Stanford
ENERGY SYSTEM
INNOVATIONS

Stanford University
Energy and Climate Plan

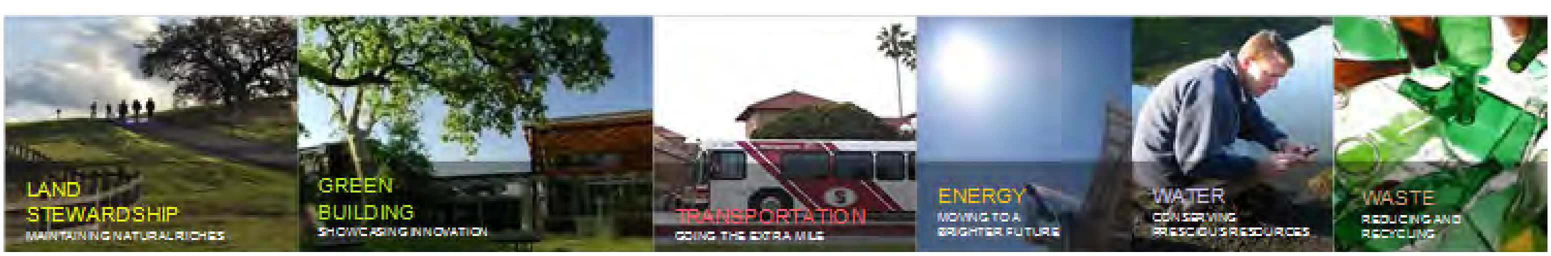
Revised February 2013
Second Edition

Concept Lead: Department of Sustainability and Energy Management

Report Produced by Office of Sustainability, Stanford University

About Us

Formed in 2007, Stanford's Land, Buildings & Real Estate's Department of Sustainability and Energy Management (SEM), led by Executive Director Joseph Stagner, brings a unique and particular focus to utilities infrastructure–related sustainability. SEM leads initiatives in campus infrastructure and programs in the areas of energy and climate, water, transportation, green buildings, and sustainable information technology. The Office of Sustainability connects campus organizations and entities and works collaboratively with them to integrate sustainability as a core value. The Office works on long-range sustainability analysis, evaluations and reporting, communications publications, conservation campaigns, and collaborative governance.



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Executive Summary

Stanford's Energy and Climate Plan, when fully implemented, will immediately reduce campus GHG emissions by 50% and potable water use by 18%, while also opening a path to full energy sustainability over time through greening the campus electricity supply. Situated on 8,180 acres, Stanford requires a significant amount of energy to support its academic mission and the research functions housed within more than 1,000 campus buildings. Efficiently managing energy supply and demand, as well as the corresponding greenhouse gas (GHG) emissions, is therefore critical to the university's future operations. Since the 1980s, Stanford has employed best practices to minimize the cost and environmental impact of its operations. The campus has employed energy metering in all its facilities, used efficient natural-gas–fired cogeneration for its energy supply, retrofitted buildings with efficient systems, implemented stringent building standards, invested in renewable power, conserved water, and reduced automobile commute emissions. Now, Stanford accepts the challenge to go beyond these efforts and raise the bar in the use of innovative and renewable energy supplies to further reduce its environmental impact and operational cost. This executive summary provides a brief overview of the purpose and approach of this plan; its benefits to and beyond Stanford University; and its approval and implementation.

Planning Purpose

Formed in 2007, Land, Buildings & Real Estate (LBRE)'s Department of Sustainability and Energy Management (SEM) brought an integrated and deliberate focus to campus sustainability. One of the first major tasks for this newly formed department was to create a long-range energy and climate plan for the campus, with the purpose of striking a balance between the critical needs of climate action and energy production and the requirements inherent in operating a large university.

Stanford's long-range Energy and Climate Plan, developed collaboratively, peer reviewed, and incorporating both engineering and financial models, presents a three-pronged, balanced approach to improve infrastructure and dramatically reduce GHG emissions—despite campus growth and without relying on market carbon instruments. Serving as a blueprint for implementation, this plan demonstrates long-term cost effectiveness and sustainable natural resource use; guides development of critical campus infrastructure; and reduces economic and regulatory risks to Stanford's long-term energy supply. It provides a vision for the campus's energy future while maintaining flexibility through a comprehensive, long-term approach to the challenge of reducing campus emissions.

The solutions provided by the Energy and Climate Plan, including the Stanford Energy System Innovations (SESI) program, not only represent the most economical energy option but will also immediately reduce campus GHG emissions by 50% and potable water use by 18%, while also opening a path to full energy sustainability over time through greening the campus electricity supply.

Planning Approach

The plan was designed with the vision of applying Stanford's intellectual and financial resources to provide leadership in climate change solutions through a long-term, holistic, and flexible approach. The first step in its development was a comprehensive analysis of current campus energy use and GHG emissions. Stanford has been accounting for its Scope 1 and Scope 2 carbon emissions since 2006. Its 2010 emissions total 191,300 metric tons of CO_2 equivalent. Using these data and campus growth projections, Stanford created a GHG emissions forecast that informed the development of the Energy and Climate Plan. Given Stanford's planned growth to support its academic mission, its large and diverse existing campus building inventory, and its current reliance on natural gas cogeneration for energy (the main source of its GHG emissions), the final Energy and Climate Plan provides a balance among **investments in new buildings, existing buildings,** and **energy supply** (see Figure 0-1).

High-Performance New Building Design

Given the university's significant growth plans, constructing high-performance new buildings to minimize the impacts of growth on campus energy systems and GHG emissions is a key strategy. The Guidelines for Sustainable Buildings, originally published in 2002 and updated in 2008, in combination with the Guidelines for Life Cycle Cost Analysis and the Project Delivery Process manual, provide the framework for minimizing energy demand in new construction and major renovation projects on campus. Programs in place to maximize energy efficiency include:

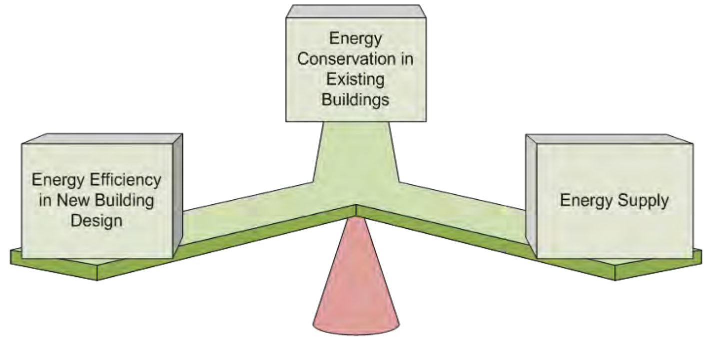
- Optimization of current space through Stanford's Space Planning Guidelines. Before undertaking any building project, Stanford first conducts a rigorous space utilization study to see if renovation of existing buildings can create space for new needs.
- Mandatory efficiency standards for new buildings, which must use 30% less energy than required by code and 25% less potable water than comparable buildings.
- Guidelines for sustainable buildings that address site design; energy use; water management; materials, resources, and waste; and indoor environmental quality.

All new campus buildings completed in recent years embody these guidelines in action.

Energy Conservation in Existing Buildings

Since the 1980s, Stanford has employed building-level energy metering of all its facilities to understand how and where energy is used in order to facilitate strong energy efficiency programs. Reducing energy use in existing buildings is central to creating a sustainable campus. It is also a formidable task, given the growing energy needs of research universities. However, Stanford has a strong foundation for success, building on a decades-long commitment to energy conservation and efficiency. It has substantial programs to improve campus energy efficiency, including:

Figure 0-1 A Balanced Approach to Energy and Climate Solutions



- The Energy Retrofit Program, which improves building energy efficiency and has led to cumulative annual energy savings of 33 million kWh since 1993.
- The Whole Building Retrofit Program, which targets the campus's most inefficient buildings for retrofits. Twelve projects have been completed as of 2012, and 10 more are under way. The program is expected to achieve almost $6 million of annual energy savings.
- The Energy Conservation Incentive Program, which targets reductions in energy use through human behavior, rather than technology.
- The Sustainable IT program, which holistically examines Stanford's computing infrastructure and promotes energy efficiency through both behavioral and infrastructural improvements, from power management settings to energy-efficient data centers.

While the university has pursued aggressive energy conservation for many years, the continuation and expansion of programs like these is another key strategy of the Energy and Climate Plan.

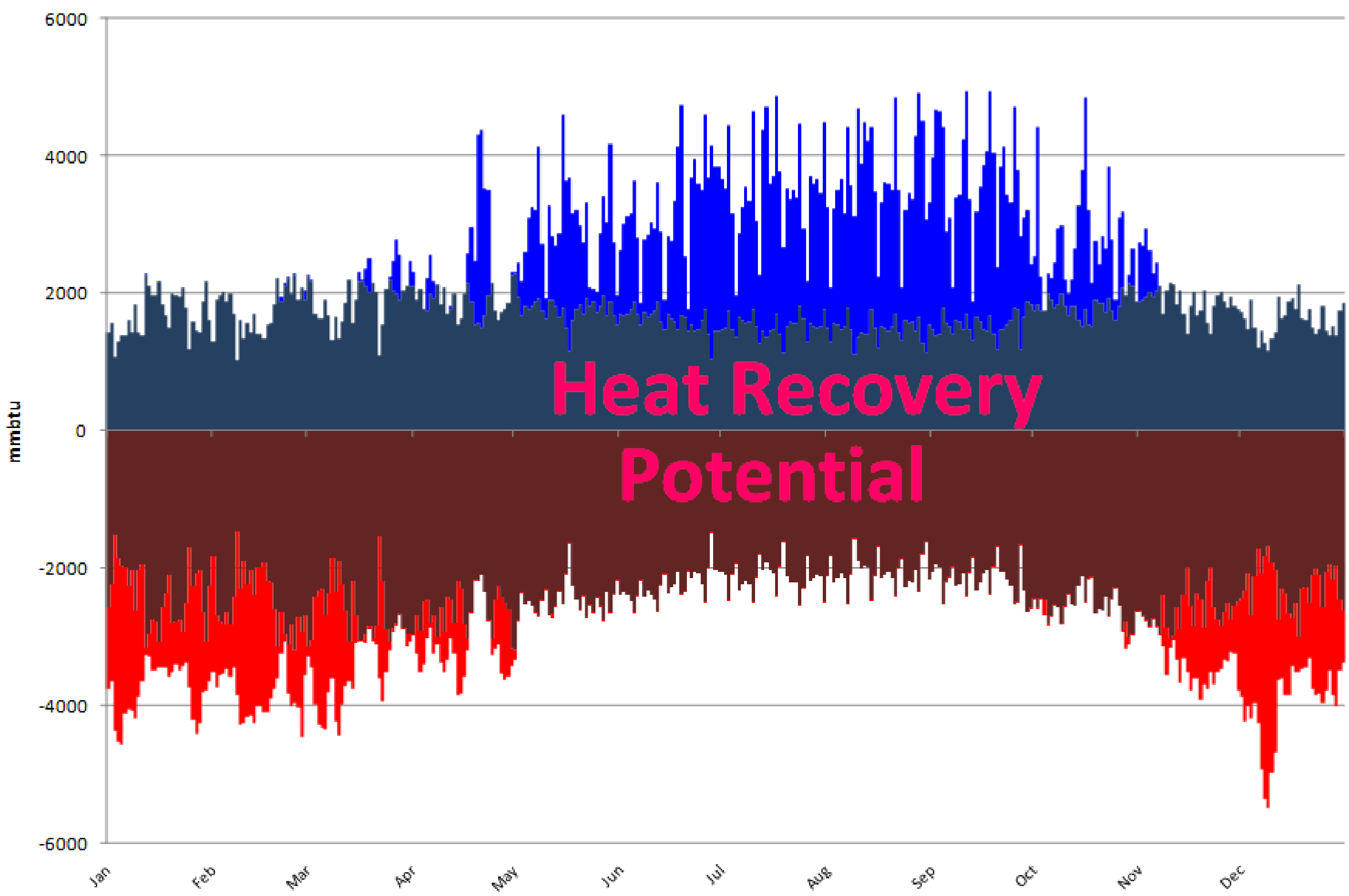
Stanford Energy System Innovations (SESI)

Given that energy production at the existing Central Energy Facility (CEF) produces 90% of Stanford's GHG emissions and consumes 25% of its potable water supply, changes to Stanford's energy supply are the major focus of the Energy and Climate Plan. Stanford has pursued an efficient energy supply by using natural gas–fired cogeneration for virtually all its energy since 1987, but as the current cogeneration plant is reaching the end of its useful life, Stanford has examined conversion to new options that assure reliability, contain cost, and reduce GHGs. Stanford Energy System Innovations (SESI) aims to green Stanford's energy supply through an innovative new campus energy system.

Under Stanford's current district heating and cooling system, the CEF produces heat, which the steam system transports to buildings for heating and hot water. Simultaneously, the chilled water system collects unwanted heat from buildings and transports it to the CEF, where it is discarded to the atmosphere via evaporative cooling towers.

While much heating is done in winter and much cooling in summer, any overlap of the two provides an opportunity to recover and reuse heat energy that is normally discarded to the atmosphere. The heart of SESI is heat recovery—capturing waste heat from the chilling system to produce hot water for the heating system. In 2009, investigation of sustainable options to succeed the current gas-fired cogeneration system uncovered a major real-time overlap of heat production and chilling. The study revealed that 70% of the waste heat from the chilled water system could be reused to meet 80% of campus heating loads if adequately sized, efficient industrial heat pumps were available and the heat distribution system were converted from steam to hot water (see Figure 0-2).

