2013 APPA Award Application - Effective & Innovative Practices
Submitter: Stanford University, Department of Land, Buildings & Real Estate (LBRE)
Program: Stanford Energy System Innovations (SESI)

Overview Statement/Abstract:

The Stanford Energy System Innovations (SESI) project is a $438 million major transformation of the campus district energy system from gas-fired combined heat and power with steam distribution to electrically-powered combined heat and cooling with hot water distribution. When completed, the new heat recovery system will be 52% more efficient than the existing cogeneration system; immediately cut Stanford's greenhouse gas emissions in half; save 18% 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. During planning, a major real-time overlap of heat production and chilling within the district energy system was uncovered. The study revealed that 70% of the waste heat from the chilled water system could be reused to meet 80% of campus heating loads. Now under implementation, the project includes:

- A new electrically-powered central energy facility built around heat recovery;
- 20 miles of new hot water distribution piping;
- Conversion of 155 building connections from steam to hot water;
- Concurrent building hot water hydronic system improvements ; and
- Installation of a new campus high voltage substation.

Criteria 1: Institutional benefits

The SESI program provides both social and environmental benefits to the campus.

- **District level heat recovery:** A heat recovery scheme is the most innovative component of SESI. By recovering and repurposing waste heat discharged from the cooling system in order to meet campus heating loads, Stanford will be able to recover up to 70% of the heat now discharged to meet 80% of simultaneous campus heating demands, significantly reducing fossil fuel and water use in the process. Based on this finding, Stanford will replace the current natural-gas powered cogeneration plant with an electricity-powered heat recovery plant. This change will also require conversion of the campus steam distribution system to a hot water system.
- **Input and output saving – carbon and water**: Once SESI's replacement Central Energy Facility comes online, the campus will have cut its current carbon emissions in half, reducing them to 50%. This reduction in carbon emissions will be accompanied by a flexible and electricity-dependent energy supply system; offering higher reliability, lower cost and greater flexibility for greener power procurement. Having recently achieved Direct Access to the California electricity market, Stanford is now exploring opportunities for a more economic and environmentally-sound power portfolio. A great feature of the heat recovery design is the significant reduction in water use. Since the majority of the waste heat from the chilled water loop is reused instead of being discharged out the evaporative cooling towers, potable water use is reduced by 18%. In addition to carbon and water savings, SESI will also contribute significant dollar savings over time, allowing Stanford the flexibility to further invest in sustainability projects.
- **People First:** Keeping the campus community **safe and informed** is of the utmost importance at all times. By replacing the existing steam system, the SESI project provides a higher level of safety for utilities operations team members. Steam systems have more injury and safety concerns than hot water-based systems. The replacement of the legacy steam system reduces the risk of facility damage and public and staff injury from system leaks or failures. Outside the system facility itself, Stanford has made it a priority to inform campus community members about the ongoing progress of the project, as well as its benefits to the University and the environment. SESI has been a steady source of **education** for Stanford students and community members. Not only were students involved during the planning of SESI; student and campus community outreach has been pervasive during implementation stage. The Department of Project Management and the Office of Sustainability launched a comprehensive outreach effort and met with over 30 campus departments and entities to explain the importance of energy action and Stanford's leadership role with SESI, as well as to coordinate the scheduling of the widespread construction. The campus community has been extremely supportive, despite the short-term inconvenience with the utility scale road construction. The SESI website launched in the summer of 2012 to provide an avenue for interested community members to learn about the program and follow associated construction on a real-time interactive campus map.
- **Improvements to built environments:** While 20 miles of new water pipe will have been installed by 2015 (20% of it already completed), changes are already being made in the mechanical rooms of 155buildings in order to get them ready for hot water. In the process, those building are receiving efficiency improvements. The overall energy efficiency improvements in the built environment are already accounted for in the carbon and water reduction calculations.

