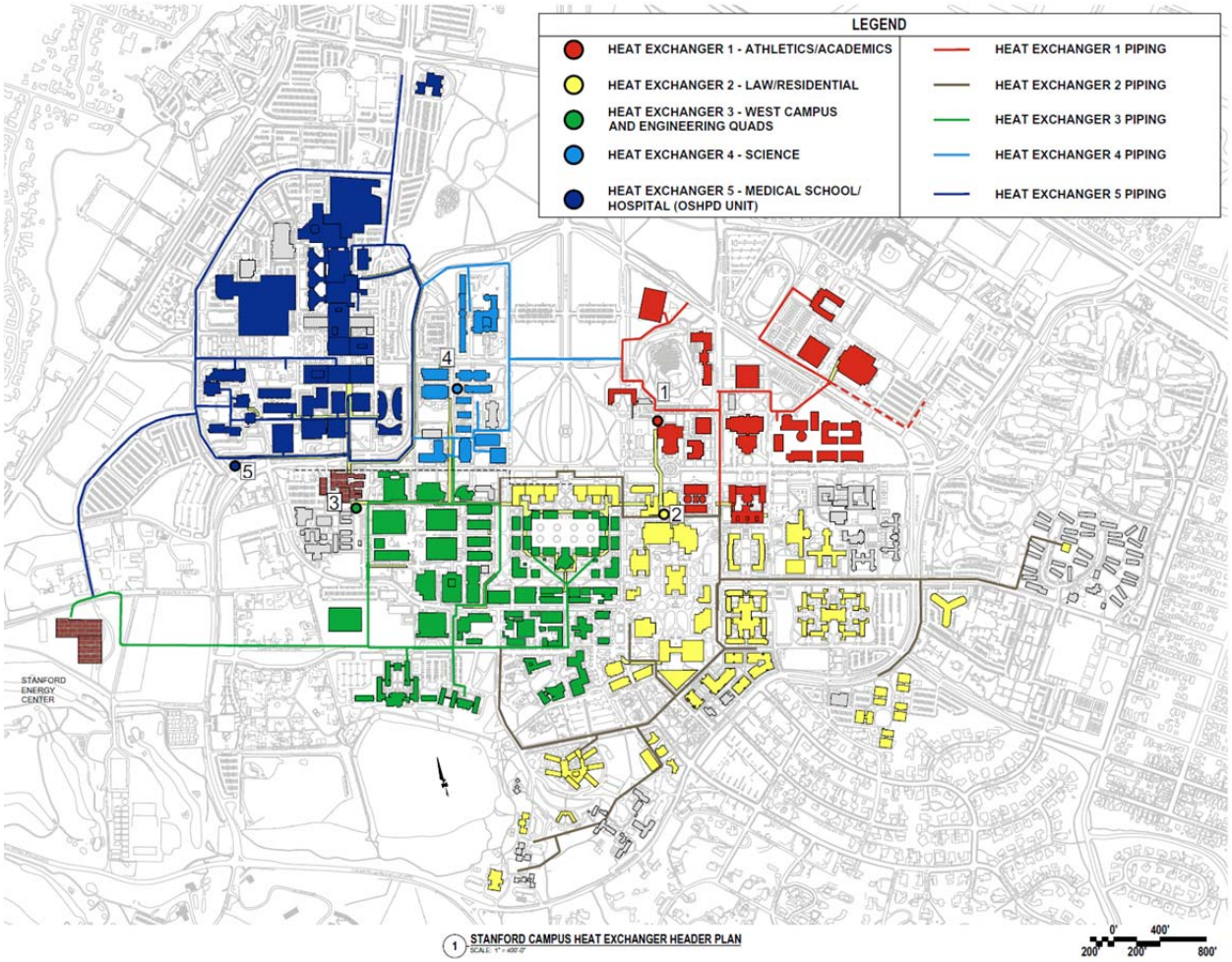


As shown the selected option, heat recovery + hot water distribution represents the lowest life cycle cost and also presents one of the lowest up front capital cost options since on-site power generation infrastructure is avoided.

Project Challenges

SESI is a complete transformation of Stanford's district energy system from gas fired combined heat and power (CHP) to electricity powered combined heat and cooling (CHC). The conversion was performed in multiple phases as shown below and required major coordination with a very large and diverse campus research and residential community. Several building conversions from steam to hot water required special work due to their historical nature and use of steam radiators throughout for space heating.