Figure 0-2 Heat Recovery Potential at Stanford

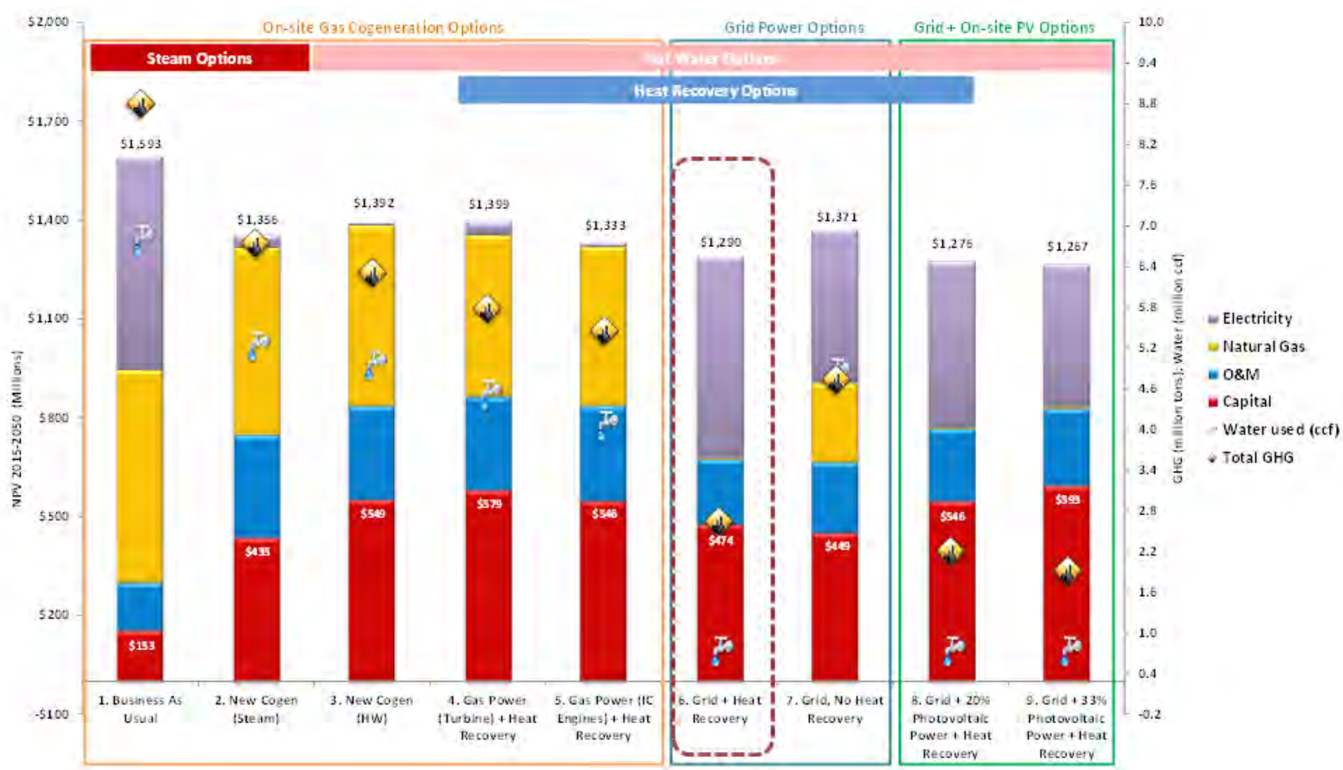


Nine major options (see Figure 0-3) for Stanford's next energy system were developed in detail:

- Gas-fired cogeneration and steam distribution (owned and operated by third party [business as usual]; owned and operated by Stanford)
- Gas-fired cogeneration with hot water distribution
- Hybrid cogeneration + heat recovery with hot water distribution (turbine and internal combustion 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 with 20% to 33% on-site photovoltaic (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 Figure 0-3, which compares the life cycle costs of the options as well as the relative GHG emissions and water use. Based on these results, Stanford selected the electrically powered combined heat and 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 (grid + heat recovery) represents the lowest life cycle cost and one of the lowest up-front capital costs because on-site power generation infrastructure is avoided.

Figure 0-3 Comparative Cost, GHG, and Water Use of Energy Supply Options



Benefits to Stanford University and Beyond

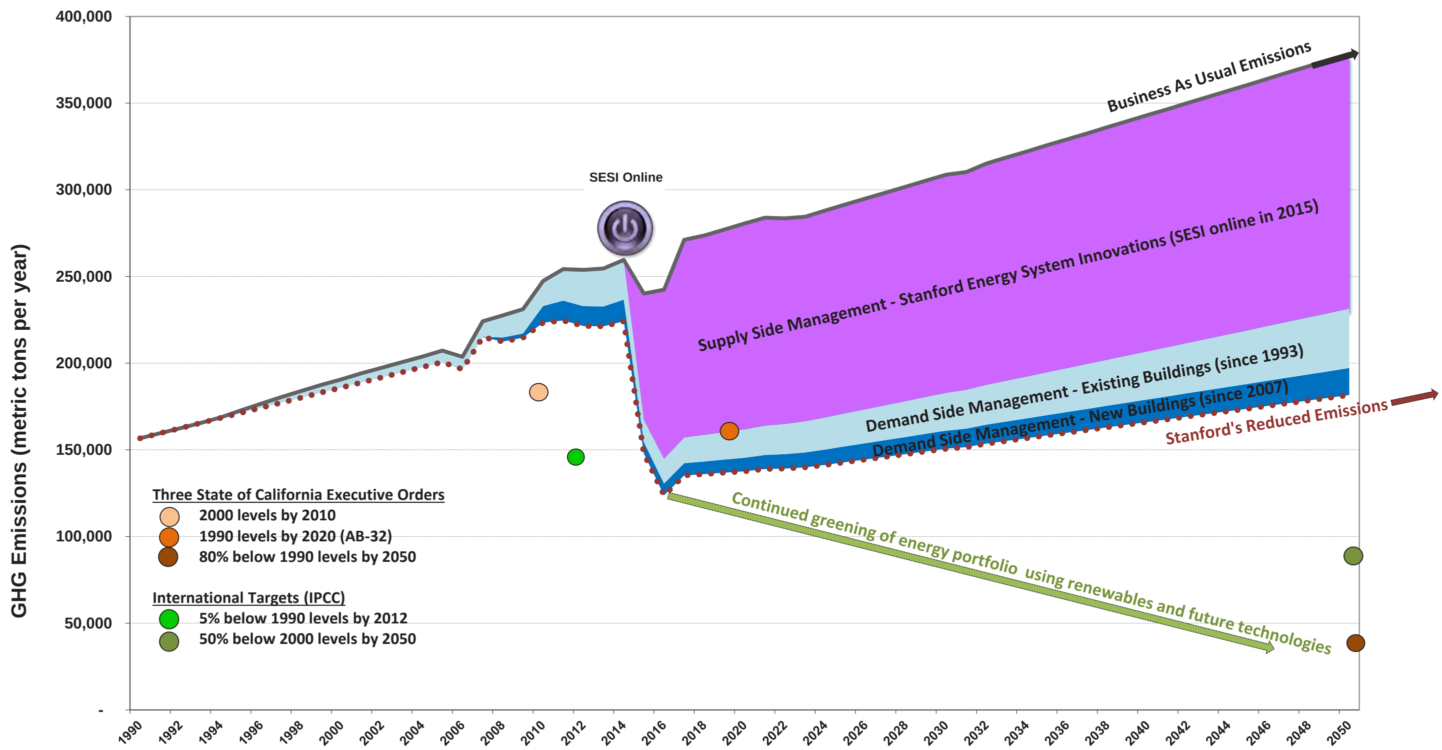
The Energy and Climate Plan signifies a new chapter for Stanford, as the campus moves to lead sustainability by example through a balanced approach to emissions reduction. SESI, the most significant component of the plan, represents a significant transformation of the university's energy supply from 100% fossil fuel–based cogeneration to a more efficient electric heat recovery system powered by a diverse mix of conventional and renewable energy sources.

When SESI is completed in April 2015, the new heat recovery system will be 50% more efficient than the existing cogeneration system, cutting Stanford's Scope 1 and 2 GHG emissions in half (see Figure 0-4). In addition, SESI will reduce the use of drinking water for cooling processes 18%, saving $303 million over the next 35 years compared to the existing system.

Combined with demand-side management programs that target energy efficiency in both existing and new buildings, SESI promises to make Stanford a pioneer in the low-carbon energy future.

Having achieved Direct Access to the California electricity market in 2011, Stanford is now exploring opportunities for a more economically and environmentally sound power portfolio. Built on principles and practices of high quality and transferability, SESI provides a model for the business community to replicate. As its primary technical innovation is district-level application of heat recovery in a campus/municipal facility, many entities that have district-level heating and cooling systems 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 overall heating and cooling overlaps are diagnosed. 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 their design and maintenance, SESI-type implementation is possible throughout the country.

Figure 0-4 Emissions Reduction Wedges and Targets



Approval and Implementation

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). 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 queries. This is truly an all-campus project that has solicited, welcomed, and benefited from faculty and student input throughout the years.

In December 2011, Stanford's Board of Trustees gave concept approval to the SESI program, focused on the supply-side component of the Energy and Climate Plan. In 2012, engineering firms completed the design for the new CEF, equipment manufacturers were selected, and a general contracting firm was hired.

The program is currently being implemented with oversight by the Department of Project Management in LBRE, in direct collaboration with Architect/Campus Planning and Design, Land Use and Environmental Planning, and all other departments in LBRE. A $438 million overhaul of the campus district energy system, SESI includes:

- Installation of a new, electrically powered CEF built around heat recovery;
- Demolition of the existing cogeneration plant;
- Installation of 20 miles of new hot water distribution piping;
- Conversion of 155 building connections from steam to hot water;

Figure 0-5 Renderings of New RCEF

- Concurrent improvement of building hot water hydronic systems where required for lower operating temperatures and higher delta T return; and
- Installation of a new campus high-voltage substation.

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 new CEF will be made, the regional heat exchange stations will be removed, and the cogeneration plant will be decommissioned and removed. The new CEF will be an all-electric, state-of-the-art heat recovery plant featuring both hot and cold water thermal storage.

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. 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 very 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 that shows the current and future construction zones and project progress. Please visit http://sesi.stanford.edu for real-time project updates and construction details.

Next Steps for Caretakers of a legacy

SESI is built on the principle of innovation and flexibility to adapt to new technologies; we aim to meet the needs of the future without compromising the needs of the present. By design, SESI balances pragmatism and vision, meeting short- and long-term needs of an institution of higher learning that leads sustainability by example. 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. These include potential on-campus PV power installations as well as development of a ground source heat exchange system to complement the core heat recovery process based on the chilled water system.

Also, in recognition that a path to full energy sustainability has been opened up through conversion of the campus from gas to electricity, the university will next embark upon design of the electricity portfolio that will serve the campus upon the commissioning of SESI in April 2015. From late 2013 through 2014 the university will explore opportunities for economic, reliable, and sustainable electricity supplies that can support its new high-efficiency electric campus, and the first incarnation of that electricity supply will be put in place to support the 2015 switchover from gas-powered cogeneration to electrically powered heat recovery.

Chapter 1: The Need for Climate Action

Stabilization and reversal of greenhouse gas (GHG) emissions into the atmosphere from human activity is a challenge that seeks solutions in the areas of both research and implementation. Climate science has instilled a sense of urgency to climate action. The UN Intergovernmental Panel on Climate Change (IPCC) has found that developed countries, as a group, need to reduce emissions by 25–40% by 2020, from a 1990 baseline, in order to contain warming to 2.0–2.4 degrees. This standard translates to about a **50% reduction in GHG emissions from 2000 levels by 2050**, in order to restrict global warming to levels believed to be manageable.[1] Most widely recognized GHG reduction goals specify both interim (2010 to 2020) and long-term (2050) reductions.

Such significant reductions worldwide will require strong carbon regulations and effective technology implementation both globally and locally. This provides an opportunity for any entity to take local action within a global regulatory and economic framework. This chapter outlines the key events in climate action globally and locally, to contextualize Stanford University's approach towards its Energy and Climate Plan.

Major Events in Global Climate Action

International recognition of climate change as a serious global issue began in 1988 with the establishment of the **IPCC**. This group consists of the world's leading climate scientists. Its first report on climate change science was published in 1990; the fourth and most recent assessment, published in 2007, warned that serious effects of global warming had already become evident. The following key steps have shaped climate action globally and locally, and have informed Stanford's decisions and analytical framework for climate action planning.

UNFCCC: International efforts to address climate change began in 1992 with the passage of the United Nations Framework Convention on Climate Change. The UNFCCC established the aim of stabilizing atmospheric GHG concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, 1992).

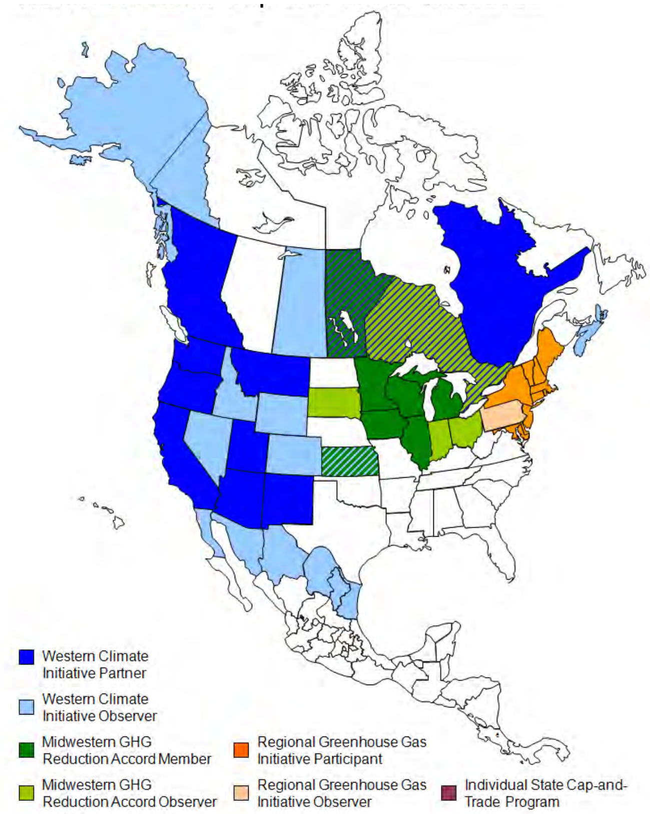
Kyoto Protocol: In 1997 the Kyoto Protocol quantified the UNFCCC's objective by establishing specific targets and timetables for GHG reduction. The Kyoto Protocol set binding targets for developed countries to reduce GHG emissions (7% below 1990 levels for the U.S., 8% for Europe) by the 2008–12 commitment period, but did not mandate reduction commitments for developing countries (UNFCCC, 1997).

1 Ref: IPCC http://www.ipcc.ch/ (Box 13.7 in the IPCC Fourth Assessment Report)

Countries began to develop a variety of mechanisms to help meet Kyoto Protocol goals. The European Union (EU) established the **EUROPEAN UNION GREENHOUSE GAS EMISSION TRADING SCHEME (EU ETS)**. Launched in 2005 and based on "cap and trade" principles, the EU ETS now covers 11,000 power stations and industrial plants in 30 countries across Europe (European Commission, 2007). Another reduction mechanism developed in response to the Kyoto Protocol is the **CLEAN DEVELOPMENT MECHANISM (CDM)**. Under this program, emission reduction or avoidance programs in developing countries can provide carbon credits for developed countries to use towards their Kyoto goals. While the CDM contains strict guidelines for qualifying projects, some loopholes in protocol have caused undesired market behavior. Another program currently under development is the **UNITED NATIONS COLLABORATIVE PROGRAMME ON REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION IN DEVELOPING COUNTRIES (UN-REDD)**. Launched in 2008, UN-REDD provides carbon credits for standing forests in developing countries as an incentive to slow or halt deforestation.

As the Kyoto Protocol only established reduction requirements through 2012, the international community is currently working to develop new long-term goals to reduce carbon emissions using existing frameworks.

Figure 1-1 North American Cap and Trade Initiatives



Source: Center for Climate and Energy Solutions

Major Events in Regional and National Climate Action

The United States is party to the UNFCCC but not to its implementing treaty, the Kyoto Protocol. Following the issuance of the Byrd-Hagel Resolution, expressing the Senate's concern over the potential negative economic impacts of emissions restrictions and its objection to participating in a treaty that did not also cover developing countries, the administration did not send the Kyoto Protocol to the Senate for ratification.

Supreme Court Ruling that CO_2 is a Pollutant: On April 2, 2007, the Supreme Court handed down Massachusetts v. EPA, its first pronouncement on climate change. The Court ruled that carbon dioxide is a pollutant under the Federal Clean Air Act and said the EPA "abdicated its responsibility" under that act in deciding not to regulate carbon dioxide. The Court's decision leaves the EPA with three options: find that motor vehicle GHG emissions may "endanger public health or welfare" and issue emission standards; find that they do not satisfy that prerequisite; or decide that climate change science is so uncertain as to preclude making a finding either way. The decision has implications for other climate change–related litigation, particularly a pending suit seeking to compel EPA regulation of GHG emissions from stationary sources.