Criteria 2: Characteristics or qualities that make this program innovative

Primary Innovation

Core to SESI's design is the concept of heat recovery - capturing waste heat from the district chilling system to produce hot water for the district heating system. In 2009, during an investigation of sustainable energy supply options to succeed the current gas-fired cogeneration system, a major overlap of heat production and waste heat collection (from chilling process) was uncovered. The study revealed that 70% of the waste heat from the chilled water system could be reused to meet 80% of campus heating loads. Heat recovery data and concept were further studied, peer-reviewed and supported by faculty experts and industry consultants before Stanford's Department of Land, Buildings & Real Estate (LBRE, the SESI project lead) then began design plans for a utility replacement project: SESI. LBRE drew upon expertise from both North America and Europe for the planning, design and construction of the heat recovery plant –representing a global collaboration effort to develop a district energy system for the 21st century. The new heat recovery plant will be an all-electric, state-of-the-art plant featuring both hot- and cold-water thermal storage. Many entities that have a district level heating and cooling system may find opportunities for duplicating SESI's model.

New Tools for Industry

SESI also offers a first-of-its-kind planning, design and operation tool that could have worldwide applicability. Stanford found that the analytical tool needed to plan, design and operate the heat recovery technology being employed simply did not exist anywhere in the world. As a result, LBRE developed its own in-house tool: a computer program for planning, designing and operating the combined heating and cooling plant with both hot and cold thermal storage. This tool includes a continual forward-looking load forecast and plant-dispatching function that optimizes plant efficiency and minimizes cost. This new software is now being commercialized through a startup company (ROOT3 Inc.) to provide previously unavailable tools to district energy plants of all types that will improve their energy and economic efficiency.

Bold Investment

SESI implementation will not only result in significant energy savings and operational efficiencies; it will also generate significant cost savings over the next few decades. Nine different energy and cost models were studied to arrive at the best option. Based on the best option selected, the estimated cost for implementing SESI is $438 million – which includes conversion of the campus energy distribution system from steam to hot water, construction of the new heat recovery plant, other system improvements and deferred maintenance. While this is a significant amount, it is actually $108 million less than the cost of installing a new gas-fired hot water-based cogeneration system (at $546 million) which would have continued to add carbon to the emissions inventory. This upfront investment – a cost borne fully by Stanford – is made possible through an increase in the internal utility rates charged to Stanford schools and departments over the life of the project, offering a significant financial gain of $300 million cost savings over the next decades.

Open Architecture

SESI is built on the principle of innovation and flexibility to adapt to new technologies. By design, SESI is also the platform for future installment of renewable energy onsite to further reduce emissions from campus operations. As core elements of the SESI program are being implemented, feasibility studies of additional potential major enhancements to the campus energy system are also being completed. Project additions with conceptual approval that are now under final feasibility study include the installation of 4 to 7 MW of on-site behind-the-meter photovoltaic (PV) power generation; installation of a Ground Source Heat Exchange system to augment the base heat recovery scheme; and the installation of a new 60kV high voltage transmission line connecting SLAC, Stanford, and the City of Palo Alto to strengthen the local transmission grid. Stanford will also work to uncover and develop sustainable electricity supplies to augment the electrification and optimization of its campus energy demand and supply systems in its pursuit of true energy sustainability.

Criteria 3: How this practice can be used by others

A Model to Follow

SESI is a model for other universities and businesses across the country because it is built on principles and practices that are both of the highest **quality standards** and highest **transferability.** With the primary technical innovation of SESI being district level application of heat recovery in a campus/municipal facility, many entities that have a district level heating and cooling system may find opportunities for duplicating SESI's success. This technology is highly transferable. Facilities in a moderate climate have the same heat recovery potential if the overall campus/facility heating and cooling overlaps are diagnosed. Chances are very high that other campuses will repurpose heat discharged from the cooling system in order to meet campus heating loads. Due to the fact that SESI incorporates both hot water and chilled water systems with thermal storage on each – and as North America has many chilled water systems and a wealth of knowledge and experience in the design and maintenance of such systems – SESI-type implementation is possible throughout the country. In fact, SESI employed numerous industry consultants (Affiliated Engineers, Enginomix, Black & Veatch, COWI, Johnson Controls, York amongst others) to provide model and data verification.

Through this verification process and based on lessons learned from SESI research and the demonstrated benefits, several industry best practices with great potential for duplication were identified. These findings have already been shared with great interest (to audiences at district energy conferences, regulatory agency gatherings, and environmental seminars) in an effort to spread the word about this innovative sustainability tool, which provides both energy efficiency and cost reduction over other conventional technologies.

