Global District Energy Climate Award 2013

Submittal by Stanford University

Project/Program Title

Stanford Energy System Innovations (SESI)

Name and Location of District Energy System

Stanford University District Energy System, Stanford, California 94305

Name of System Owner

Stanford University

Name, relationship to the project/program, address, phone number & email of the person submitting the application

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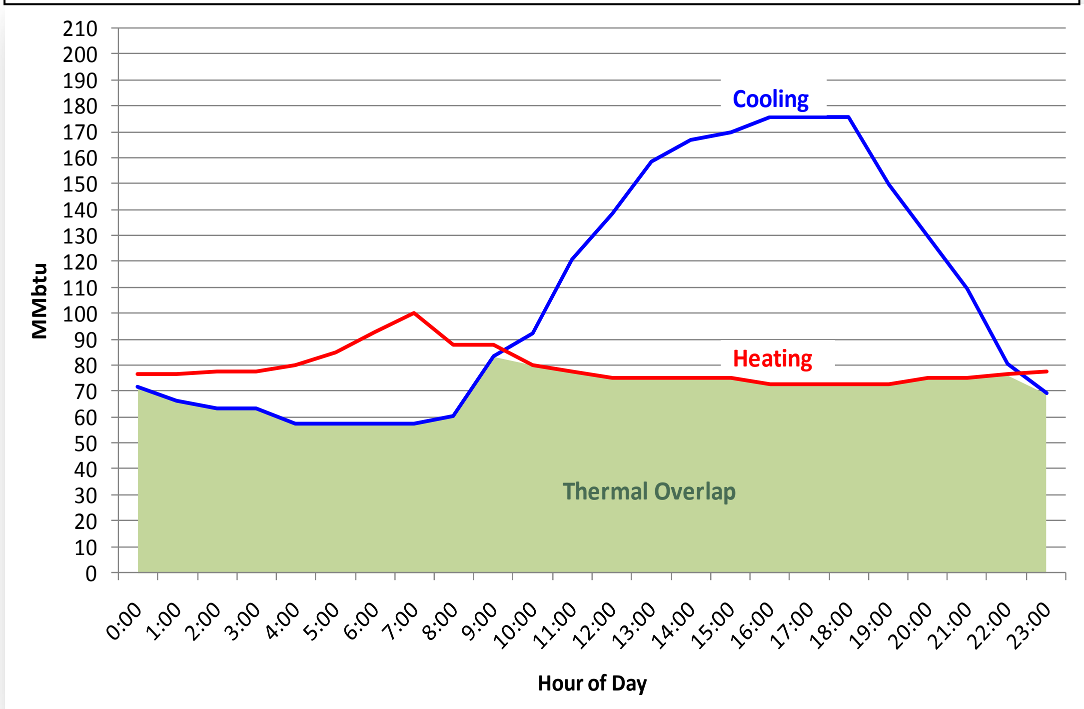
Executive Summary