Voluntary Programs: While the United States has not elected to participate in a mandatory emissions reduction scheme, a number of voluntary efforts are currently under way across the country. The federal government has implemented programs to encourage personal emissions reductions, such as **ENERGY STAR**, a program for identifying and promoting energy-efficient appliances, and the **CLIMATE VISION** initiative, which works with private-sector companies to establish and meet emissions reduction goals. The federal government has also entered into international partnerships that do not include mandatory emissions reductions, such as the **ASIA-PACIFIC PARTNERSHIP ON CLEAN DEVELOPMENT AND CLIMATE**.

There are also a number of regional emissions reduction programs.

Western Climate Initiative (WCI): Launched in February 2007, the WCI is a collaboration of seven U.S. governors and four Canadian premiers. Created to identify, evaluate, and implement collective and cooperative ways to reduce GHGs in the region, the partnership is currently working towards a regional, market-based cap-and-trade system.

Regional Greenhouse Gas Initiative (RGGI): Signed in 2005, the RGGI is the first mandatory, market-based effort in the United States to reduce GHG emissions. Ten northeastern and mid-Atlantic states will cap CO_2 emissions from the power sector, then reduce them 10% by 2018, with emission allowances sold via an auction mechanism.

Midwest Greenhouse Gas Reduction Accord (MGA): Nine midwestern governors and two Canadian premiers have signed on to participate in or observe the MGA, first agreed to in November 2007 in Milwaukee, Wisconsin. The most coal-dependent region in North America, the Midwest also has great renewable energy resources and opportunities that allow it to take a lead role in addressing climate change. Through the accord, these governors and premiers agreed to establish a program to reduce GHG emissions in their states and provinces, as well as a working group to provide recommendations regarding its implementation.

U.S. Mayors Climate Protection Agreement: Committed to promoting more action at the local level, in 2005 Seattle Mayor Greg Nickels launched this initiative to advance the goals of the Kyoto Protocol through leadership and action by American cities. By June of that year, 141 mayors had signed the agreement—the same number of nations that ratified the Kyoto Protocol. By late 2011, a total of 1,055 mayors representing 88,924,506 citizens had signed the agreement. Participating cities commit to strive to meet or beat the Kyoto Protocol targets in their own communities, through actions ranging from anti-sprawl land use policies to urban forest restoration projects to public information campaigns.

American Colleges and Universities Presidents Climate Commitment (ACUPCC): On the academic front, in late 2006 a group of college and university presidents launched a high-visibility effort to address global warming by making a joint commitment to reduce GHG emissions at their institutions, modeled after the U.S. Mayors Climate Protection Agreement. Twelve presidents agreed to become founding members of the Leadership Circle and launch the ACUPCC. Membership now exceeds 670 universities. Stanford University is not a signatory but expects to make a decision on membership based on whether new ideas and tools within this framework become available.

Major Events in State Climate Action

California is pioneering GHG regulation in the United States. The 6th-largest economy and 12th-largest GHG emitter in the world, California has the leadership and legislative potency to define an emissions management standard for the entire nation.

Executive Order S-3-05: In 2005, California Governor Arnold Schwarzenegger signed Executive Order S-3-05, committing California to specific emissions reduction targets and creating a climate action team to help implement them. Three specific emission targets have been established: 2000 levels by 2010, 1990 levels by 2020, and 80% below 1990 levels by 2050.

Assembly Bill 32: California next demonstrated national and international leadership in climate action by passing AB 32 in 2006. Authored by Fran Pavley (D–Agoura Hills) and Fabian Núñez (D–Los Angeles), the Global Warming Solutions Act of 2006 codified the middle target of Executive Order S-3-05, requiring the state to reduce its emissions to 1990 levels by 2020. In early December 2008 the California Air Resources Board finalized a scoping plan to fulfill the key provisions of AB 32. The plan suggests a cap-and-trade program as a major and viable emissions reduction option; specifically, it recommends that California implement a cap-and-trade program that links with other WCI partner programs to create a regional market system.

Senate Bill 1368: On September 29, 2006, Governor Schwarzenegger signed into law Senate Bill 1368 (Perata, Chapter 598, Statutes of 2006). The law limits the state's utilities to investing in power plants that meet an emissions performance standard jointly established by the California Energy Commission and the California Public Utilities Commission, effectively banning new coal-powered generation for the state. This law followed the establishment in 2003 of a "loading order" requiring utilities to attempt to meet new demand with energy efficiency and renewable energy before building conventional fossil fuel power plants.

State Bill 375: To tackle issues of smart land use and transportation, SB 375, authored by state senator Darrell Steinberg (D-Sacramento) and signed by Governor Schwarzenegger in 2007, compels local planning agencies to make planning choices that reduce vehicle miles traveled. SB 375 builds on AB 32 by adding the nation's first law to control GHG emissions by curbing sprawl.

The growing awareness of climate change and the need for timely action is converging with the national scope of regulatory and business action. There are regulatory solutions on the horizon; local governments and businesses are realizing economic gain from tighter resource management; and the dependence on fossil fuel is now politically unpopular. However, it is still uncertain whether timely action will be taken that will actually and cumulatively bring CO_2 concentration down to a steady state.

Many institutions, including Stanford University, are compelled to act now to meet the timetable determined by the earth's atmospheric balance. Often referred to as a long-term problem that now requires a short-term solution, climate change poses the difficult task of innovating and implementing new solutions in parallel.

Photo: Zachary Brown, PhD '13, is carrying out environmental research through a fellowship endowed through the Initiative on the Environment and Sustainability.

Climate Action at Stanford University

In Academics

Since the 1970s Stanford researchers have sought climate change solutions by participating on the IPCC and working on numerous initiatives, such as the Global Climate and Energy Project, the Stanford Woods Institute for the Environment, the Precourt Institute for Energy, and the Program on Energy and Sustainable Development. In 2006 President Hennessy announced the Stanford Challenge, a university-wide program seeking solutions to the century's most pressing global challenges. An important facet of the Stanford Challenge is the **Initiative on the Environment and Sustainability**, which promotes interdisciplinary research and teaching across Stanford's schools, centers, and institutes in recognition of the fact that solutions to complex challenges demand collaboration across multiple fields.

The Initiative is coordinated by the **Stanford Woods Institute for the Environment**, an interdisciplinary institute that harnesses the expertise and imagination of university scholars to develop practical solutions to the environmental challenges facing the planet. The institute brings together prominent scholars and leaders from business, government, and the nonprofit sector through a series of dialogues and strategic collaborations designed to produce pragmatic results that inform decision makers.[2]

2 Final Report on the Initiative: http://thestanfordchallenge.stanford.edu/highlights-by-initiative/environment-sustainability/

In Campus Operations

On the operations side, Stanford has employed energy metering for all of its facilities to ascertain how and where energy is being used and has pursued strong energy efficiency programs for over 10 years. These programs include the following (see Chapter 5 for more detailed discussion):

- The **ENERGY CONSERVATION INCENTIVE PROGRAM**, which provides financial incentives for electricity conservation in buildings
- The **ENERGY RETROFIT PROGRAM**, which reinvests utility savings in additional energy conservation projects such as HVAC replacement and lighting upgrades
- The **MAJOR CAPITAL IMPROVEMENT PROGRAM** for extensive retrofits of the most energy-intensive campus buildings
- The **ADVANCED BUILDING MANAGEMENT PROGRAM** for optimizing building system operating schedules to occupancy patterns, detecting energy leaks, and continuously commissioning building systems
- **COGENERATION:** While Stanford now plans to advance beyond cogeneration to heat recovery, it has for the past 20 years employed natural gas–fired cogeneration for virtually all its energy. Although gas-fired cogeneration does emit GHGs, it is one of the most efficient forms of fossil fuel–based energy production. In fact, both EU and California policies and regulations promote cogeneration as a means of achieving overall GHG reductions.[3] However, at Stanford heat recovery offers superior benefits and does not commit the university long-term to a fossil fuel–fired energy source such as cogeneration.

Stanford has done much to reduce GHG impacts from its operations. However, these efforts have largely been guided by general principles and specific policies rather than a detailed overarching plan. Given the challenges and the scale of resources required, the university embarked on development of a formal energy and climate action plan in November of 2007.

As described in Chapter 2, the campus administration decided to focus the climate plan on the energy sector, which contributes to the majority of campus GHG emissions. The university will proceed with emissions reduction from transportation and other sectors in the upcoming years.

3 EU Directives on Cogeneration 2004/8/EC & 2007/74/EC: http://europa.eu/legislation_summaries/energy/energy_efficiency/l27021_en.htm. Climate Change Scoping Plan: http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm.

Chapter 2: Principles, Approach, and Process

The previous chapter discussed Stanford's commitment to climate action in the context of state, national, and international developments. This chapter outlines the key principles, planning, and analysis approach used to develop Stanford's Energy and Climate Plan.

Guiding Principles

Three principles underlie Stanford's Energy and Climate Plan:

1. **Holistic and Long-Term Approach:** Recognize that emissions reduction may come from a number of areas in campus facilities design, construction, operations, and maintenance, affecting a diverse group of students, staff, and faculty across all academic and administrative departments as well as the surrounding community; recognize that Stanford has to operate within the broader context of energy infrastructure, emissions reduction, and regulation; recognize that both short- and long-term improvements are needed and that the long-range impacts of many upcoming decisions on long-lived buildings and infrastructure must be considered before those decisions are made.
2. **Vision:** Apply Stanford's intellectual and financial resources to provide leadership in climate change solutions, even if these efforts may differ from popular perceptions of how to pursue GHG reduction or are greater than governmental regulations may require.
3. **Flexibility**: Recognizing that achieving the ultimate vision of climate stability could take decades and require technologies that may not yet exist, provide for both specific short- and long-term actions to achieve GHG goals and flexibility to accommodate new technologies and changes in climate science as they are developed.

Energy and Climate Plan Process

This section discusses the key steps taken to develop this Energy and Climate Plan. (Note: Though these steps are shown chronologically, a number of revisions were required as new information became available.)

Summary of Steps:

1. Formation of an analysis team under the **leadership** of the executive director of the Department of Sustainability and Energy Management (SEM).
2. Preparation of an **inventory** of current campus energy uses and GHG emissions; development of campus growth and base case energy demand and GHG emissions forecasts (Chapter 3), development of **options** and costs for different levels of energy efficiency in our new building standards (Chapter 4), energy conservation in existing facilities (Chapter 5), and energy sources (Chapter 6).
3. Creation of a composite **energy model** including all viable supply-side GHG reduction options to allow detailed comparison and prioritization of options for minimizing, and then meeting, campus energy demands, while

reducing GHG emissions (Chapter 6). This step included consideration of carbon instruments for achieving GHG reductions indirectly (Appendix A).

4. Creation of financial models and budget schemes to support the most efficient choice and preparation of final recommendations for campus and Board of Trustees approval (Chapter 6).

Leadership

The Stanford University administration felt strongly that the plan should be developed in the departments directly responsible for implementing it. The planning exercise began in the SEM, under the leadership of its executive director. In addition, staff and faculty members of the Sustainability Working Group (SWG) and Utilities staff came together for the initial, intermediate, and final evaluations of emissions reduction options.

Inventory, Base Case, and Initial Options

As a member of the California Climate Action Registry (CCAR) and then the Climate Registry (TCR), Stanford has been accounting for its Scope 1 and Scope 2 emissions since 2006 (Appendix B).[1] The energy and climate planning exercise benefited from existing accounting processes but also considered Scope 3 emissions. In 2007, the campus prepared an expanded inventory that included emissions from commuter traffic, business travel, and provision of steam and chilled water to the Stanford Hospital and Clinics from the Stanford central energy facility (CEF), the Cardinal Cogeneration plant, which cogenerates electricity and steam from natural gas. This inventory was the base case for energy demand and GHG emissions.

A team of staff and faculty then proposed various options for energy conservation and alternative forms of energy supply to reduce operating cost and the campus emissions footprint. This effort yielded close to 40 options, including ideas for reducing energy use in existing buildings, designing new buildings to require less energy, promoting travel alternatives, and switching to more efficient, less carbon-intensive energy sources. Initiatives in many of these areas were already in progress as pilots or at a greater magnitude.

The options were then organized and screened for practical application at Stanford to create a toolbox of possible options for constructing a long-term GHG reduction plan. *The use of carbon instruments such as renewable energy credits and carbon offsets was evaluated but not relied on for any significant role in planning due to scientific, regulatory, and financial uncertainty (see Appendix A).*

To test the effectiveness of and prioritize the many GHG reduction options identified, a long-term campus energy model was constructed, with continuance of a third-party, on-site cogeneration plant as the business-as-usual scenario. Two other major long-term options for campus energy supply were then developed and compared to that scenario for potential cost and GHG reduction:

1. A new high-efficiency combined heat and power (CHP) cogeneration plant, sized appropriately for university needs only and owned and operated by the university
2. A new high-efficiency separate heat and power (SHP) plant using gas-fired boilers and electric chillers, owned and operated by the university and importing electricity from the off-site grid

Next, the team identified the projects from the toolbox with the highest potential to increase cost efficiency and reduce emissions in the long run. These energy conservation and alternative energy supply projects were then evaluated under the three options in the long-term energy model and ranked within each scenario based on their emissions reduction potential and average cost per metric ton of CO_2 reduced.

Based on these findings, an initial **GHG Reduction Options Report** was prepared in February 2008, recommending the campus move to the use of high-efficiency gas-fired boilers and electric chillers at the CEF upon retirement of the current cogeneration plant in 2015. After assessing the findings, and with agreement on the analysis approach and findings thus far, work began on a far more in-depth analysis of long-term energy and climate management options, culminating in this Energy and Climate Plan.

1 Scope 1 encompasses direct GHG emissions from on-site energy production or other industrial activities. Scope 2 accounts for energy purchased from off site (this is primarily electricity, but can also include, for example, steam). Scope 3 is much broader and can include anything from employee travel to “upstream” emissions embedded in purchased or processed products to “downstream” emissions associated with transporting and disposing of products. (World Resources Institute and the World Business Council on Sustainable Development Protocol)

Composite Energy Model with Options

The analysis team next took some in-depth approaches towards modeling the energy flow (input and output) in the overall campus energy system, applying concepts of thermodynamics and numerous cost variables (see Chapter 6). This extensive modeling was needed to determine whether preserving the cogeneration plant was important for the "greater grid"—the energy distribution system in the state or region beyond Stanford. In parallel, the team started the following investigations:

- A revised long-range utilities growth model was developed. Its calculations needed to be tied to growth in campus gross square footage (GSF), thus reflecting not just total units (kWh) of energy used, but average energy intensity (kWh/GSF). The energy intensity (or load growth) projections were calculated using the GSF growth projections from the University Planning Office (Appendix C). The exercise reaffirmed that Stanford was growing in terms of both GSF and kWh/GSF due to its laboratory buildings and increased plug load. Total electrical growth was around 4%, chilled water growth around 6%, and steam growth around 2%.

- Two parallel and complementary energy models were developed to compare options for meeting campus energy load. The models were periodically calibrated and reconciled to assure reliable results for decision making; common assumptions and variables used are described in Chapter 6 and the associated appendices.