The estimated cost for implementing SESI is $438 million – which includes conversion of the campus energy distribution system from steam to hot water, construction of the new heat-recovery plant, and other system improvements. While this is a significant amount, it is actually $108 million less than the cost of installing a new gas-fired hot water-based cogeneration system (at $546 million) which would have been more costly to maintain in the long run and would have continued to add carbon to the emissions inventory. In addition to a lower upfront investment, SESI will also **pay Stanford back $300 million** over the next 35 years. This financial return, complemented by significant environmental sustainability benefits, is an important advantage to this new energy supply system.

Criteria 4: Demonstration of management involvement/employee commitment

Sustainability is a core value at Stanford, and executive leadership is committed to environmental stewardship, for the benefit of the University and the planet. The development of the SESI program has been an all-hands priority, setting a precedent for campus involvement with major capital investment projects at Stanford.

Importance of Stakeholder Inclusion

SESI set out to demonstrate leadership by example from the onset. The **vision** was to provide leadership in climate change solutions using Stanford's intellectual and financial resources, even if these efforts may differ from popular perceptions of how to pursue greenhouse gas reductions or are greater than what governmental regulations require. Central to this vision was the need to include, educate and involve all campus and community stakeholders throughout planning and implementation. The planning principles were infused with these leadership goals:

- To recognize that emissions reduction may come from a number of areas in campus facilities design, construction, operations and maintenance and will **affect a diverse group** of students, staff, and faculty across all academic and administrative departments, as well as the surrounding community.
- To recognize that Stanford must operate within the broader context of energy infrastructure, emissions reduction and regulation.
- To recognize that both short and long-term improvements are needed and that the long-term impact must be considered before decisions are made regarding existing buildings and infrastructure. In planning for the long-term, we must account for **sustainable and responsible growth.**

Active support from Campus Community: SESI has set a precedent for campus involvement with major capital improvement projects at Stanford. In setting the vision and principles for this multi-year initiative, the SESI program integrated input and leadership from **all stakeholders on campus** (staff, students, faculty), while maintaining steady communication with Stanford leadership (executive cabinet and the Board of Trustees) from 2009-2012. Faculty and leadership stakeholders played an active role in determining major social and environmental impact decisions throughout planning. For example, in order to test and prioritize the many greenhouse gas (GHG) reduction options available, a long-term campus energy model was constructed and various scenarios were developed to determine which energy solutions met the long-term need for campus energy supply and demand. The results from each scenario were compared to the current energy model for potential cost and GHG reduction. Based on these findings, an initial GHG Reduction Options Report was prepared in 2008 and presented to the university administration for initial review. Subsequent reviews with more detailed analysis were held with the Board of Trustees in 2009, 2010 and throughout 2011, and two different faculty advisement committees actively participated during this inception phase of the project (President's Blue Ribbon Taskforce in 2008, 2009 and Board of Trustees Energy Advisory Committee in 2010, 2011). In total, over the entire course of SESI planning and implementation, more than 25 faculty members and 100 students have been involved through student groups and departmental query. This is truly an all-campus project that has solicited, welcomed and benefited from faculty and student input throughout the years.