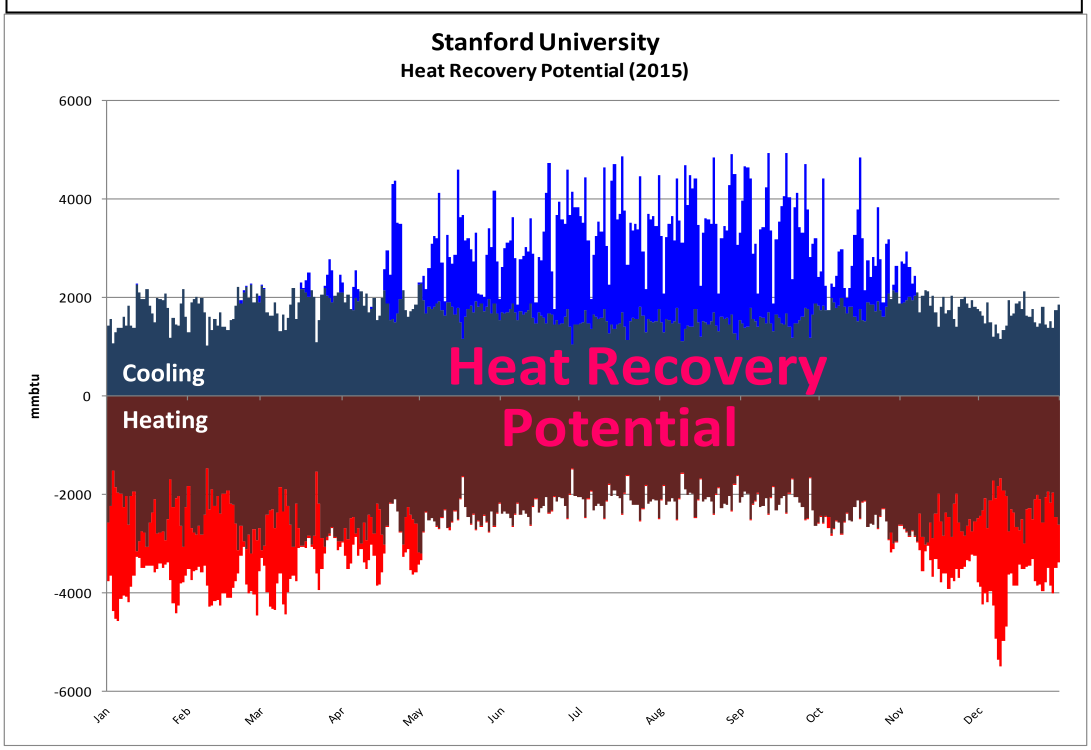
The Stanford Energy System Innovations (SESI) project is a $438 million major transformation of the campus district energy system. The transformation is from gas fired combined heat and power with steam distribution to electrically powered combined heat and cooling with hot water distribution. When completed in April 2015, the new heat recovery system will be 52% more efficient than the existing cogeneration system; immediately cut Stanford's Category I and II GHG emissions in half; save 20% of Stanford's drinking water supply; and save $303 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 70% of the waste heat from the chilled water system (currently being discharged out evaporative cooling towers) will be reused to meet 80% 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