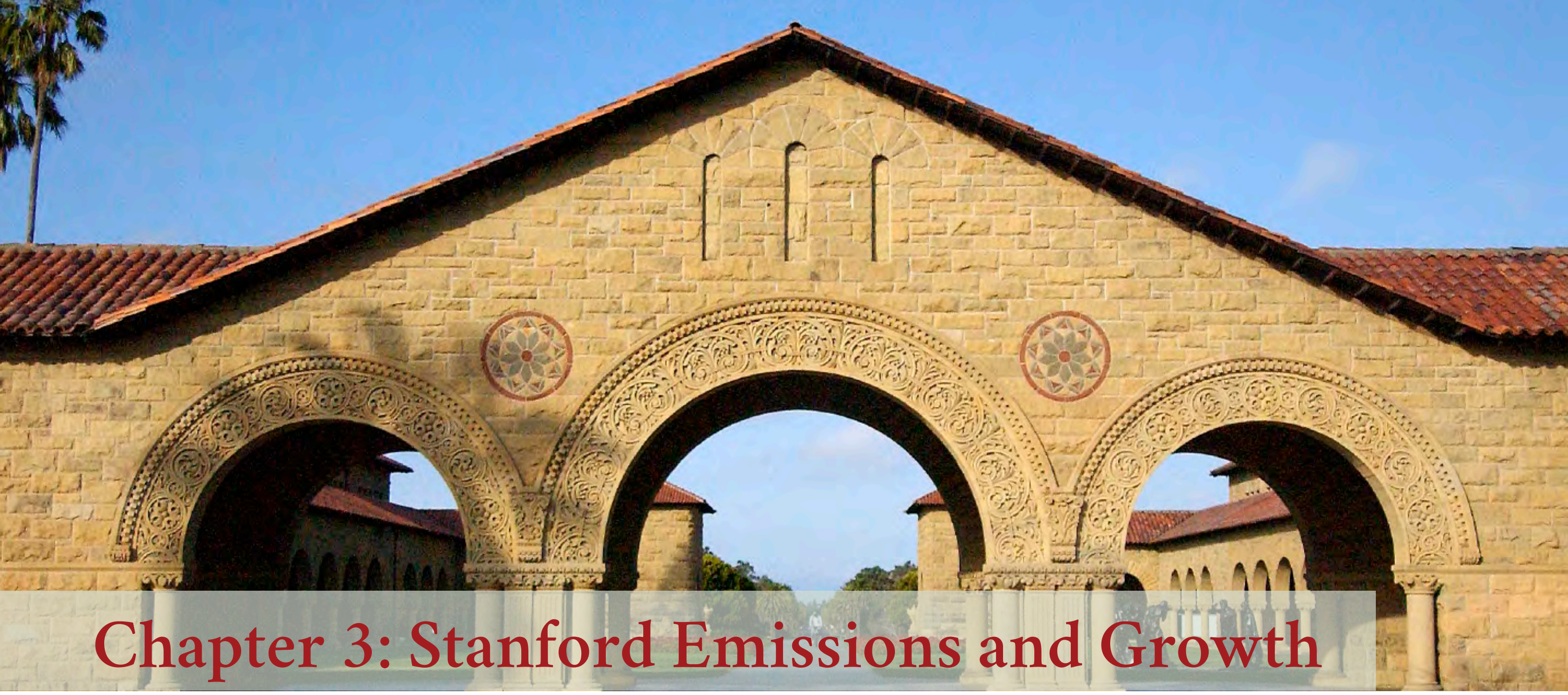
- To facilitate advanced modeling, Utilities next began assembling even more detailed information on campus energy flows to, including hourly energy flows into and out of the CEF for a full year. An encouraging discovery occurred along the way regarding the potential for recovering heat from the existing chilled water system as well as for reducing heat distribution line losses by switching from a steam to a hot water distribution system. Initial calculations showed that a heat recovery system could reclaim about 70% of the heat from the chilled water system and satisfy 50% of Stanford's heating load, substantially reducing the necessity for heat generation at the cogeneration plant. Though extra electricity would be required to reclaim this available heat, the net energy gain was still attractive, and switching from CHP to SHP would allow the power component of Stanford's energy portfolio to be supplied with renewable energy if desired. This appeared to be a better proposition for emissions reduction, as well as the utilities budget, in the long run. Given the high emissions reduction potential of a heat recovery system, the team focused on analyzing its long-term viability at Stanford. The details of this analysis and its findings are in Chapter 6 and related appendices.

- The Energy and Atmosphere Sustainability Working Team created a subcommittee to investigate the role of carbon instruments in Stanford's Energy and Climate Plan. The team considered whether carbon instruments should play a critical role in the planning process, given the rapidly evolving and uncertain market and mechanism for these instruments in California and nationwide. The findings are discussed in Appendix A.

Preparation of Recommendations

After completion and internal peer review of this Energy and Climate Plan, an external peer review of the analyses and conclusions developed by SEM was commissioned in January 2009. Two independent consulting firms reviewed the models and assumptions used and examined whether any other major options for long-term energy supply should have been considered. They also provided advice on the cost, methods, timeframes, and other considerations involved in converting the campus steam distribution system to a hot water system. The detailed peer review reports are available upon request, and the summary findings are discussed in Chapter 6.

From the start, the Energy and Climate Plan was intended to take a holistic approach towards long-term energy and climate planning, including major infrastructure improvement to reduce dependence on fossil fuel and protect against cost volatility and regulatory uncertainty. The following chapters provide details on the emissions inventory, growth projections, and various energy and climate solution options.



Chapter 3: Stanford Emissions and Growth

Making an inventory of the source and magnitude of emissions is the first step in preparing an energy and climate plan. Stanford has been accounting for its Scope 1 and Scope 2 emissions as a member of the CCAR and TCR since 2006. This accounting process expedited the development of opportunities for emissions reduction in the Energy and Climate Plan. This chapter describes the protocols the Stanford emissions inventory follows, quantifies the campus emissions, and most importantly, outlines the campus emissions growth trends underlying short- and long-term energy and climate planning.

Protocols for the Emissions Inventory

In 2001, the State of California created the nonprofit CCAR to facilitate the voluntary accounting and reporting of GHG emissions within the state. The CCAR established a General Reporting Protocol based on the World Business Council for Sustainable Development (WBCSD) Greenhouse Gas Protocol. In 2010, the CCAR transitioned its membership to TCR, a nonprofit emissions registry for North America.

The World Resources Institute and the WBCSD have defined three scopes of GHG emissions to avoid overlap in accounting by different organizations. The WBCSD Greenhouse Gas Protocol requires organizations to separately account for and report on Scope 1 and 2 emissions, with Scope 3 accounting and reporting being optional. Likewise, the CCAR General Reporting Protocol required participants to file inventories of Scope 1 and 2 emissions with independent third-party verification, and encouraged them to file inventories of Scope 3 emissions. Stanford used this protocol to prepare and file its GHG emission inventories through 2009. In 2010, Stanford transitioned to the TCR protocol, and it has received third-party verification of its emissions inventory.

Scope Descriptions

Scope 1: Direct GHG emissions

Direct GHG emissions from sources that are owned or controlled by the organization. Examples are emissions from combustion in owned or controlled boilers, furnaces, or vehicles.

Scope 2: Electricity indirect GHG emissions

GHG emissions from the generation of electricity purchased by the organization. Scope 2 emissions occur at the facility where electricity is generated, not at the end user site.

Scope 3: Other indirect GHG emissions

All other indirect emissions. Scope 3 emissions are a consequence of the activities of the organization but come from sources it does not own or control. Examples include extraction and production of purchased materials and use of sold products and services.

Climate Registered™

Stanford University Emissions Inventory

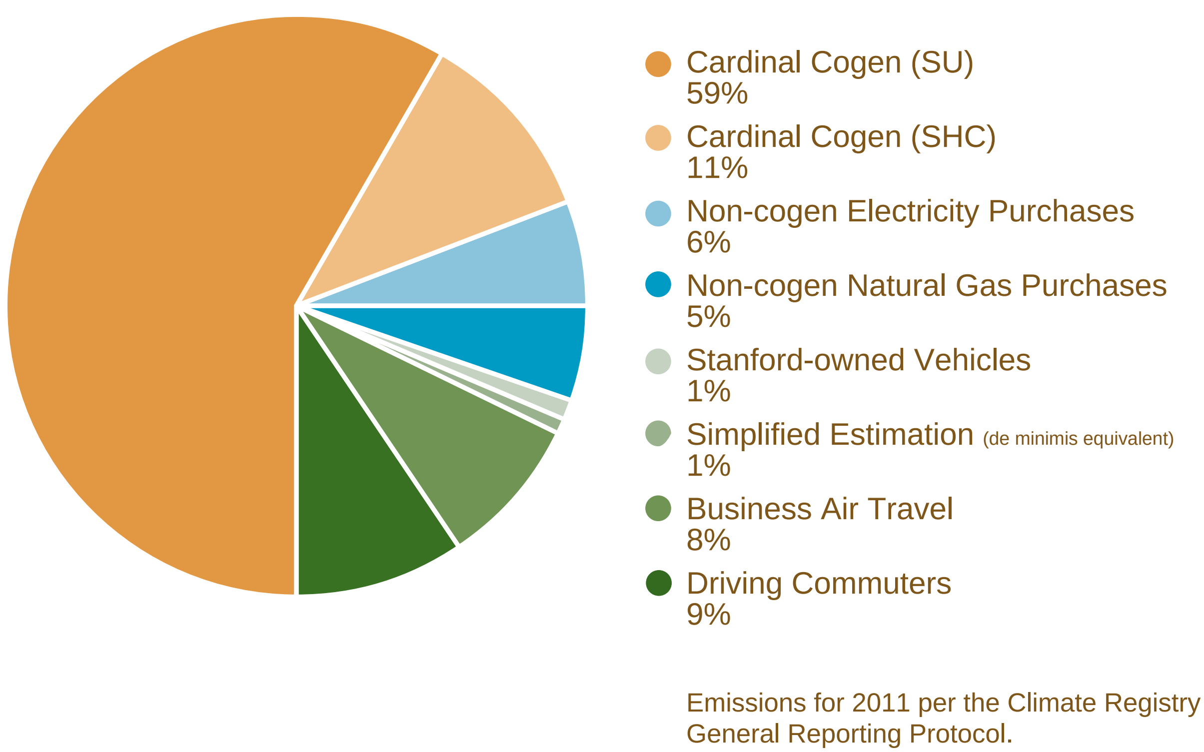
Stanford University GHG reporting covers the Stanford main campus, which does not include Stanford Hospital and Clinics (SHC) or SLAC National Accelerator Laboratory.[1] Stanford's certified emissions inventory can be viewed at https://www.climateregistry.org/CARROT/public/Reports.aspx.

- In 2006, Stanford's initial inventory under Scope 1 and 2 of core GHG emissions (CO_2 equivalent) from the main campus totaled approximately **168,400 metric tons**.
- In 2007, Stanford's initial inventory under Scope 1 and 2 of core GHG emissions (CO_2 equivalent) from the main campus totaled approximately **182,900 metric tons**.
- In 2008, Stanford's initial inventory under Scope 1 and 2 of core GHG emissions (CO_2 equivalent) from the main campus totaled approximately **180,700 metric tons**.
- In 2009, Stanford's initial inventory under Scope 1 and 2 of core GHG emissions (CO_2 equivalent) from the main campus totaled approximately **182,400 metric tons**.
- In 2010, Stanford's initial inventory under Scope 1 and 2 of core GHG emissions (CO_2 equivalent) from the main campus totaled approximately **195,800 metric tons**.
- In 2011, Stanford's initial inventory under Scope 1 and 2 of core GHG emissions (CO_2 equivalent) from the main campus totaled approximately **198,400 metric tons**.
- The campus has also prepared unofficial inventories of its Scope 3 emissions and emissions attributed to steam and chilled water deliveries to SHC from Stanford's CEF.
- Emissions of the five other GHGs identified in the Kyoto Protocol (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) were reported to the CCAR for the first time in 2009. They make up one-tenth of one percent of Stanford's total GHG emissions.

Figure 3-1 shows the official Scope 1 and 2 emissions inventory and the unofficial Scope 3 emissions for the university, plus CEF emissions attributable to steam and chilled water deliveries to the SHC, for 2011.

1 SHC and the SLAC National Accelerator Laboratory are distinct organizations that do not fall under the university's operational control.

Figure 3-1 Stanford University Emissions Inventory 2011 (metric tons CO_2)



Source: Stanford Utilities, per CCAR, General Reporting Protocol. Total emissions in 2011, including Scope 3, were 276,500 metric tons CO_2 equivalent.

Campus Growth and Emissions Trends

Long-term energy demand projections were developed based on projections of campus growth and expected average energy intensity per square foot.

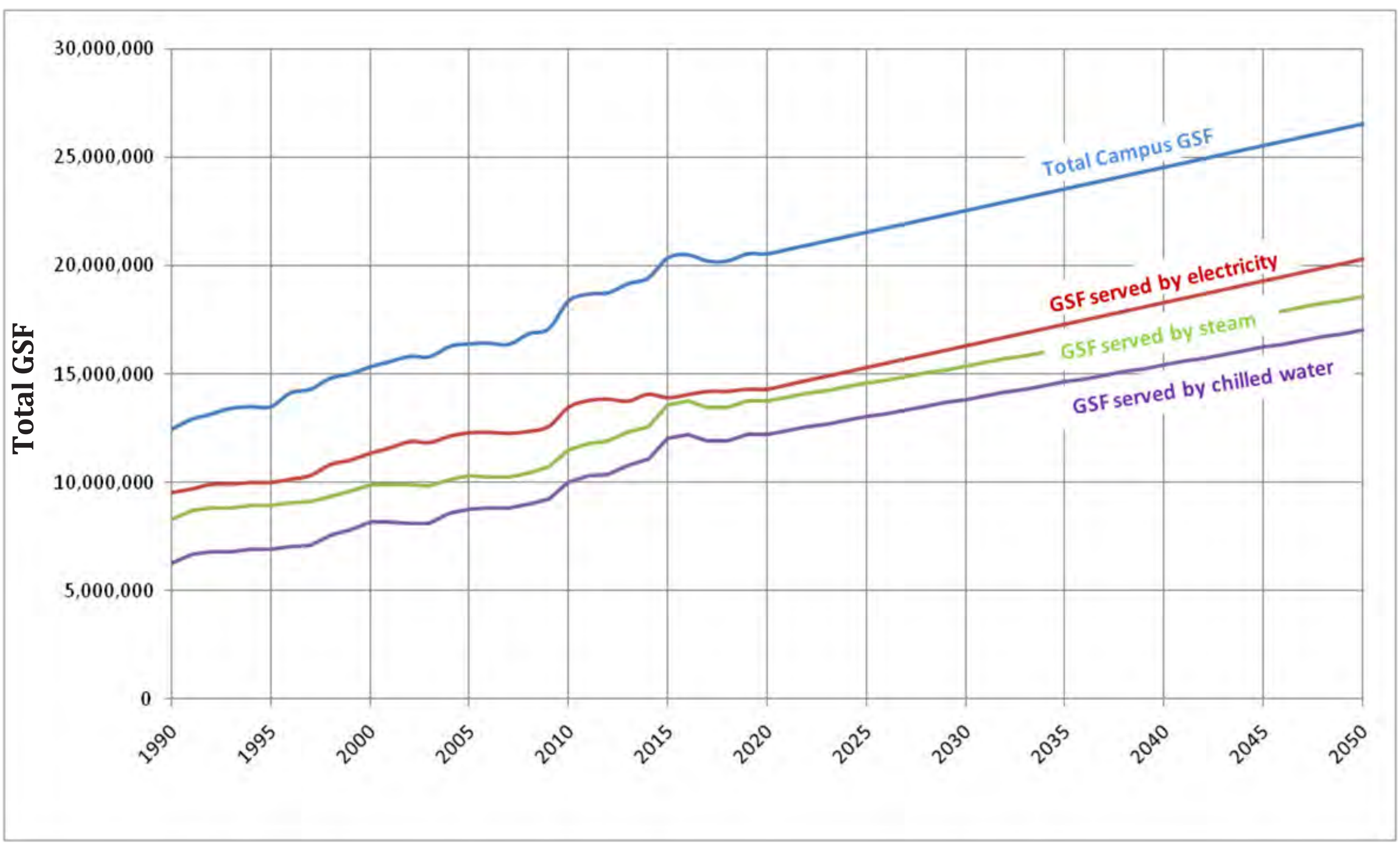
The campus GSF served by each type of energy service (electricity, steam, and chilled water) as of 2008 were determined based on actual data and planned growth from the campus capital plan, which covers the period through approximately 2020. For the period after 2020, the following three growth scenarios were developed consistent with the campus Sustainable Development Study, recently completed by the Planning Office:[2]

- **AGGRESSIVE GROWTH:** 300,000 GSF/year
- **MODERATE GROWTH:** 200,000 GSF/year (considered most likely scenario, see Figure 3-2)
- **MINIMAL GROWTH:** 115,000 GSF/year

More specifically, projections of average energy intensity per square foot were calculated by first determining the overall net growth rates in energy demand over the past 20 years. These rates—4% for electricity, 6% for chilled water, and 2% for steam—were then divided by actual growth in GSF over the same period to derive an average change in energy intensity per GSF. The resulting percentages were applied to the GSF projections above to develop growth projections for each of the three energy services. These projections are provided in Appendix C.