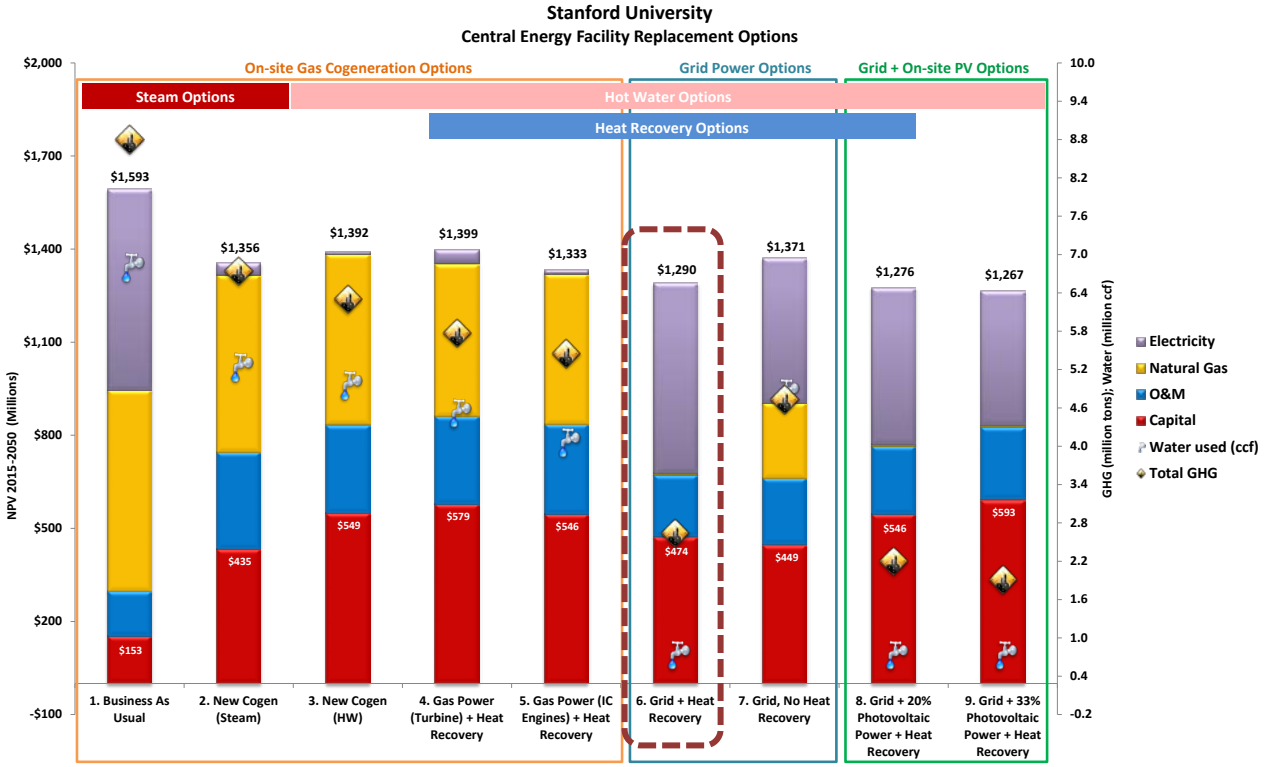
Integrating student work

Integrating **student work and aspirations** has been a priority for both the Energy and Climate Plan and SESI. Student groups have been informed and solicited for support and ideas since 2008, and their opinions and voices have been carried through every major decision stage of the SESI approval. Most recently, LBRE partnered with the Stanford Solar and Wind Energy Project, a student group, to carry out studies on the campus solar potential. Solar photovoltaic (PV) integration is one aspect of SESI currently under investigation, and the students assisted in analyzing data while gaining practical hands-on experience. Stanford staff will continue to partner with students and faculty as SESI proceeds.

Criteria 5: Documentation of results, analysis, customer feedback, and resulting benchmarks

Nine major options (graphic below) 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

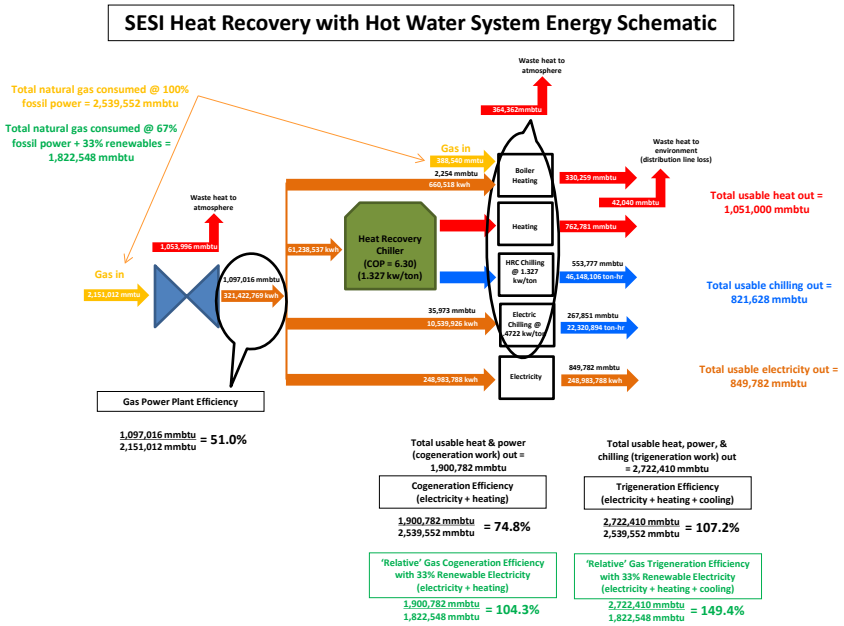


These options were modeled for energy and exergy efficiency, economics, and environmental impact and subjected to substantial peer review. Results are presented in the chart below which compares the life cycle cost of each option as well as the relative GHG emissions and water use. Based on these results 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. 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 as 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.