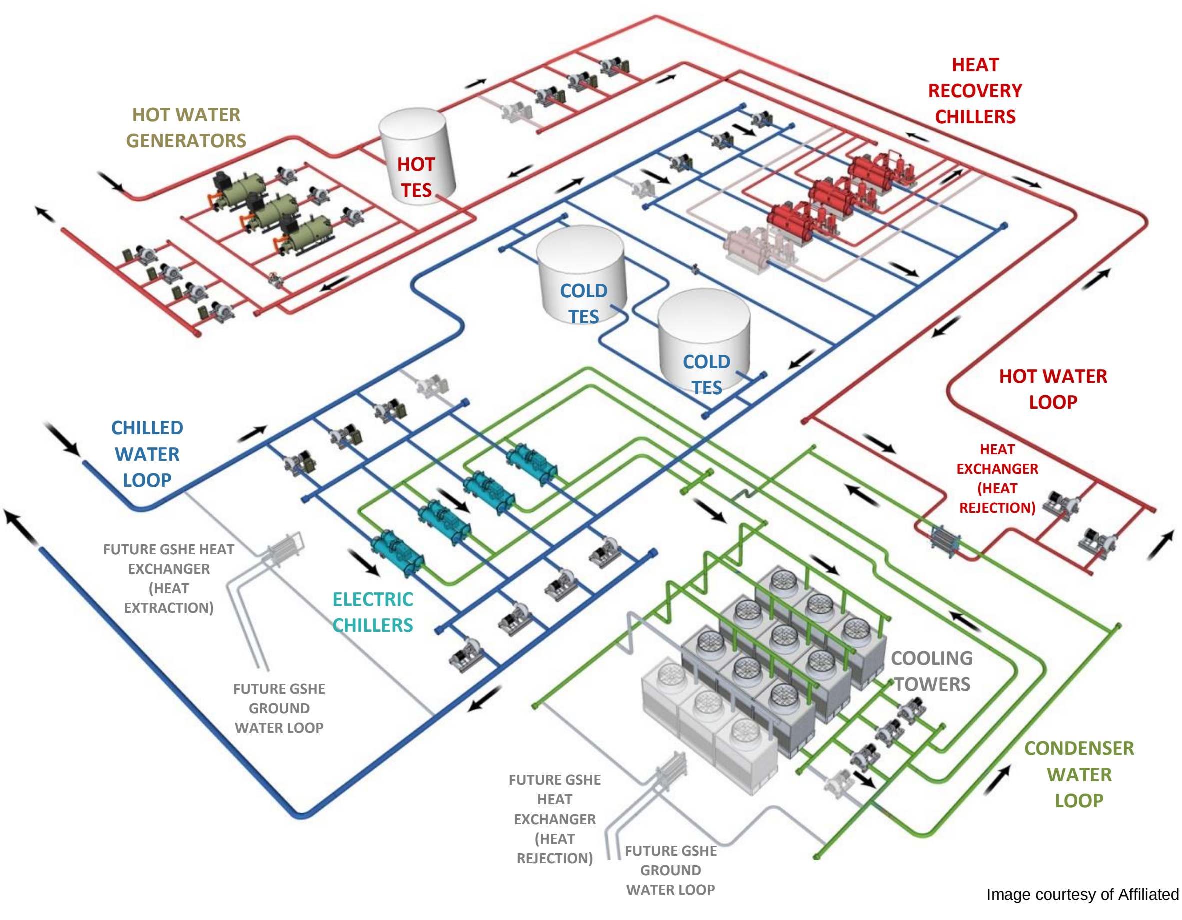
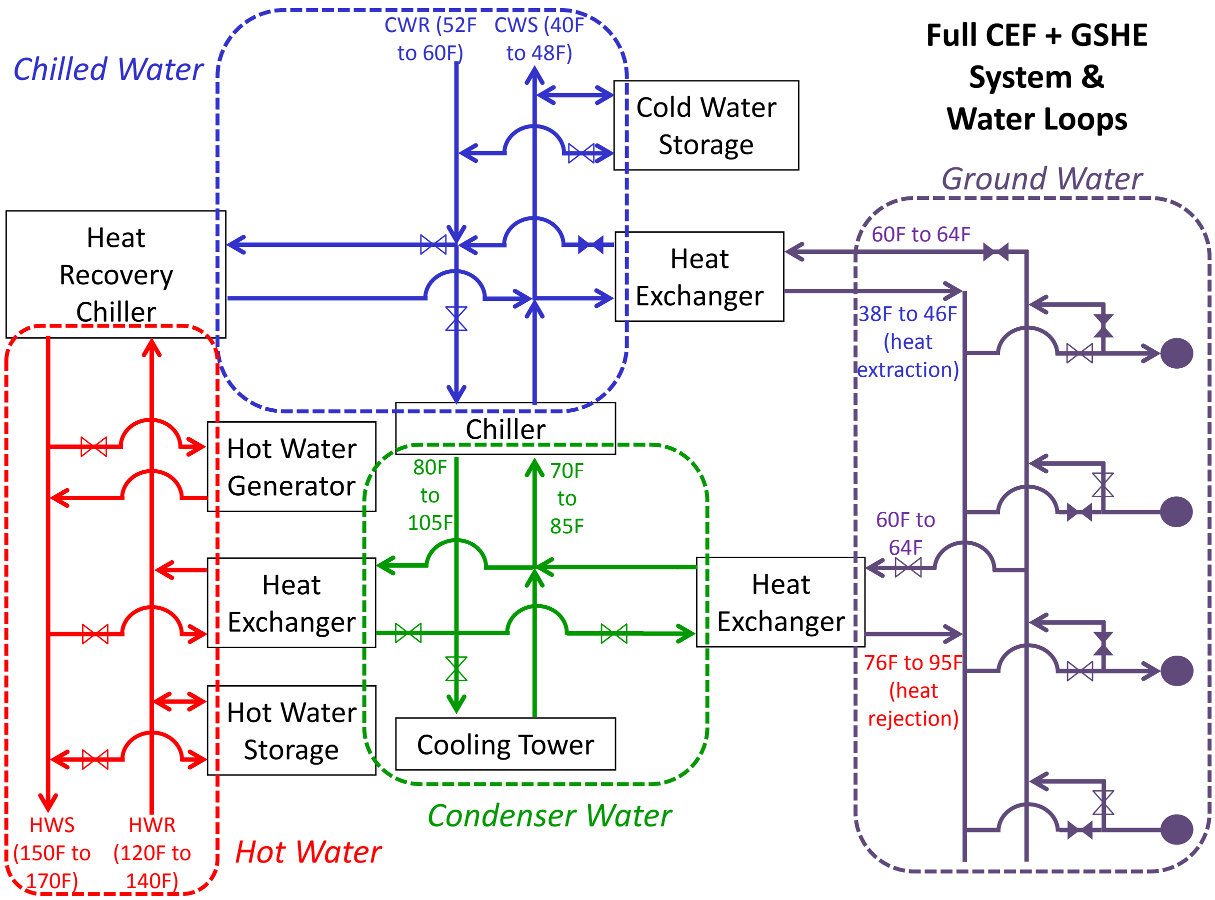