2 The Sustainable Development Study is available at http://sds.stanford.edu/.

Figure 3-2 Stanford University Space Growth Projections (most likely scenario)



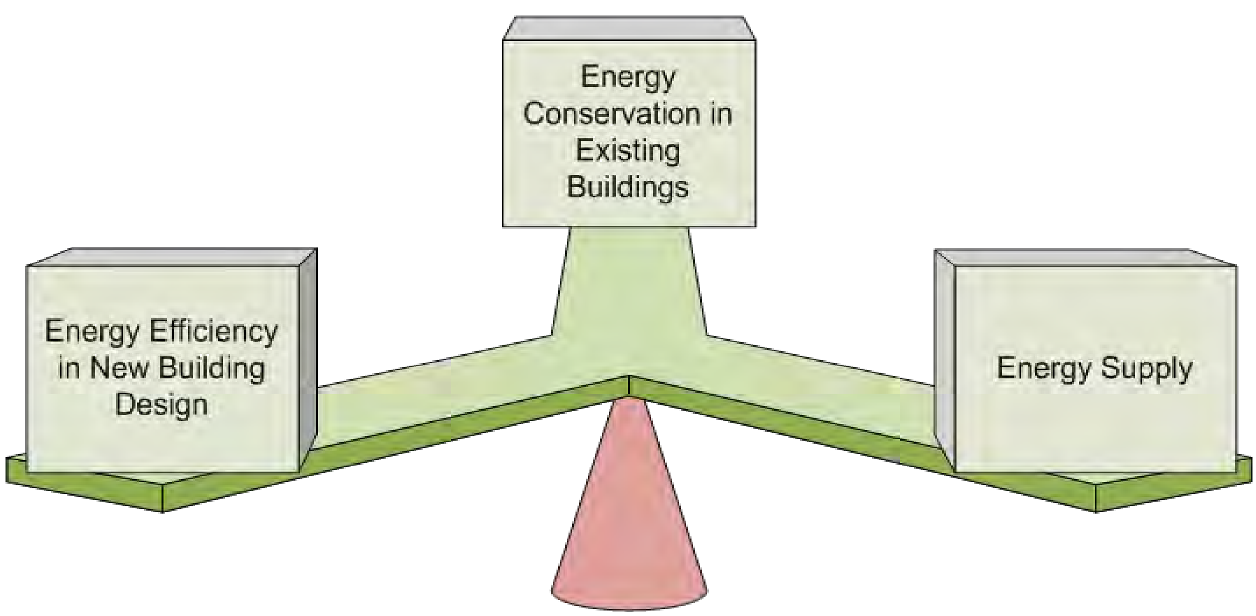
Source: Stanford Utilities. excludes parking structures, Quad 90 buildings, and faculty housing. Includes student housing.

Three Critical Paths: A Balanced Approach to Finding Solutions

Given Stanford's plans for significant growth to support its academic mission, its large and diverse existing campus building inventory, and its current reliance on natural gas co-generation for energy (the main source of its GHG emissions), a successful long-range Energy and Climate Plan requires a balance among investments in new buildings, existing buildings, and energy supply.

- **High-performance new building design:** Given the university's significant growth plans, constructing high- performance new buildings to minimize the impacts of growth on campus energy systems and GHG emissions is a key strategy. The Guidelines for Sustainable Buildings, originally published in 2002 and updated in 2008, in combination with the Guidelines for Life Cycle Cost Analysis and the Project Delivery Process manual, provide the framework for minimizing energy demand in new construction and major renovation projects on campus (Chapter 4).
- **Energy conservation in existing buildings:** Since the 1980s, Stanford has employed building-level energy metering of all its facilities to understand how and where energy is being used in order to facilitate strong energy-efficiency programs. While the university has pursued aggressive energy conservation for many years, the continuation and expansion of programs like the Whole Building Energy Retrofit Program is another key strategy of the Energy and Climate Plan (Chapter 5).
- **Greener energy supply:** Stanford has also been one of the most progressive universities in pursuing efficient energy supply through use of natural gas–fired cogeneration for virtually all its energy since 1987. However, fossil fuel use in cogeneration is the largest contributor of GHG emissions for Stanford, and conversion to new options that assure reliability, contain cost, and reduce GHGs is an essential third strategy in the Energy and Climate Plan (Chapter 6).

Figure 3-3 A Balanced Approach to Energy and Climate Solutions



Chapters 4, 5, and 6 provide detailed analysis of options in each of these three areas. Chapter 7 offers the total portfolio of solutions in this plan.

Chapter 4: Minimizing Energy Demand in New Construction

While the university has pursued aggressive demand-side energy management for many years, continued campus expansion calls for even greater attention to initial demand reduction and energy efficiency in new building design. In addition, the energy efficiency and water conservation standards for new buildings, existing buildings, and major renovations are no longer reviewed in isolation, but in the context of the whole campus, as each project ties into the electricity, heat, chilled water, and domestic water loops. This chapter outlines the key standards for Stanford's high-performance, sustainable built environment.

Optimized Space Utilization

Before any building project, Stanford conducts a rigorous space utilization study to see if renovation of existing buildings can create space for new needs. The Department of Capital Planning has updated the university's Space Planning Guidelines and conducted numerous studies to ensure that Stanford adds new space only when truly necessary. Studies confirmed that offices applying the guidelines could recover up to 10% of their existing space.

To further encourage more efficient use of office space, Stanford requires selected schools to pay a charge for underutilized space. Several schools are working to reduce this charge through efforts such as conducting master space plan studies and renovating spaces in conformance with the revised Space Planning Guidelines.

New Building Standards

As described in Stanford's Project Delivery Process (PDP) manual, the university is committed to providing a sustainable and inspiring built environment for its students, faculty, staff, and visitors. At Stanford, sustainability refers to ensuring that buildings not only use energy, water, and other natural resources efficiently, but also provide a safe, productive, and educational environment and meet the teaching and research needs of faculty, staff, and students. Stanford recognizes that the building industry has a tremendous impact on the natural environment, both regionally and globally, and the university has the opportunity to take a leadership role in creating buildings that conserve resources and inspire users. This requires an integrated process with sustainability as a base criterion in all development stages.

Stanford's PDP manual therefore incorporates sustainability through the Guidelines for Life Cycle Cost Analysis, the Guidelines for Sustainable Buildings, salvage and recycling programs, and strict commissioning processes. In 2008, Stanford updated the Guidelines for Sustainable Buildings to include aggressive energy and water reduction goals. New construction and major renovation projects on campus are expected to use 30% less energy than code (ASHRAE 90.1-2004 / CA Title 24) and consume 25% less potable water than comparable buildings. Setting energy and water goals instead of designing prescriptive measures allows the project teams flexibility to choose the best technologies and practices that meet the needs of the occupants and fit within the project budgets.

Stanford's guidelines, which adapt the U.S. Green Building Council (USGBC)'s Leadership in Energy and Environmental Design (LEED) system and the U.S. government's Labs21 guidelines to the university setting, address a wide spectrum of qualities across five categories. They specify attention to the following areas:

SITE DESIGN AND PLANNING

- Focus on district development driven by the Campus Master Plan
- Pedestrian and bike connections
- Building siting to reduce energy use through east-west axial elongation

ENERGY USE

- High-performance building envelopes, including high-efficiency glazing and shading devices
- Effective control systems for lighting and HVAC
- Energy modeling to optimize life cycle cost decisions
- Renewable energy systems where economic

WATER MANAGEMENT

- Native and/or drought-tolerant landscapes
- Use of alternative water sources for both interior and exterior applications
- Efficient fixtures and systems for water conservation

MATERIALS, RESOURCES, AND WASTE

- Salvage and reuse of demolished materials
- Recycling and reduction of construction waste
- Use of environmentally appropriate materials and products, including low-VOC paints

Photo: Stanford's recycled water facility supplies many new buildings, including the new Science and Engineering Quad and Knight Management Center.

INDOOR ENVIRONMENTAL QUALITY

- Integrated daylighting
- Use of natural ventilation

Core Sustainability Features

In the new high-performance buildings on campus, natural ventilation, sophisticated control systems, and daylight-focused design leverage Stanford's climate and maximize energy-saving opportunities. In addition, Stanford has expanded the service area for its recycled water system, which now sends cooling tower blowdown from the CEF to flush toilets and urinals throughout more than one million square feet of the new high-performance buildings.

Continual Innovation and Learning through Building Design

Stanford's internal guidelines also encourage experimentation with new technologies. The university recognizes that not all new building projects will individually achieve established efficiency targets, but Stanford engineers and architects transfer information learned through design, construction, and operation of new buildings to subsequent buildings with the goal of achieving these targets in the overall building portfolio.

For example, the anchor building of the second Science and Engineering Quad (SEQ), the Yang and Yamazaki Environment and Energy Building (Y2E2), exceeded Stanford's Guidelines for Sustainable Buildings and solidified the case for high-performance buildings. The success of Y2E2 spurred the university to commit to constructing the subsequent three buildings in the 500,000-square-foot complex "to the same level of environmental standards [as Y2E2], so that we can become a leader not only in research, but in the practice of building new facilities" (as Stanford President John Hennessy told the Faculty Senate in 2009). Similarly, former Stanford Board of Trustees Chair Burt McMurtry lauded Y2E2 as a "model for what we should be thinking about for practically all of our construction" in terms of environmentally sustainable buildings.

It is no coincidence that the university's new high-performance buildings house many of its most cutting-edge, interdisciplinary, and recognized academic programs. In many ways the sustainable design features directly support the mission of these programs. Whether by passive facilitation of collaboration through its circulation patterns and inclusion of open space or by active engagement through its use as a research subject, each new building serves as a teaching tool for the university.

Impact of Standards

In the late 1990s Stanford renewed its commitment to reducing the impact of new structures on the environment. Early successes at the Leslie Shao-ming Sun Field Station and the Global Ecology Center (GEC) led it to set specific energy and water targets for subsequent buildings. Development of life cycle cost guidelines and standardized rule sets for building energy models has enabled Stanford's building design teams to make the most educated sustainability and efficiency choices.

Photo: The other three buildings in Stanford's SEQ are being modeled after the successful Y2E2.

Setting targets above the already strict California Title 24 building codes and ASHRAE 90.1 standards, Stanford has reduced energy use by over 40% and reduced carbon emissions by over 12,000 metric tons to date for all the buildings described in this chapter. Stanford has also significantly reduced energy and water costs in these buildings. The funds saved can be used for teaching and research.

Examples of High-Performance Buildings at Stanford

Many recently completed high-performance building projects meet or far exceed energy and water efficiency recommendations outlined in Stanford's guidelines. Across the board, each subsequent high-performance building emphasizes the success of its predecessors and capitalizes on important lessons learned to achieve greater sustainability within the built environment.

Photo: Leslie Shao-ming Sun Field Station

Leslie Shao-ming Sun Field Station at the Jasper Ridge Biological Preserve (2002)

The 10,000-GSF Leslie Shao-ming Sun Field Station is located on the 1,200-acre Jasper Ridge Biological Preserve southwest of the main campus. From the beginning the Sun Field Station was designed to demonstrate principles of sustainability and energy efficiency with a goal of net zero annual carbon emissions. Another key design principle was the extensive use of recycled or reclaimed building materials to reduce consumption of virgin materials. The Sun Field Station provides an award-winning natural laboratory for researchers and rich educational experiences for students.

Key sustainability features include:

- A 22kW grid-connected photovoltaic (PV) system
- Daylight harvesting
- A solar thermal system for space heating and domestic water heating
- A sophisticated energy monitoring system used for educational purposes and performance measurement
- Waterless urinals, dual-flush toilets, and tankless water heaters
- Use of salvaged materials for siding, brick paving, casework, furniture, and bathroom partitions
- High-volume fly ash concrete

Photo: Carnegie Institution Global Ecology Center

Carnegie Institution Global Ecology Center (2004)

The 11,000-GSF GEC is a two-story laboratory and office building with a research focus on sustainability and minimizing climate change. It is an extremely low-energy building that emits 72% less carbon and uses 33% less water than a comparable building constructed with conventional practices. According to a report prepared by the Rocky Mountain Institute in 2011, the GEC is one of the most energy-efficient labs in the United States.

Key sustainability features include:

- A night-sky radiant cooling system
- Daylight harvesting
- Natural ventilation
- High-volume fly ash concrete
- Exterior made from salvaged wine-cask redwood.

Photo: Yang & Yamazaki Environment & Energy Building (Y2E2)

Yang & Yamazaki Environment & Energy Building (2008)

Y2E2 showcases high-performance design and construction well beyond Stanford's guidelines. It provides a home for multidisciplinary research and teaching focused on sustainability, and the building itself serves as a learning tool and living laboratory.

The 166,500-GSF building uses 42% less energy than a traditional building of comparable size and 90% less potable water than one with traditional fixtures and systems. Significant portions of the building require no air conditioning, and much of it relies on natural light during the day. Y2E2 is currently undergoing certification by the LEED for Existing Buildings program.