SESI Building Conversion and Steam-To-Hot Water Conversion Phases

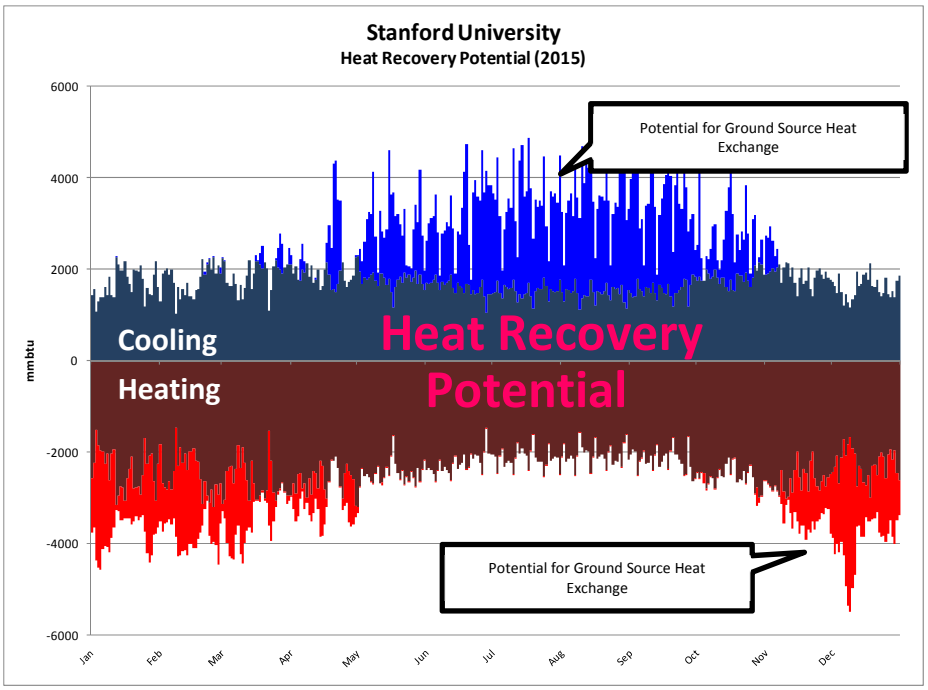


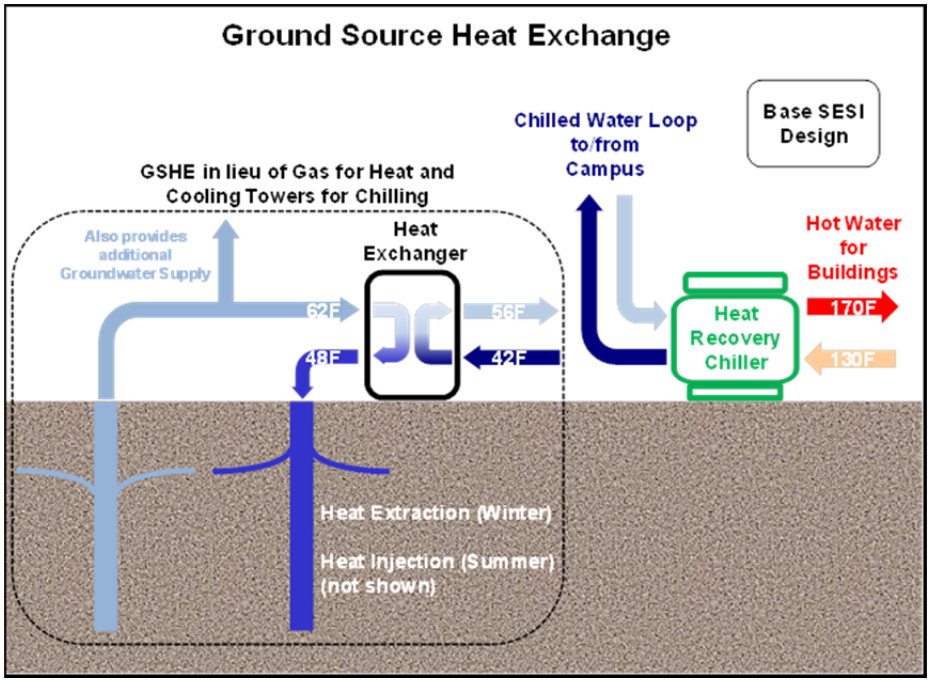
Looking Ahead

Several potential enhancements to SESI are being investigated by Stanford at this time.

Ground Source Heat Exchange

Ground Source Heat Exchange (GSHE) could augment the basic heat recovery scheme of SESI by providing a more sustainable way to meet the remaining winter heating and summer cooling needs of the university that can't be met by building heat recovery. Recently completed studies including exploratory borings to fully map subsurface hydrogeology, regulatory reviews, and conceptual system designs indicate that GSHE may be a feasible addition to SESI and this will be explored further after the system is commissioned.





On-site Photovoltaic Power

Stanford has completed the conceptual design of a 5.8MW of on-campus photovoltaic (PV) power generation system with solar panels on over a dozen major buildings and the largest parking garage on campus. A system this size is capable of supplying about 3% of the university's total electricity and would meet about 20% of campus load at times of peak daily demand. Stanford is also exploring much larger scale off-campus renewable electricity generation as part of its grid electricity sourcing effort as described later in this report. Both the on- and off-campus renewable power generation opportunities will be considered as Stanford finalizes the composition of its power portfolio to begin April 1, 2015 when the cogeneration plant is decommissioned.

Plug-In Electric Vehicle System

Stanford has begun electrification of the Marguerite bus fleet and campus small vehicle fleets and the number of commuters using PEVs is also growing steadily. To support the adaption of electric vehicles Stanford is in the process of designing a campus wide plug in electric vehicle charging system for use by both commuters and university vehicles. The system will support both Level II and DC fast charging, will be distributed throughout the campus for convenience, will be expandable based on demand, and will be managed as part of the overall campus energy demand management system. The total estimated electricity use from a fully electrified campus fleet plus 5% to 10% of commuter vehicles is about equal to the electricity that will be generated from the new photovoltaic power generating system to be installed on the campus. Installation of the PEV charging system is expected to begin in the spring of 2015.

Electricity Supply

Upon retirement of the existing Cardinal Cogeneration plant in 2015 Stanford will rely primarily on electricity supplied by the California grid. Having achieved Direct Access to the state's electricity markets the university is now in a position to control its power portfolio and shape its future energy supply to meet the risk, economic, and environmental profile established by university leadership. Work to develop Stanford's long term electricity supply strategy and initiate the grid power procurement process to start next year is now underway.

Conclusion

In addition to teaching, research, and public service in the field of sustainability Stanford University is committed to practicing sustainability in its own operations and is making significant transformations of the campus toward that goal. The Stanford Energy System Innovations program is but one example and will provide the university an efficient, economic, and sustainable energy system for the 21st century.

More information on SESI may be found at: http://sustainable.stanford.edu/sesi