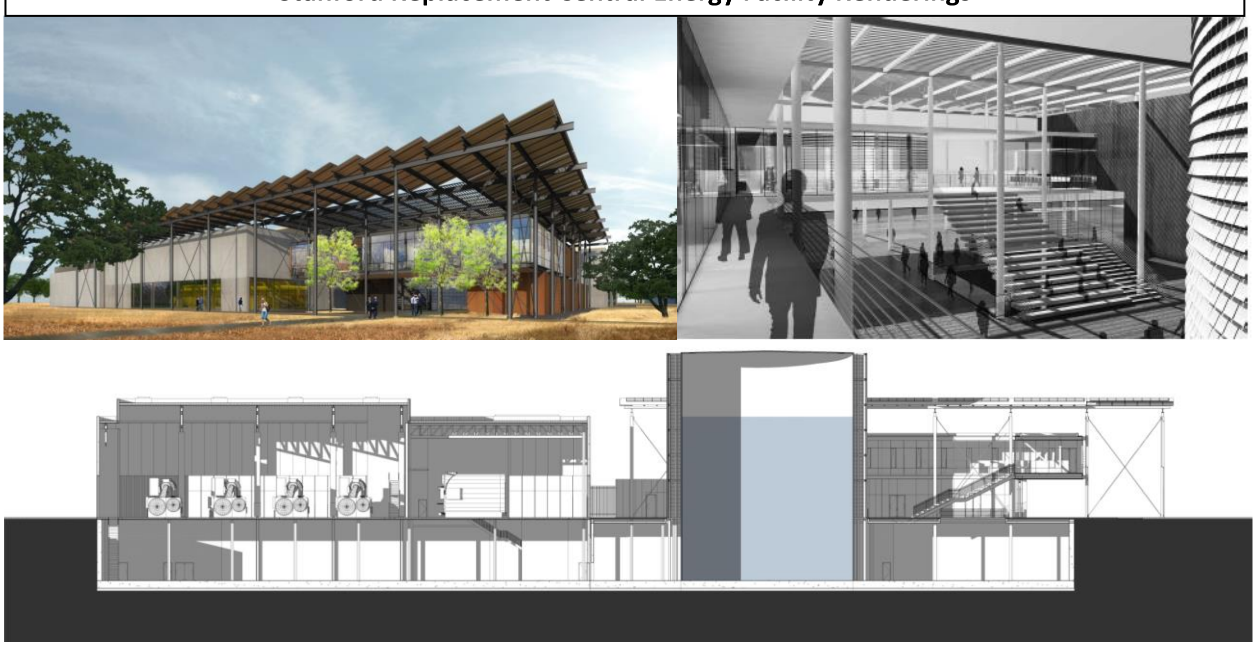