Key sustainability features include:

- A high-performance envelope (roof, walls, windows, sunshades, and light shelves) that reduces heating and cooling loads
- Active chilled beams to supply heating and cooling more efficiently
- Natural ventilation via four internal atria, windows, and vents
- A 14kWdc grid-tied solar PV installation using three different types of modules to both offset electrical use and provide a learning opportunity for students
- Water conservation systems, including waterless urinals and dual-flush toilets; use of recycled water from Stanford's CEF for toilets and lab processes
- Extensive use of recycled materials and sustainable products, such as bamboo and drywall
- Exposed concrete floors, which significantly reduced carpet use and avoided use of tons of raw materials
- Extensive electrical and HVAC monitoring to improve building performance and provide a learning opportunity for students

Photo: Jen-Hsun Huang Engineering Center

Photo: Spilker Engineering and Applied Science building

Jen-Hsun Huang Engineering Center (2010)

The Huang Engineering Center (HEC) is the second completed building of the four that will make up the award-winning SEQ2. HEC is mostly offices and conference rooms but also houses a large auditorium, a popular café, and a large separately metered server room. Like Y2E2, HEC epitomizes high-performance design and construction. The 130,000-GSF building uses 46% less energy than a traditional building of comparable size.

Key sustainability features include:

- A high-performance envelope (roof, walls, windows, sunshades, and light shelves) that reduces heating and cooling loads
- Daylight and photocell technology to reduce electrical lighting loads
- A combination of natural ventilation and active and passive chilled beams
- Rapidly renewable materials in architectural woodwork and furniture
- Use of the university's recycled water system to flush toilets and urinals
- A 30kWdc solar PV installation to reduce electricity demand
- Salvage of 316 seats from the demolition of Kresge Auditorium; the seats were refurbished and redeployed to complete the NVIDIA auditorium

Spilker Engineering and Applied Science (2010)

The 104,000-GSF Spilker Engineering and Applied Science building is the third building in SEQ2 and supports interdisciplinary programs, including research at the atomic scale with a range of applications—new drugs, innovative designs for new semiconductors, improved communications networks, improved water purification methods. Spilker Engineering was designed with many of the same features as Y2E2 and HEC and shares their ambitious energy and water goals.

Key sustainability features include:

- A high-performance envelope (roof, walls, windows, sunshades, and light shelves) that reduces heating and cooling loads
- Extensive use of daylight and photocell technology
- Rapidly renewable materials in architectural woodwork and furniture
- Use of the university's recycled water system to flush toilets and urinals
- A 30kWdc solar PV installation to reduce electricity demand

Photo: Lorry I. Lokey Stem Cell Research Building

Lorry I. Lokey Stem Cell Research Building (2010)

The Lorry I. Lokey Stem Cell Research Building (SIM1), a 200,000-GSF School of Medicine building, has a basement vivarium and three above-grade floors with research labs and support facilities. Stanford established targets comparable to a LEED-Silver rating for the project. An example of high-performance building in the face of highly technical programmatic requirements, SIM1 serves as a national model for laboratory design and construction. It was built with a goal of energy use 32% below similar laboratory buildings of its type but has far exceeded expectations during its first year of operation.

Key sustainability features include:

- Segregated laboratory and other occupancy types to increase HVAC operating efficiency
- Sloped ceilings in labs for increased daylighting and solar photo cells for lighting control
- Reusable animal cages throughout the vivarium, eliminating cage wash equipment and avoiding the use of approximately nine million gallons of water annually
- Elimination of relative humidity controls from air-handling equipment and the vivarium rooms due to the local climate
- Innovative room-level heating and cooling approach that reduces energy use significantly

Photo: Li Ka Shing Center for Learning and Knowledge

Li Ka Shing Center for Learning & Knowledge (2010)

The Li Ka Shing Center for Learning and Knowledge, a 118,000-GSF School of Medicine building, includes medical simulation and virtual reality environments to advance teaching, learning, and knowledge management. The Li Ka Shing Center was designed to use 25% less energy and 40% less water than buildings of similar function. Four above-grade floors house a conference center, classrooms, and study areas. The basement features the Center for Immersive and Simulation-based Learning.

Key sustainability features include:

- Use of recycled water for flushing toilets and urinals
- High-performance glazing, sun shades, and a reflective roofing surface
- An HVAC system with chilled beams and displacement ventilation
- Diversion of 95% of construction and demolition debris from landfill

Photo: Knight Management Center

Knight Management Center (2011)

The Stanford Graduate School of Business (GSB) has formally dedicated and opened the Knight Management Center, a new facility of eight buildings designed to support teaching and research functions. The center received a LEED-NC Platinum certification, the USGBC's highest rating for sustainability in the built environment. The 360,000-GSF facility underscores what is taught in many GSB electives, such as Environmental Entrepreneurship and Environmental Science for Managers and Policy Makers, as well as in core classes covering sustainability across business functions and the MBA/MS Environment and Resources joint degree program.

Among many significant sustainability features, the GSB solar PV system stands out. The system generates over 500,000 kWh per year, enough electricity to meet 12.5% of the center's demand. Rated for a peak output of 355 kW, the PV installation is currently the largest on campus. As with other features of the new facility, the university's careful monitoring and commissioning programs will ensure performance meets design expectations.

Key sustainability features include:

- A high-performance envelope (roof, walls, windows, sunshades, and light shelves) that reduces heating and cooling loads
- Natural ventilation and night flush, including operable windows and ceiling fans
- Active chilled beams to supply heating and cooling more efficiently
- An extensive building monitoring system to continually evaluate building performance
- Water conservation systems, including dual-flush toilets; use of recycled water from Stanford's CEF for toilets and urinals
- Extensive use of recycled materials and sustainable products, including Forest Stewardship Council–certified wood
- A 355 kWdc PV system

Photo: William H. Neukom Building

Photo: Bioengineering and Chemical Engineering building

William H. Neukom Building (2011)

The William H. Neukom Building, a LEED-Gold equivalent project set to use 30% less energy and water than required by code, strengthens the law school community and overall campus integration by fostering the interdisciplinary collaboration essential to a rich educational experience. Prominently situated south of the existing law school complex, this 65,000-GSF building creates a new focal point along the route that connects the campus's residential and academic precincts and provides much-needed clinic, seminar, meeting, and office space.

Key sustainability features include:

- A high-performance envelope (roof, walls, windows, sunshades, and light shelves) that reduces heating and cooling loads
- Daylight and photocell technology to reduce electrical lighting loads
- Maximized use of natural light
- Automated lighting and HVAC control systems
- Operable windows and ceiling fans to allow natural ventilation

Bioengineering and Chemical Engineering (Expected 2014)

The new Bioengineering and Chemical Engineering building (BioE/ChemE) is the last of the four buildings in SEQ2. The new 227,000-GSF building is currently under construction and will match the architectural character of the neighboring SEQ2 buildings. BioE/ChemE will predominantly comprise both wet and dry laboratory spaces designed for intensive research, as well as shared specialty labs. BioE/ChemE will be completed in spring 2014. Its energy and water goals match those of the other buildings in SEQ2.

Key sustainability features include:

- A high-performance envelope (roof, walls, windows, sunshades, and light shelves) that reduces heating and cooling loads
- A 125 kWdc grid-tied solar PV system to reduce electric demand
- Water conservation systems, including dual-flush toilets, and the use of recycled water from Stanford's CEF for toilets and urinals
- Extensive use of recycled materials and sustainable products, such as bamboo and drywall
- Exposed concrete floors, which significantly reduce carpet use and avoid use of tons of raw materials
- A variable air volume fume hood system
- An innovative room-level heating and cooling approach that reduces energy use significantly

Chapter 5: Reducing Energy Use in Existing Buildings

Reducing energy use in existing buildings is central to creating a sustainable campus. It is also a formidable task, given the growing energy needs of research universities. However, Stanford has a strong foundation for success, building on a decades-long commitment to energy conservation and efficiency, as well as the advantages of a temperate climate and aggressive state building energy codes.

Current energy-saving strategies will continue to decrease consumption in existing buildings, but campus growth is likely to outpace those savings, requiring new efforts. Recent experience illustrates why: total energy use increased 9% from 2001 to 2012, due to new construction, more energy-intensive research, and more people and electricity-using equipment in existing buildings. However, energy intensity (energy use per square foot) has decreased about 10% since 2001. Building on Stanford's substantial successes and drawing on its culture of innovation and leadership, demand-side energy management will continue to be critical to reducing campus GHG emissions. This chapter outlines the key initiatives and strategies for this management.

Energy-Saving Programs

Stanford has several substantial programs to promote energy efficiency and conservation on campus. Each program is designed to serve a unique market sector and provide enabling incentives to the associated decision makers.

Energy Retrofit Program (ERP)

The purpose of the ERP is to reduce overall energy costs on campus by improving the energy efficiency of building components. Since 1993 over 380 ERP projects have been completed, for cumulative annual energy savings of 33 million kWh, or about 15% of the current electricity consumption baseline. ERP projects typically fall into one of three main categories—lighting, HVAC, or plug load. Because they are low risk, use technologies that are well understood, and have a positive return on investment, they are an important part of Stanford's GHG emissions reduction strategy.

Whole Building Retrofit Program

The Whole Building Retrofit Program identifies energy efficiency measures through comprehensive energy studies in Stanford's largest buildings. The program originated in 2004 with a review of the 12 buildings with the highest energy consumption. These initial studies identified $4 million of annual energy savings potential from an investment of $15 million. While pursuing the implementation of energy-saving measures identified in these studies, the program identified other buildings for review and future project work. In total, the program is expected to achieve almost $6 million of annual energy savings at a construction cost of roughly $30 million.

Photo: New high-efficiency ultrasonic humidfier in operation

Photo: Department of Biology greenhouses were outfitted with efficient LED lighting under the ERP program, saving 248,000 kWh/year.

Twelve building projects were completed as of 2012, with 10 more under development. Common energy efficiency measures included:

- HVAC controls upgrades—these allow advanced monitoring and enable energy-saving techniques such as scheduled setbacks, temperature setpoint deadbands, and demand-based air supply temperatures and pressures
- Conversion of constant-volume ventilation systems to variable air volume systems
- Reduction in building exhaust air flow quantity and exhaust stack velocities
- Replacement of steam-based humidification systems with ultrasonic systems

Energy Conservation Incentive Program (ECIP)

Initiated in 2005, Stanford University's ECIP is designed to reduce energy use through human behavior rather than technology. The ECIP uses financial rewards and penalties to promote more efficient daily habits and purchasing decisions by Stanford's schools and administrative units. Each is given an annual electricity budget to manage to and is held responsible for deviations. This program helps reduce electricity use inexpensively and fosters a campus culture that supports energy efficiency activities on both personal and institutional levels. To date, the schools and administrative units have achieved an average annual savings of 3% below budget.

Sustainable IT

As a joint effort between SEM and Information Technology Services, Sustainable IT is able to take a holistic look at the university's computing infrastructure, both the machines themselves and the buildings housing them. Stanford faculty, staff, and students have about 35,000 personal computers, and approximately 6,000 servers are used for administrative and research computing across campus.

Since 2008, Sustainable IT has reached out to users around campus to promote energy-efficient technologies and practices and to bring together staff and faculty to help further these efforts. Sample initiatives include the following:

- **Desktop Computer Power Management:** In 2007, Stanford deployed a centrally controlled desktop power management tool to help set and track power management settings in Windows and Macintosh operating systems. Desktop power management is enabled on over 9,000 computers across the university.
- **Energy-Saving Power Strips:** In addition to turning off computers and monitors, Stanford is working to reduce "phantom" power. When computing peripherals are in standby mode, they continue to draw meaningful amounts of electricity, yet are producing no useful work. By deploying smart power strips, Stanford is able to automatically turn peripherals off when computers go off, thus reducing energy usage.

- **Hardware Procurement:** Stanford has joined the Green Grid (formerly the Climate Savers Computing Initiative), and SEM is working with University Procurement to ensure that Stanford purchases energy-efficient servers whenever possible. On the Stanford Reuse site, used equipment in good condition is offered to others around campus.

- **Data Center Energy Efficiency:** The campus data center is among the buildings using the most energy. Stanford has developed an overall plan to reduce energy usage by modifying the computing infrastructure, the facility, and the other infrastructure components. Specific efforts include revamping the cooling system, restructuring the racks, replacing lighting, enclosing aisles, adding sensors, and enabling more refined monitoring.

- **Server Replacement, Consolidation, and Virtualization:** One of the most effective ways to reduce energy in the data center is to reduce the number of computers it takes to produce the same output. Replacing old hardware with new, more energy-efficient hardware, consolidating underutilized servers, and deploying server virtualization are all means to achieve this goal.

Photo: Data center end-aisle isolation

Building Operations

Stanford deployed its first centralized energy management and control system in the 1980s to monitor building-level utility interface, control major building systems, and perform system scheduling. Coupled with an experienced operations and maintenance (O&M) staff, adept building operating strategies have been able to achieve significant energy savings.

- **Scheduling:** Turning off building HVAC systems when they are not needed saves energy and reduces GHG emissions at minimal cost. Established campus-wide indoor temperature guidelines also achieve savings. Both can be implemented with relatively simple software solutions and increased communication between organizations and control systems.

- **Excessive Use Monitoring:** Stanford has used an automated excessive use monitoring software tool since 2004. This speeds up the identification and correction of significant problems with building operation. A number of options for enhancing this system are currently being evaluated. These include new monitoring-based commissioning and fault detection and diagnostic tools that can build upon the growing number of metering and control system points available in campus buildings.

- **HVAC Recommissioning:** Building HVAC recommissioning is a process for periodically reviewing operation of building heating, ventilation, and air conditioning systems to ensure they are performing at their optimum design efficiency. Energy savings of 1% to as much as


Photos: Room Temperature Biological Sample Storage program. Current (left): Samples are stored in energy-intense freezers. Future (right): Samples are kept at a constant humidity in a dry storage cabinet. The new technology is in the wells of the plates and tubes, offering the advantage of a dense storage footprint.

10%, particularly in steam and chilled water, are achievable by "tuning up" existing systems without making any physical improvements to buildings or systems. In addition, the process helps identify opportunities for physical upgrades to buildings and systems that may be funded through the ERP or other programs.

Review and Adoption of Emerging Technologies

While continually deploying energy efficiency best practices within existing buildings, Stanford also looks to the future for new technologies that will further reduce energy needs. The university has a formal process for identifying, screening, evaluating, and demonstrating emerging energy-efficient technologies. By participating in user groups, producing technical studies, and deploying on-campus projects, Stanford promotes the development and adoption of new solutions. Examples of these technologies include the following.

High-Efficiency Transformers

Low-voltage transformers convert the 480-volt power delivered at a building's entrance to the 120-volt power supplied at its electrical outlets. A typical building may have as many as half a dozen distribution transformers in various electrical rooms. The amount of power a transformer loses in the conversion process is a measure of its efficiency. Efficiency increases can substantially affect total building electrical consumption because transformers operate continuously, whether outlets are being used or not. Furthermore, because transformers emit wasted electricity as heat, inefficient transformers place a higher burden on a building's cooling system.

Stanford recently entered a partnership with Powersmiths® that will lead to extensive use of higher-efficiency transformers for new construction and building renovations. The E-Saver-3 transformers meet the Department of Energy's CSL-3 standard, which offers the optimal life cycle balance between improved efficiency and additional cost. Upgrading only 75 standard low-voltage transformers to the CSL-3 standard would save approximately 450,000 kWh each year.

Room-Temperature Biological Sample Storage

Stanford University has completed a pilot project to evaluate an innovative technology that promises to achieve sustainability goals by reducing laboratory energy consumption (along with associated costs and GHG emissions), optimize use of valuable lab space, and better protect priceless biological samples in the event of an earthquake or other disaster. Using a stabilization technology developed by Biomatrica®, biological samples such as DNA and RNA can be safely protected and stored at ambient (room) temperature as opposed to traditional storage in ultra-cold freezers.