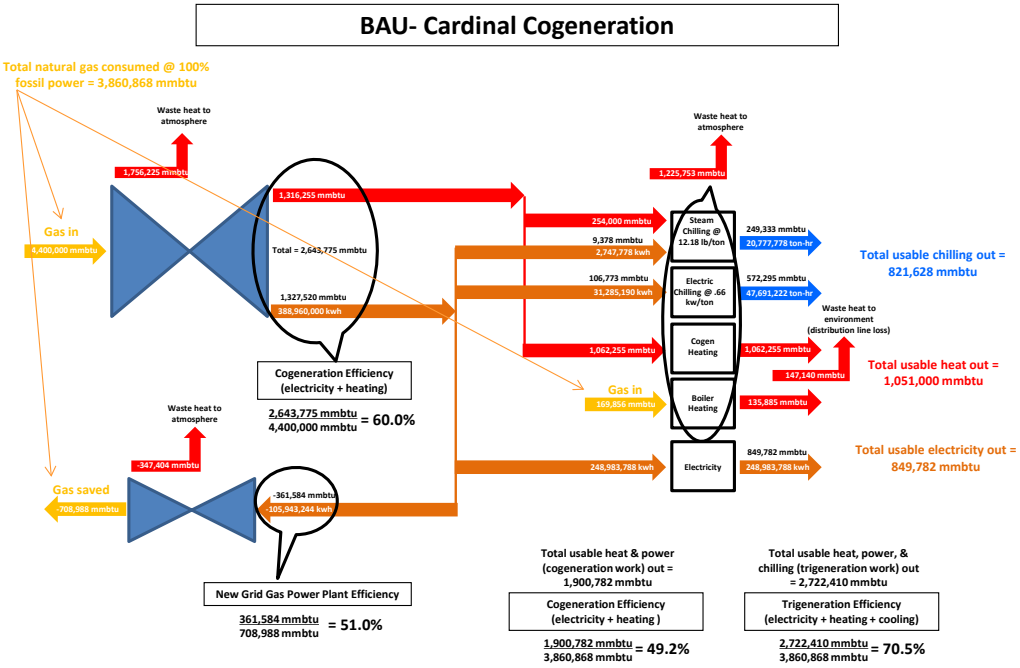
Supplemental Information:

Higher system efficiency:

SESI is built on the principle of reuse of waste heat. The low-grade heat that is currently being discarded in the cogeneration system will be recaptured and reused in the new heat recovery system. Due to the significant heat recovery and lower line losses in hot water distribution as compared to steam, the new energy system will be 70% more efficient that the existing combined heat and power process provided by the current cogeneration plant. 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.



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.