Image courtesy of Affiliated Engineers, Inc.

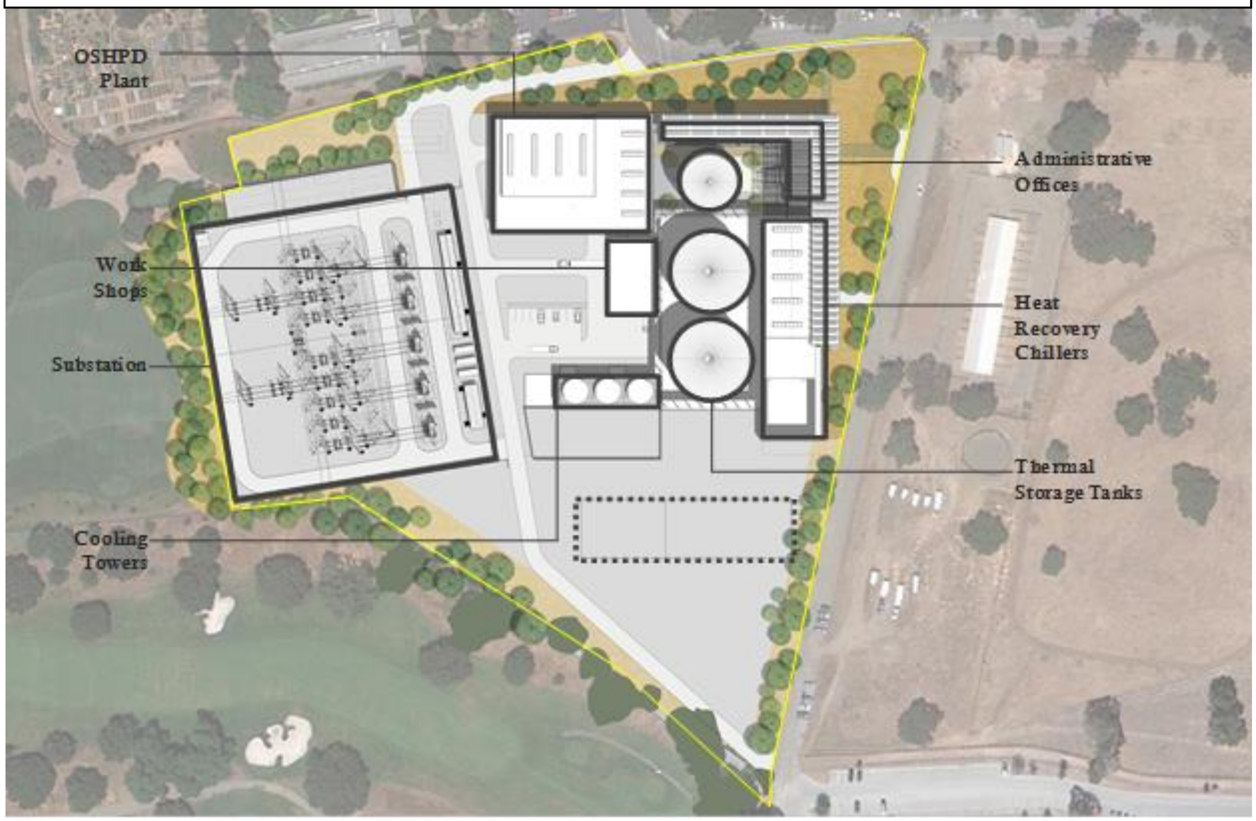
SESI Central Energy Facility Process Schematic



Stanford Replacement Central Energy Facility Renderings



Stanford Replacement Central Energy Facility Site Plan



Project innovations

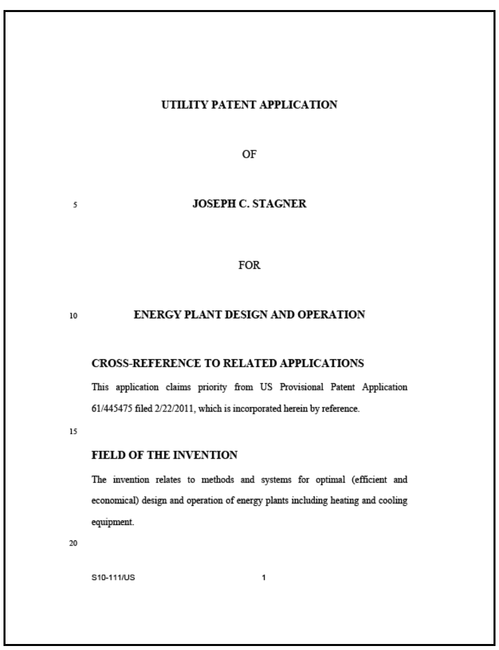
SESI is unique and innovative in design, implementation and impact. SESI advances heat recovery in district energy to scales heretofore unseen. It is achieving direct and immediate environmental improvements and cost savings at a dramatic scale, while opening a flexible and lasting path for Stanford to achieve sustainability.