The four-month project engaged 12 research laboratories to assess the number of samples that could be moved from freezers to ambient-temperature storage, validate the stor-

Photos: Lighting projects across campus work to improve energy efficiency. Left: Typical outdoor lighting fixture. Center: Pilot LED outdoor streetlamp. Right: High-efficiency LED stage lighting.

age technology, actually transfer 70,000 samples from freezer storage to room-temperature storage, and extrapolate the potential benefits to the entire campus over 10 years. Adoption of this technology for the existing sample collection alone could reduce annual electricity use by nearly two million kWh and chilled water consumption by over 300,000 ton-hours (about 2% and 0.5% of the campus totals, respectively), thereby avoiding more than 800 metric tons of carbon dioxide emissions. Such an investment could pay for itself within two years.

Outdoor Lighting

Lighting of outdoor spaces such at paths, streets, parking lots, and congregating areas serves multiple purposes. In addition to providing general illumination, the lighting must satisfy aesthetic and security requirements. Stanford's recent outdoor lighting study quantified the baseline inventory of outdoor lighting fixtures and the potential energy savings of various emerging technologies, including LED and induction lighting. Such technologies have since been deployed on a limited basis to assess their impact on perceived color and the comfort of passersby. Future full deployment of high-efficiency outdoor lighting will reduce total campus electricity consumption about 1%.

LED Lighting Demonstration

In 2011 Stanford completed a lighting demonstration project to assess the efficiency and efficacy of new LED-based general-purpose lighting fixtures. Specifically, new two-foot by two-foot LED troffers were compared to baseline fluorescent tube fixtures. Comparing energy performance was relatively simple. However, the greatest value of the demonstration was enabling various university stakeholders to look at an actual installation on campus and assess for themselves the look and feel of the light.

An advanced LED auditorium lighting demonstration was initiated in 2012. This uses new multi base color LEDs to replace the original incandescent halogen technology. The new fixtures use only 110 watts compared to the 575 used by the old Fresnel-type fixtures. The demonstration also highlights non-energy benefits of the new technology: the new LEDs can be programmed to produce a variety of colors and hues, eliminating the need for technicians to apply and switch color films.

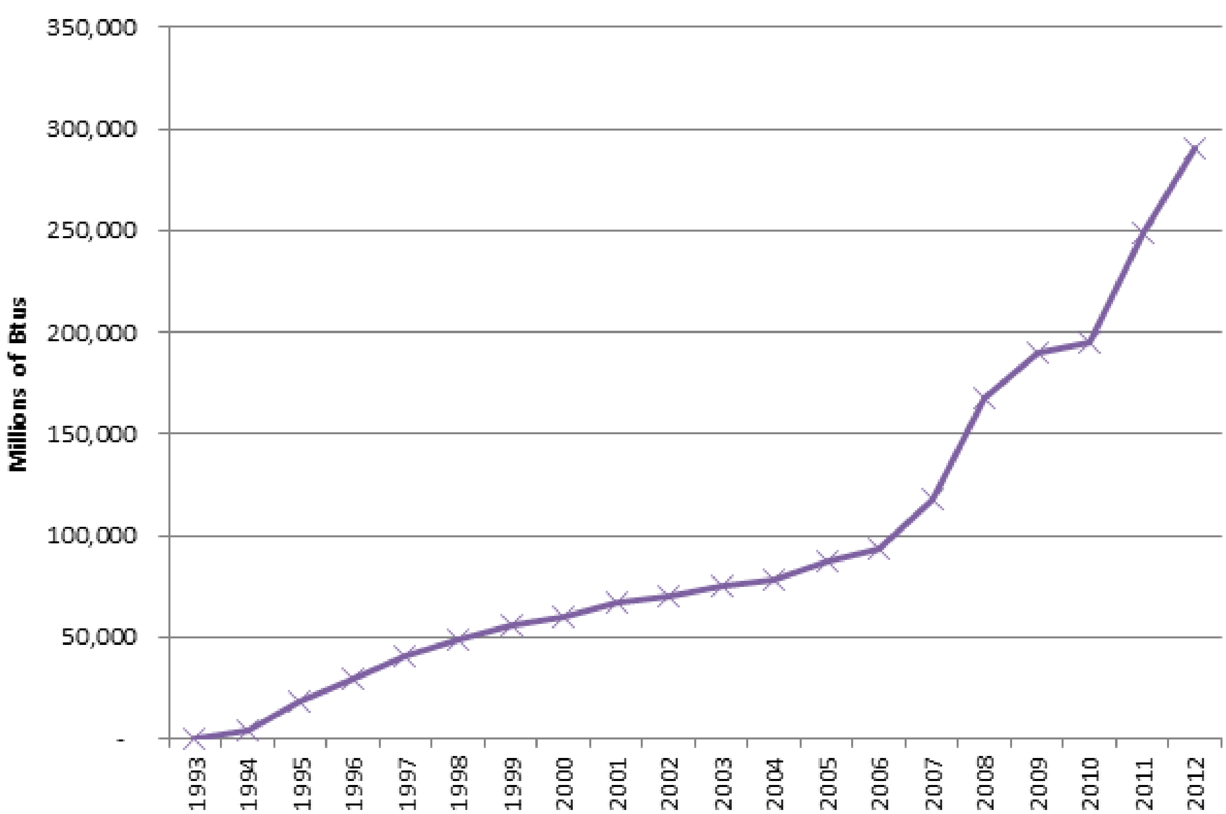
Automated Fault Detection and Diagnostics Software

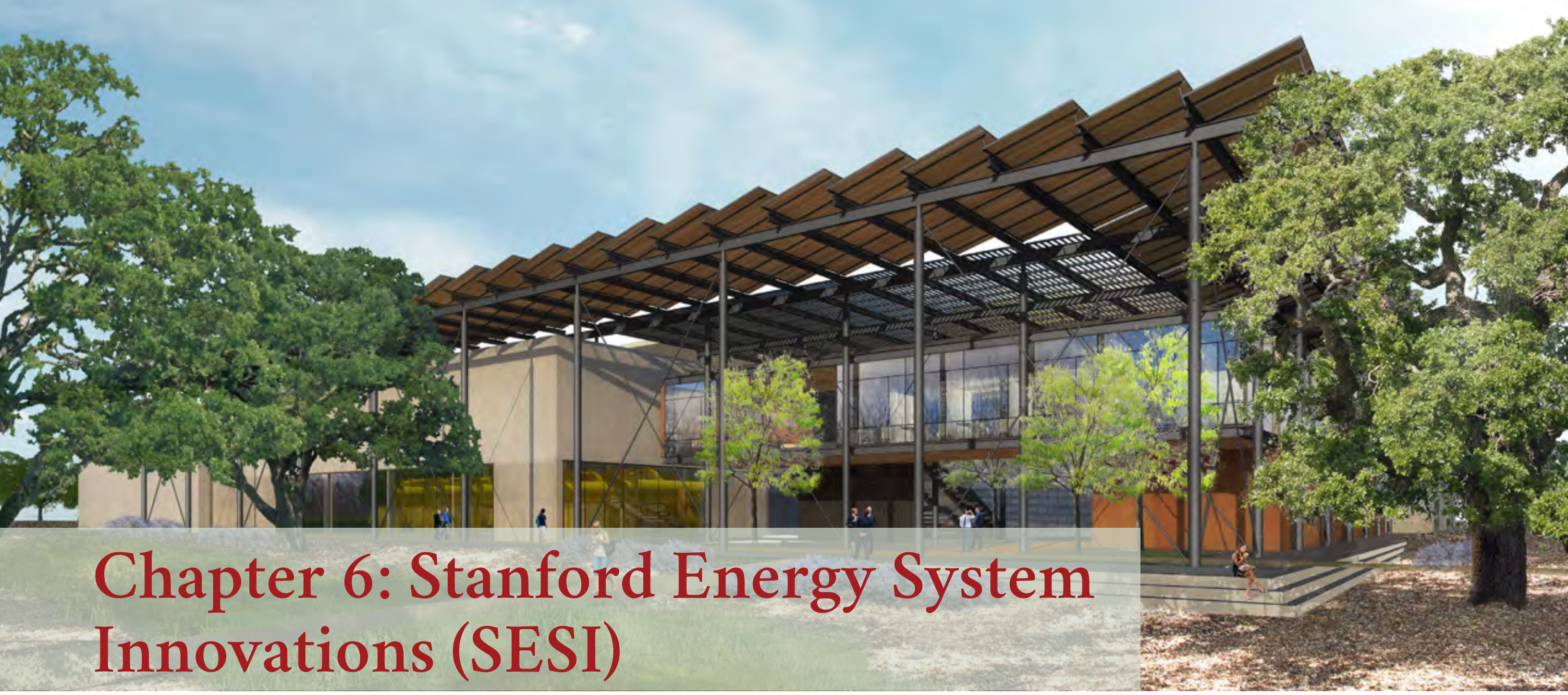
On the operations side, Stanford launched a pilot project in 2012 to evaluate the efficacy of new third-party automated fault detection and diagnostics software. This tool imports high volumes of HVAC control system operating data, analyzes trend data over a time period specified by the user, and identifies anomalies. The output is a list of faults, their likely causes, and their quantified energy costs. This enables an HVAC technician to rapidly zero in on the most important maintenance opportunities. It also enables maintenance to be planned prior to a complete failure of the associated equipment.

Program Impacts

The various energy-saving programs for existing buildings have produced impressive results since the first ERP project in 1993. The cumulative annual recurring savings in electricity, steam, and chilled water are about 300,000 million Btu per year (see Figure 5-1). This is about 13% of the current annual energy consumption baseline for Stanford Utilities.

Figure 5-1 Cumulative Annual Energy Savings for Existing Building Programs





Chapter 6: Stanford Energy System Innovations (SESI)

An innovative energy supply is the third key strategy of this Energy and Climate Plan, complementing strong new-building energy efficiency standards to reduce the impacts of growth (Chapter 4) and adept conservation measures to reduce energy use in existing facilities (Chapter 5). This chapter describes the long-term energy supply options considered by Stanford, provides an analysis of the costs and GHG emissions of meeting campus energy needs under each option, and presents key findings regarding energy supply through 2050.

Energy Supply Options

Stanford University employs a **district energy system** comprising a CEF and power, steam, and chilled water distribution systems to provide electricity, heating, and cooling to its buildings. Currently a gas-fired cogeneration plant built in 1987 and owned and operated by a third party provides all three. However Stanford's contract to purchase energy from this plant ends in 2015, when the plant will be 28 years old and near the end of its useful life. To provide these services for the next 30 years or more, Stanford considered the following energy supply options:

1. **On-site gas cogeneration (aka combined heat and power, CHP) options:** systems that primarily use natural gas to meet campus energy needs, including the following:
    a. **NEW COGEN (STEAM):** a new on-site combined cycle gas turbine (CCGT) cogeneration plant
    b. **NEW COGEN (HW):** a new on-site CCGT cogeneration plant, coupled with conversion of the campus steam distribution system to hot water
    c. **GAS POWER (TURBINE) + HEAT RECOVERY:** Option 1(b), plus ~20% heat recovery from the chilled water system to augment heat provided by the cogeneration unit
    d. **GAS POWER (IC ENGINES) + HEAT RECOVERY:** a new on-site gas-fired internal combustion (IC) engine cogeneration plant, including some heat recovery (~20%) from the chilled water system to augment heat provided by the cogeneration unit, coupled with conversion of the campus steam distribution system to hot water
2. **Grid options:** systems that primarily use electricity to meet campus energy needs, including the following:
    a. **HEAT RECOVERY:** a plant that maximizes heat recovery (~70%) from the chilled water system to meet the majority (~80%) of campus heating needs, coupled with conversion of the campus steam distribution system to hot water

b. **SEPARATE HEAT AND POWER (SHP):** a gas-fired hot water production and electricity-powered chilled water production plant, without any heat recovery, but coupled with conversion of the campus steam distribution system to hot water

c. **ON-SITE PV POWER:** a significant amount of on-site PV electricity generation to supplant a portion of grid electricity imports

Figures 6-1 and 6-2 depict the general arrangements of the gas-fired cogeneration and electrically powered heat recovery systems considered by Stanford for its long-term energy supply beginning in 2015 with the decommissioning of the existing gas-fired cogeneration plant. Detailed variations not shown include a modest amount of heat recovery in the cogeneration scheme and addition of on-site PV power generation in the grid options.

Heat Recovery: A True Potential at Stanford

Heat recovery, as shown in Figure 6-2, captures and reuses most of the waste heat collected by the chilled water system that is normally discarded into the atmosphere via cooling towers. It differs from cogeneration in that it productively uses heat naturally supplied by the environment (mostly from solar heating of buildings) rather than heat supplied by the combustion of fossil fuel.

Heat recovery for domestic heating and hot water service has potential application anywhere that cooling systems collect and discard heat from buildings or processes at the same time low-grade heat (<175F) is produced for heating, hot water, or other applications. Whenever there is a real-time overlap in the two processes or ability to use hot and cold thermal storage, there is an opportunity to use the heat collected by the cooling process (which can be thought of as a waste heat collection process) to meet low-grade heating needs instead of burning fossil fuel. This overlap will vary with the nature of facilities and their climate; however, productive use of any overlap may be a major tool in energy conservation and GHG reduction.

At Stanford, analysis of a full year of hourly heat and chilled water production data at the CEF revealed a real-time 70% overlap between (a) the collection of heat by the chilled water system and its discarding via cooling towers and (b) the generation of heat by fossil fuel and its delivery to buildings via the steam distribution system. This overlap can be seen as the green-shaded areas on the typical daily heating and cooling load charts of Figure 6-3 as well as the dark-shaded areas on the overall annual heating and cooling load chart of Figure 6-4. Adding in chiller machine heat energy, also normally discarded via the cooling towers, it was determined that recovered heat could meet about 80% of the total campus heating load, supplanting a significant amount of fossil fuel use and associated energy cost and GHG emissions.

If other productive uses of this recovered heat can be found, in addition to building heating and hot water, heat recovery can reduce cost and GHG emissions even further. For example, if ground-source heat pumping or other means to collect heat occurring freely in the environment in winter can be devised using the heat recovery system, additional substantial reductions in fossil fuel and associated cost and GHG emissions may be possible.

Because evaporative cooling towers are currently used for discharging waste heat, heat recovery could also save a significant amount of water. The CEF cooling towers are estimated to consume about 25% of the total campus domestic fresh water supply. Using heat recovery as described above would reduce CEF water use by 70% and overall campus water use by about 18%.

Though a heat recovery system requires more electricity to operate than a standard chilled water system, its use of the recovered heat means that it requires far less natural gas or other fossil fuel equivalent. Furthermore, the potential for meeting this and other electricity loads with renewable energy is a desirable flexibility in the heat recovery system that could allow further energy, water, and cost efficiencies and GHG reductions as grid electricity production technologies advance.