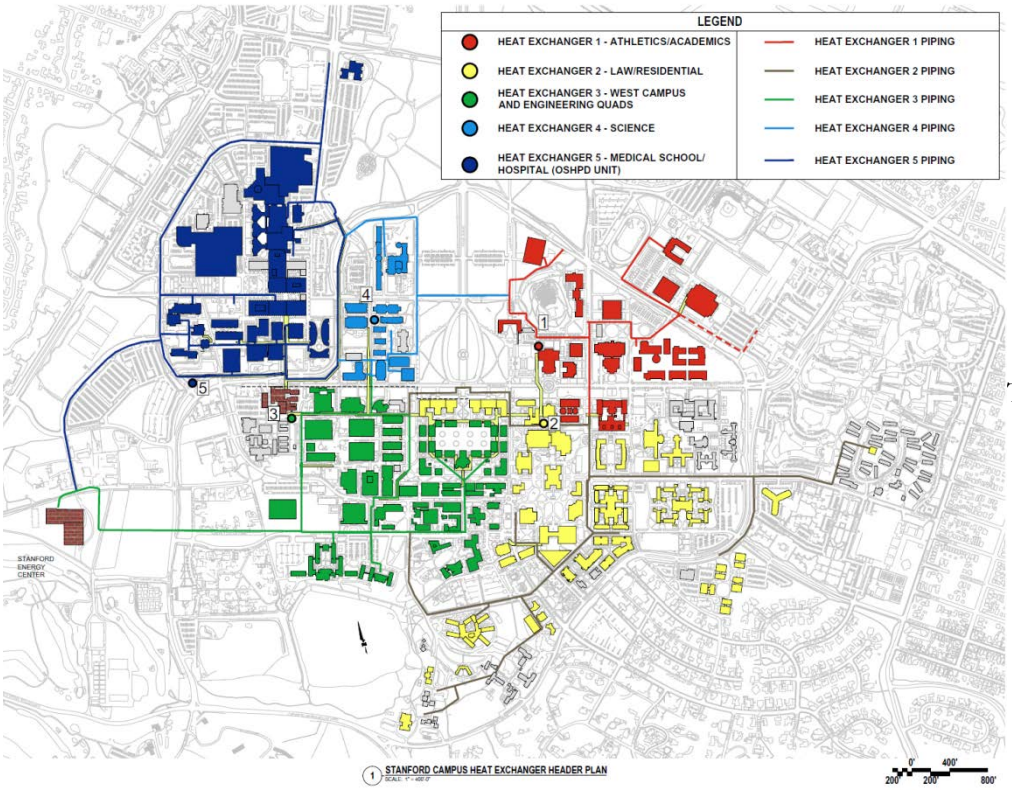
SESI Implementation

In December 2011, Stanford's Board of Trustees gave concept approval to the $438 million Stanford Energy System Innovations (SESI) program, focused on the supply side component of the Energy and Climate Plan. In 2012, the engineering firms completed the design for the new CEF, equipment manufacturers were selected, and a general contracting firm was hired. The implementation of the SESI program started in summer 2012. The Department of Project Management is managing design and construction for the hot-water pipe installation as well as the new Central Energy Facility in the west side of campus.

Hot water installation

Over the course of SESI program implementation, 20 miles of hot-water pipe will be installed, and equipment in the mechanical rooms of 155 buildings will be modified to allow the buildings to use hot water for heating instead of steam. As each phase of piping and building conversion is completed, that section of campus will be moved off steam to hot water via a regional heat exchanger that will convert steam from the existing cogeneration plant to hot water. Piping construction work is being carefully sequenced in multiple phases to minimize disruption to campus life. Once all phases of the conversion are complete, a full transition from the cogeneration plant to the RCEF will be made, the regional heat exchange stations will be removed, and the cogeneration plant will be decommissioned and removed.