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 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 new software and services for optimizing the planning, design, and operation of combined heating and cooling plants with both hot and cold TES. It provides predictive load forecasting, economic dispatching, and full plant optimization and automation tools which did not exist but were invented at Stanford for SESI. These new services and software have been commercialized by Chicago-based ROOT3 Technologies Inc. to provide new tools to central energy plants of all types to improve their energy and economic efficiency.



UTILITY PATENT APPLICATION

OF

JOSEPH C. STAGNER

FOR

ENERGY PLANT DESIGN AND OPERATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from US Provisional Patent Application 61/445475 filed 2/22/2011, which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to methods and systems for optimal (efficient and economical) design and operation of energy plants including heating and cooling equipment.

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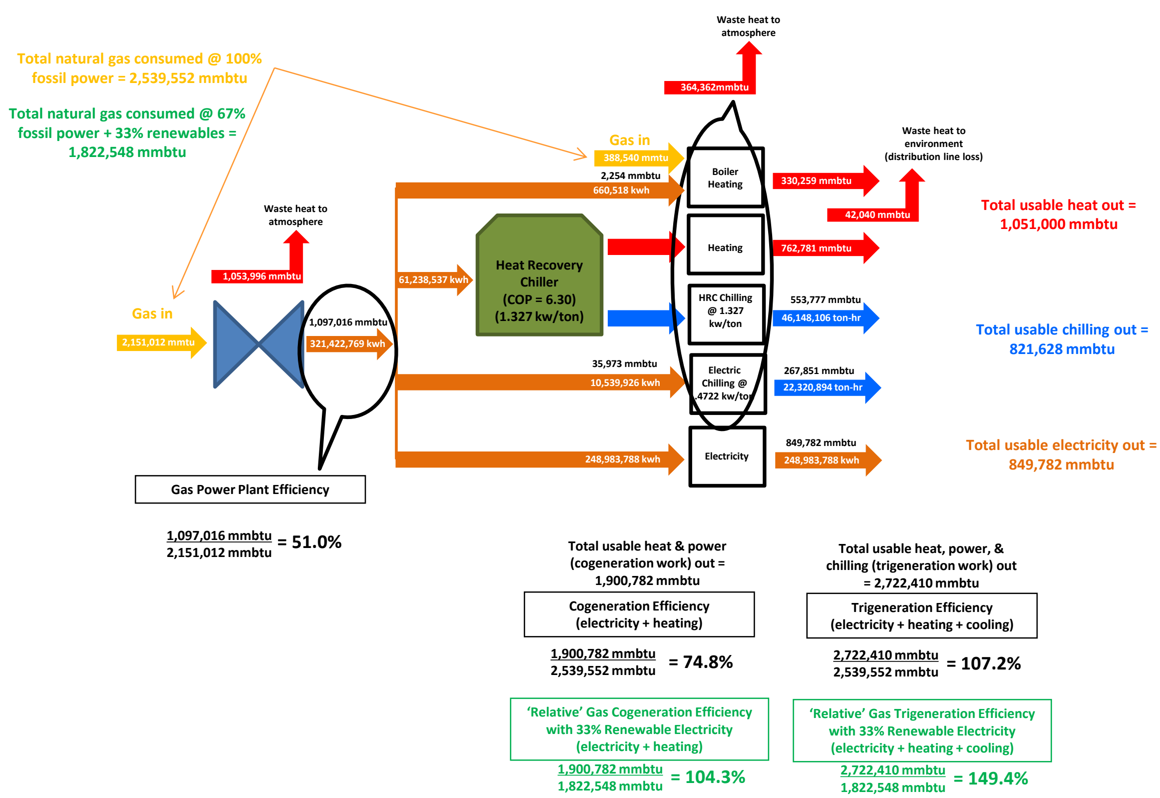
Improved energy efficiency

SESI's primary energy efficiency benefits come from substantial utilization of waste heat, followed by reducing heating distribution system line losses through the conversion from steam to hot water.