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



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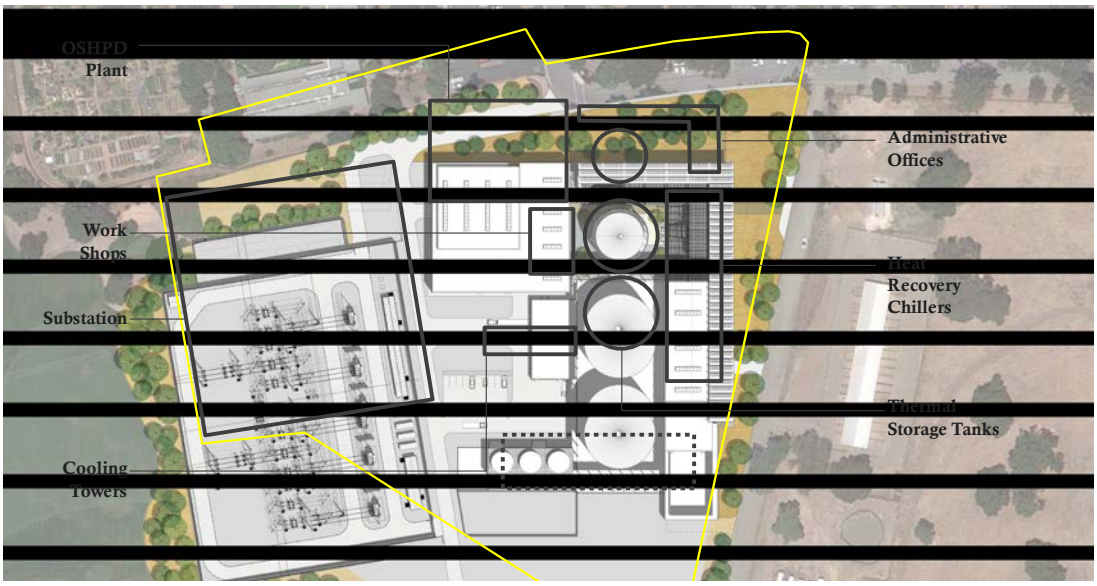
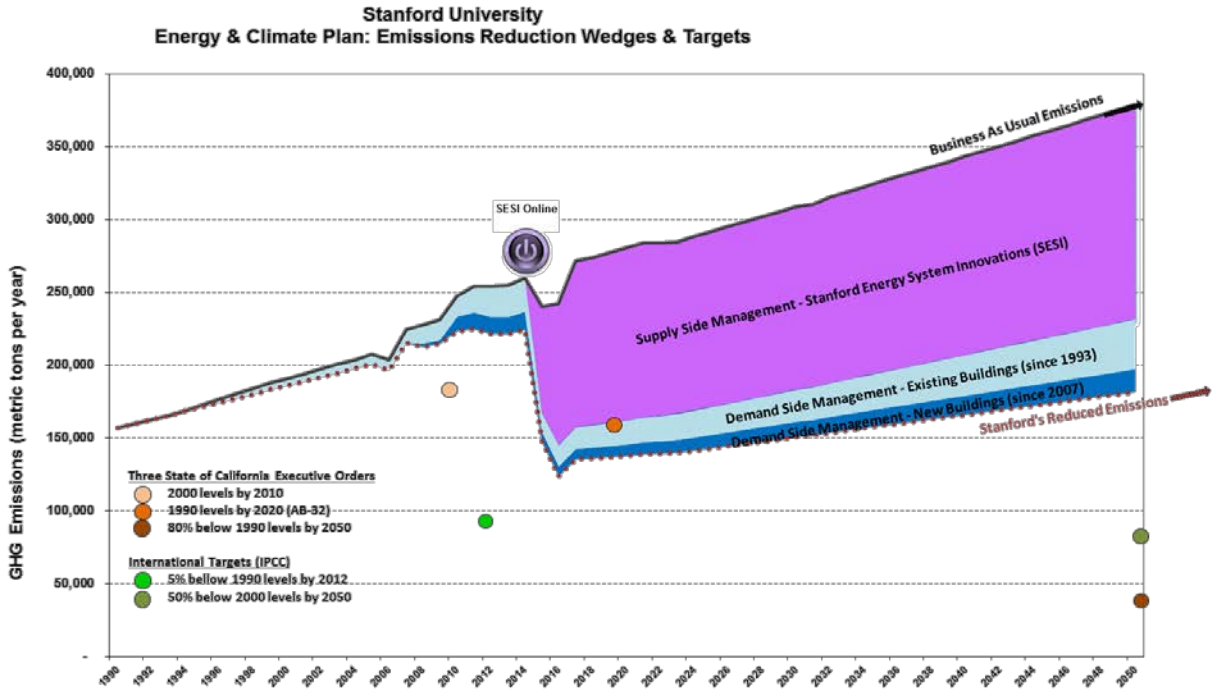
New Central Energy Facility: The RCEF will be an all-electric state-of-the-art heat recovery plant featuring both hot- and cold-water thermal storage.



Full View

When completed, the new heat recovery system will be 52% more efficient than the existing cogeneration system; immediately cut Stanford's greenhouse gas emissions in half; save 18% of Stanford's drinking water supply; and save $303 million (20%) over the next 35 years compared to the existing system.



Please visit sesi.stanford.edu for real time project updates and construction details.

Supporting Materials in "http://sesi.stanford.edu"

- Introductory video
- Energy & Climate Plan (updated plan to be made available in February 2013)
- SESI Fact sheet
- SESI Brief Overview PPT
- Campus Press Release and Outreach
    - Energy Seminar event archive: Stanford Energy Systems Innovations Project (10/29/12) (Co-chaired by Stanford's Woods Institute for the Environment & Precourt Institute for Energy)
    - Stanford's first-of-its kind energy facility will help it cut carbon emissions in half (10/9/12)
    - Stanford Fosters Green Campus Life
    - Board of Trustees Approves SESI Program (Stanford News, 2011)
    - Go Big Green: Stanford Lightens Its Carbon Load (PG&E, 2010)
    - Stanford to Cut Energy Use, Reduce Carbon Impact (Stanford News, 2009)

More technical information, schematics, or images are available upon request