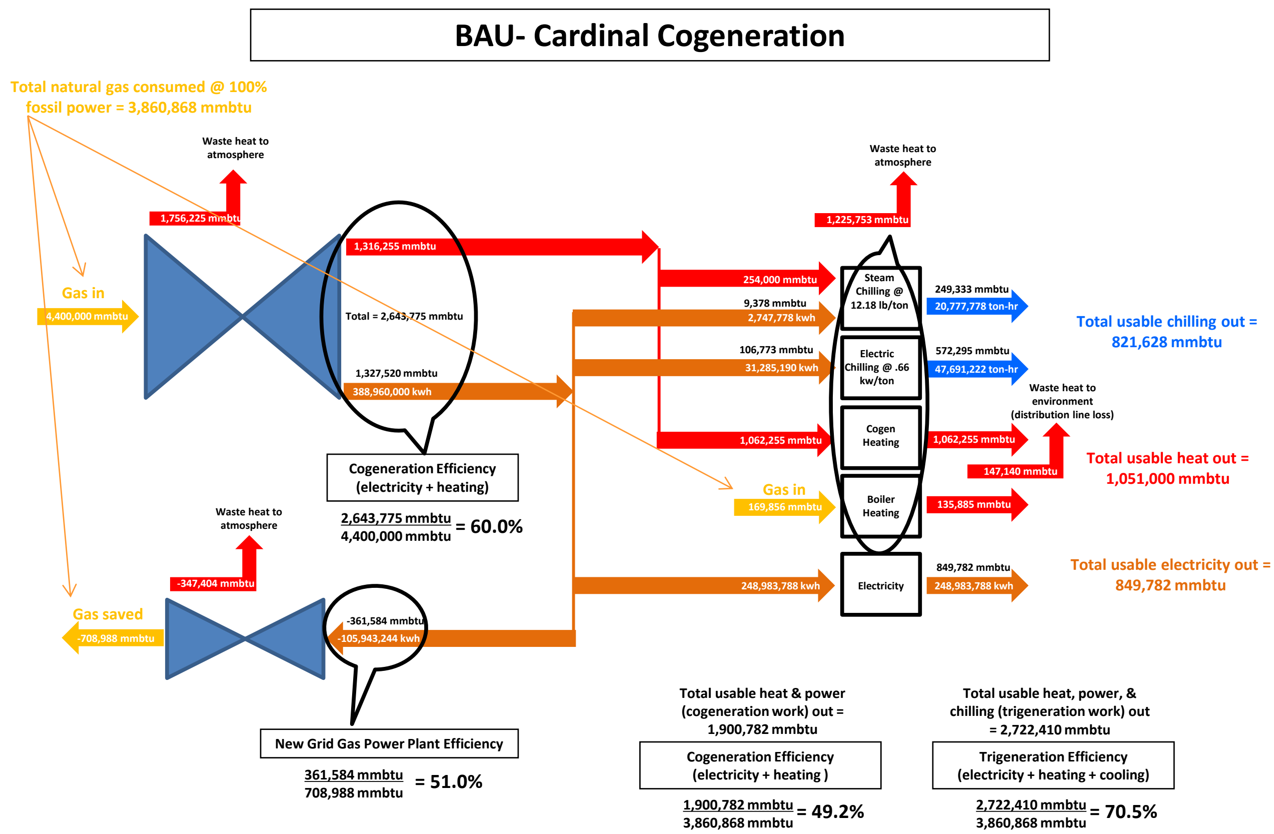
By utilizing waste heat and lowering line losses, SESI is expected to achieve an overall system trigeneration (power, heating, and cooling) efficiency of 107% on a natural gas high heating value (HHV) basis, if paired with average 51% efficient (6700 btu/kwh heat rate) grid gas power generation over its 30 year life cycle. While the current average California effective electricity market heat rate is over 7000 this is expected to continue to improve as older plants are retired. Over the next 30 years an average heat rate of 6700, equivalent to that of the nominal new grid gas plant installed today, appears a reasonable forecast.

However given California's 33% Renewable Portfolio Standard (RPS) requirement the overall effective natural gas trigeneration efficiency of this system, directly comparable to gas fired cogeneration district energy systems, is an astounding 149%. An energy schematic showing these calculations is provided below.

SESI Heat Recovery with Hot Water System Energy Schematic



A similar energy schematic for the existing Cardinal Cogeneration plant serving Stanford shows that it consumes 52% more gas than the SESI plant will, assuming SESI electricity is derived from 100% fossil fuel. However accounting for the 33% California RPS, the existing Cardinal Cogeneration plant consumes over twice the gas (3.8 mil mmbtu vs 1.8 mil mmbtu per year) required to meet campus energy needs under SESI.

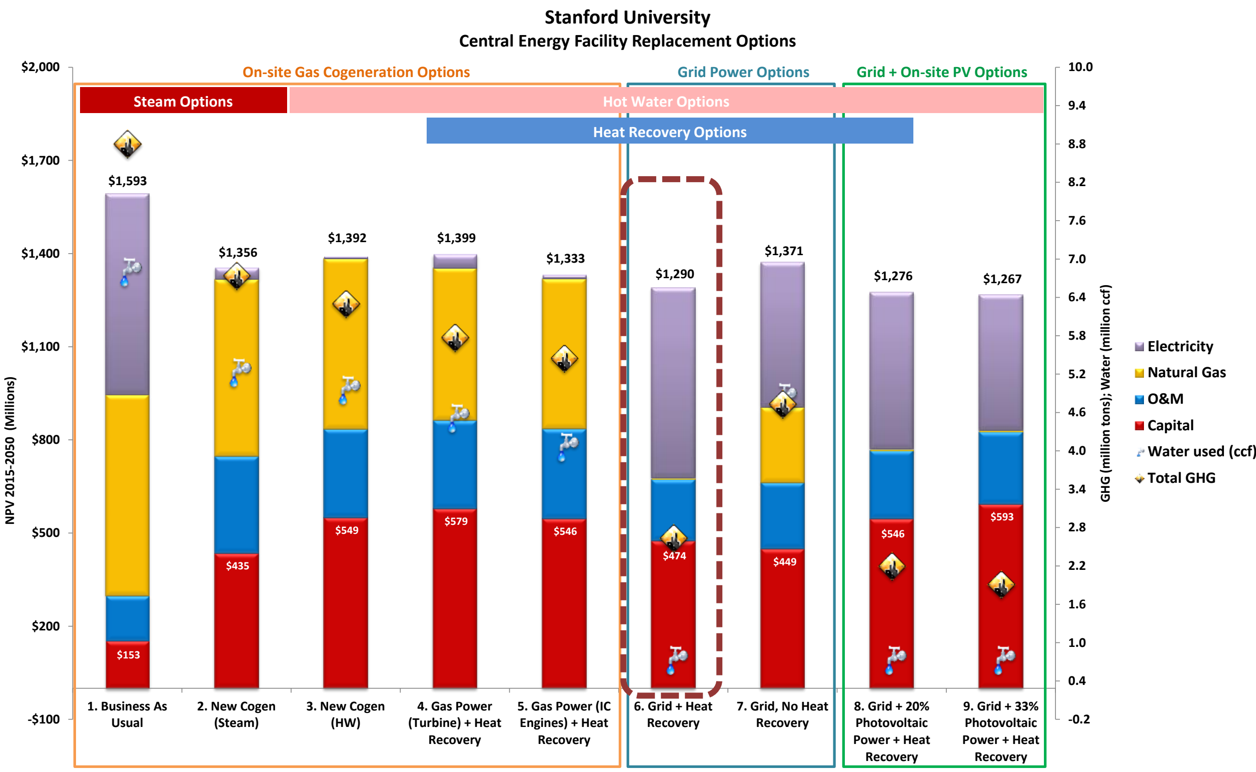


Financial advantages of the project

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. Despite requiring significant up front capital investment and significant disruption to the campus during the four year installation phase (2012 -2015), SESI received widespread support from faculty, administration, and the Board of Trustees and is now under construction

Project challenges, plans for the future, community reaction

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). Because of the popularity of gas fired cogeneration as a presumed best practice in district energy and

Stanford's previous reliance on it SESI was initially met with considerable skepticism from faculty, administration, and even current campus utilities staff. Much explanation, education and peer review throughout 2010 and 2011 provided necessary and sufficient proof to all stakeholders to demonstrate why SESI and CHC is superior to continued CHP for Stanford.

Likewise the scale of physical disruption to the university was a major concern and required many meetings to explain the project and coordinate work with a very large and diverse campus research and residential community. Given the simultaneous construction of a new adult hospital and major expansion of the children's hospital further considerable coordination and regulatory approvals were needed to assure protection of patient care and other hospital functions during the transformation.

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