FIGURE 6-1 COGENERATION, ALSO KNOWN AS COMBINED HEAT AND POWER

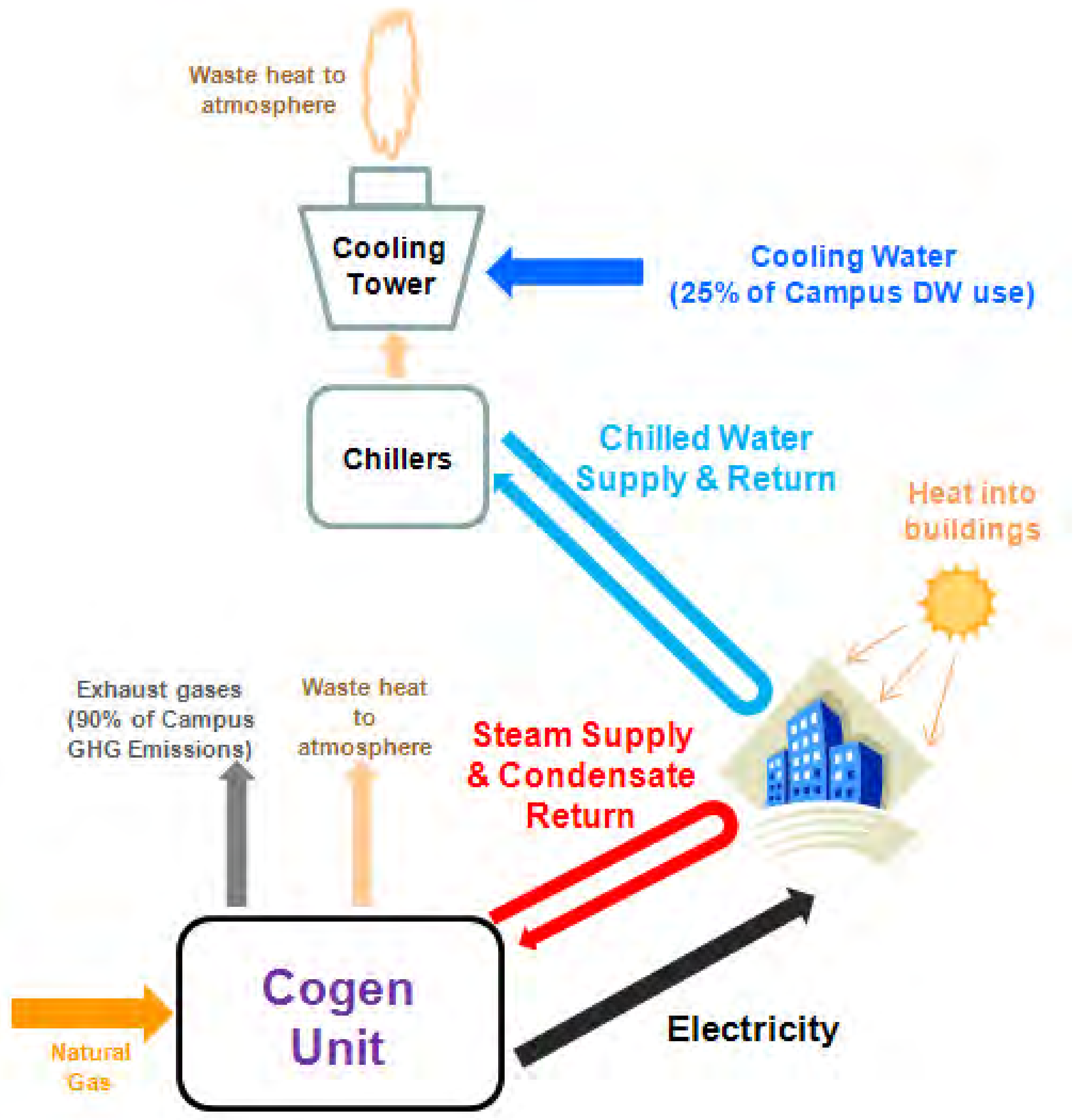
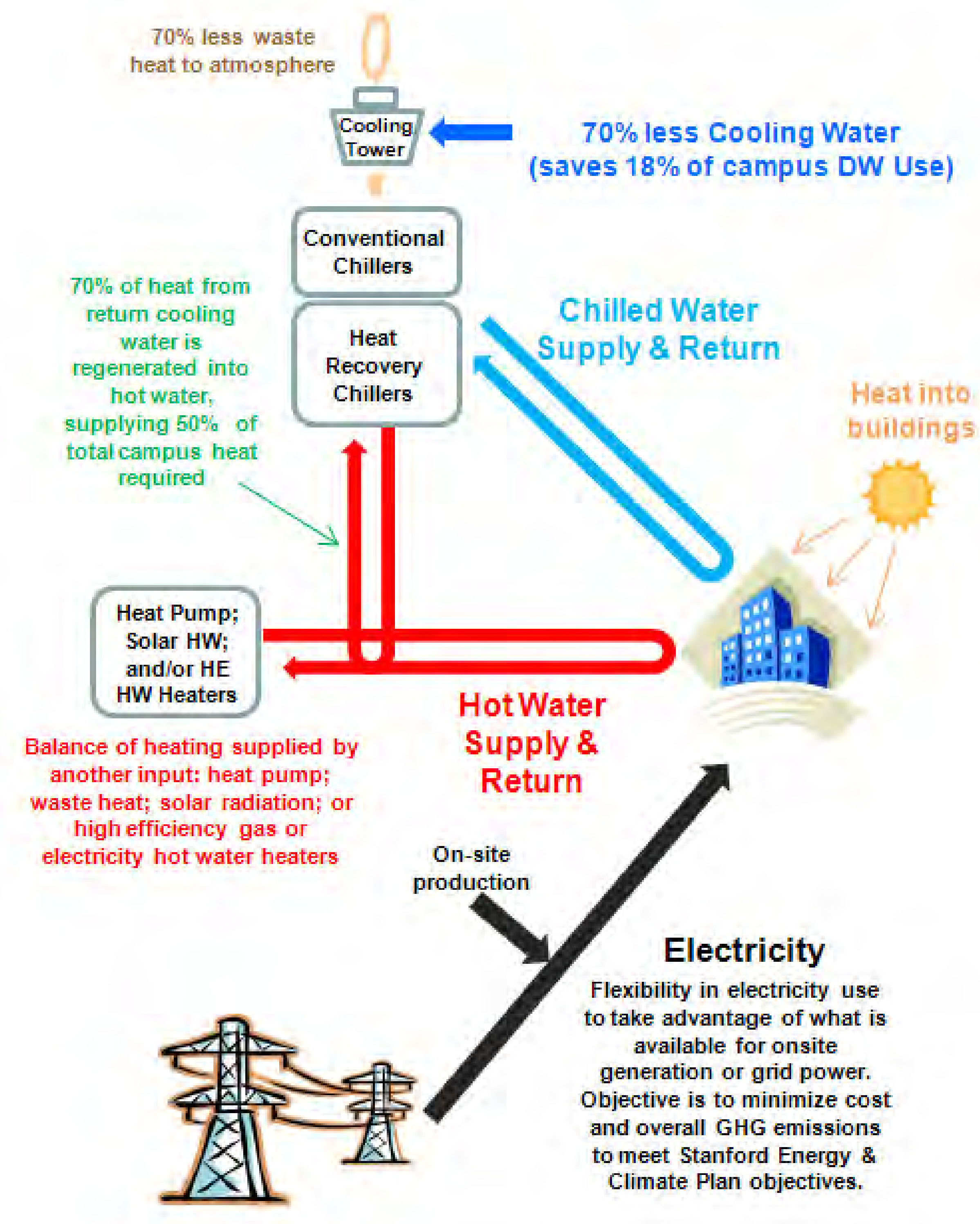


FIGURE 6-2 HEAT RECOVERY SYSTEM



Heat recovery as shown in Figure 6-2 captures and reuses most of the waste heat collected by the chilled water system that is normally discarded into the atmosphere via cooling towers. It differs from cogeneration in that it productively uses heat naturally supplied by the environment (mostly solar heating of buildings) rather than waste heat supplied by the combustion of fossil fuel.

Formulating Options for Campus Decisions

As the district-level application for heat recovery was discovered, the campus moved towards aggregating all the considerations and decision criteria for redesigning its future energy supply.

Compatibility with CHP and SHP

Because CHP would burn fossil fuel to make electricity and use the waste heat to meet heating demands year-round, it would allow little room for processes that supply heat by other means, particularly in the warmer months, when there is typically already a surplus of heat in the environment. This greatly limits the use of more sustainable forms of low-grade heat production, such as heat recovery from cooling processes or direct production of heat via renewable sources, such as solar hot water generators and ground-source heat pumps.

SHP, on the other hand, is fully compatible with heat recovery and alternative forms of heat production. SHP heat production processes are not dependent upon or tied to electricity generation. This separation allows maximum use of sustainable low-grade heat generation, which is often lower cost and cleaner than heat generation by fossil fuel via CHP.

Converting to a Hot Water Distribution System

Implementing heat recovery at this scale requires a complete conversion of the campus heat distribution system from steam to hot water because low-grade heat recovery does not reach temperatures suitable for steam production. Though this conversion represents a significant cost and operational challenge, lower system heat loss, O&M costs, and future capital costs justify it even apart from heat recovery.

- The conversion could reduce heating system line losses from about 14% to 4%.
- A hot water system would reduce O&M costs by 75%.
- The conversion could avoid substantial capital costs for replacement of aging portions of the steam system.
- Capital costs for future system expansion and interconnection to new buildings would be much lower with hot water.

A discussion of the benefits of converting the steam distribution system to hot water, along with case histories of similar applications and a conceptual phasing plan, is included in Appendix D.

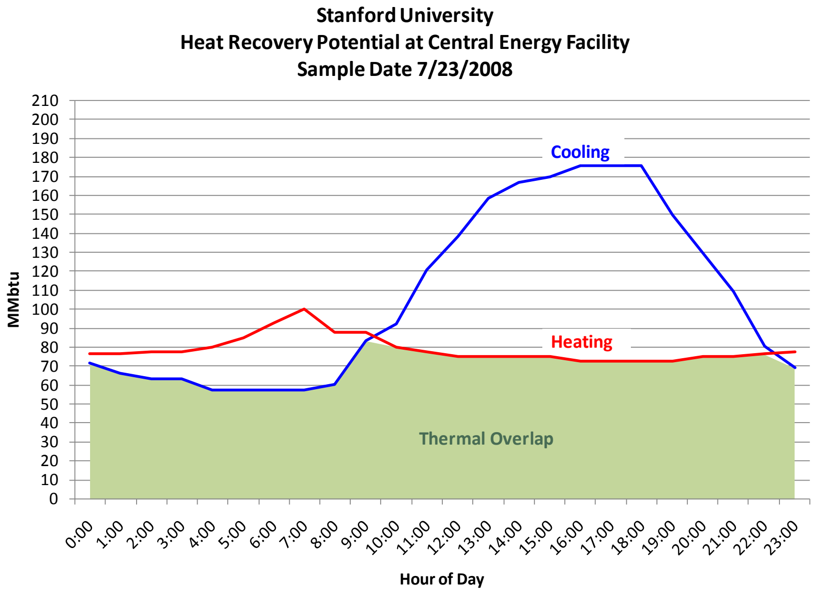
Energy Price Risk and Budget Stability

An important consideration in examining the different options is the risk associated with market energy prices. CHP relies 100% on natural gas to meet all campus energy needs. This lack of diversity exposes the university to greater energy price risk because natural gas is traded in a deregulated market known for extreme volatility. Energy modeling shows that the SHP and heat recovery options reduce direct reliance on natural gas by 60% and 80%, respectively, limiting its use to heat production in hot water generators. While these options require importing a significant amount of electricity, there are a number of ways to at least partially decouple that supply from the price volatilities of natural gas, something not possible with CHP. As a Direct Access customer, the university could choose to procure power off the California market, which currently comprises about 40% natural gas generation and has shown good price stability over the past six years, even as gas and oil prices have shown extreme volatility. Under this or other potential energy supply strategies, the university could also control the carbon content of its electricity portfolio and meet its power needs by incorporating renewable power purchases.

Power Sector GHG Reductions

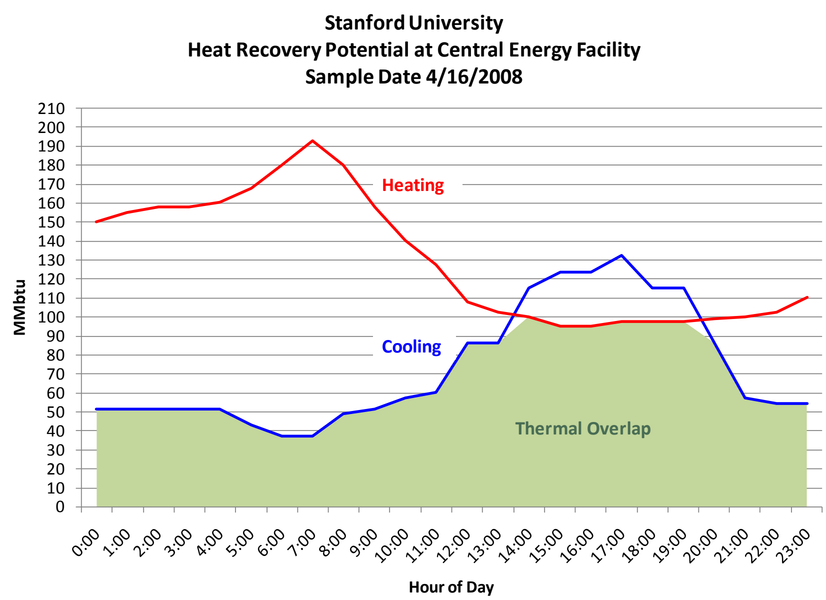
Another consideration in selecting a long-term campus energy system is whether it more broadly supports society's need to reduce its collective GHG emissions. Some current national and state-level strategies encourage distributed natural gas– based power generation (such as fuel cells) and cogeneration technologies on the assumption that these would displace less efficient or more GHG-intensive energy systems, such as coal power or older low-efficiency gas-grid power plants. However, when considering new capital investment in energy production, we should compare different new

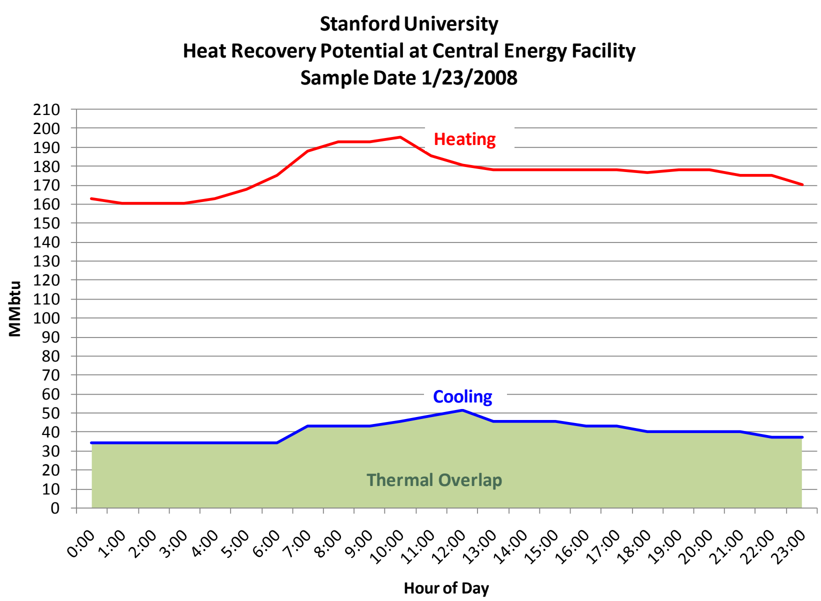
Figure 6-3 Daily Heat Recovery Potential



Summer

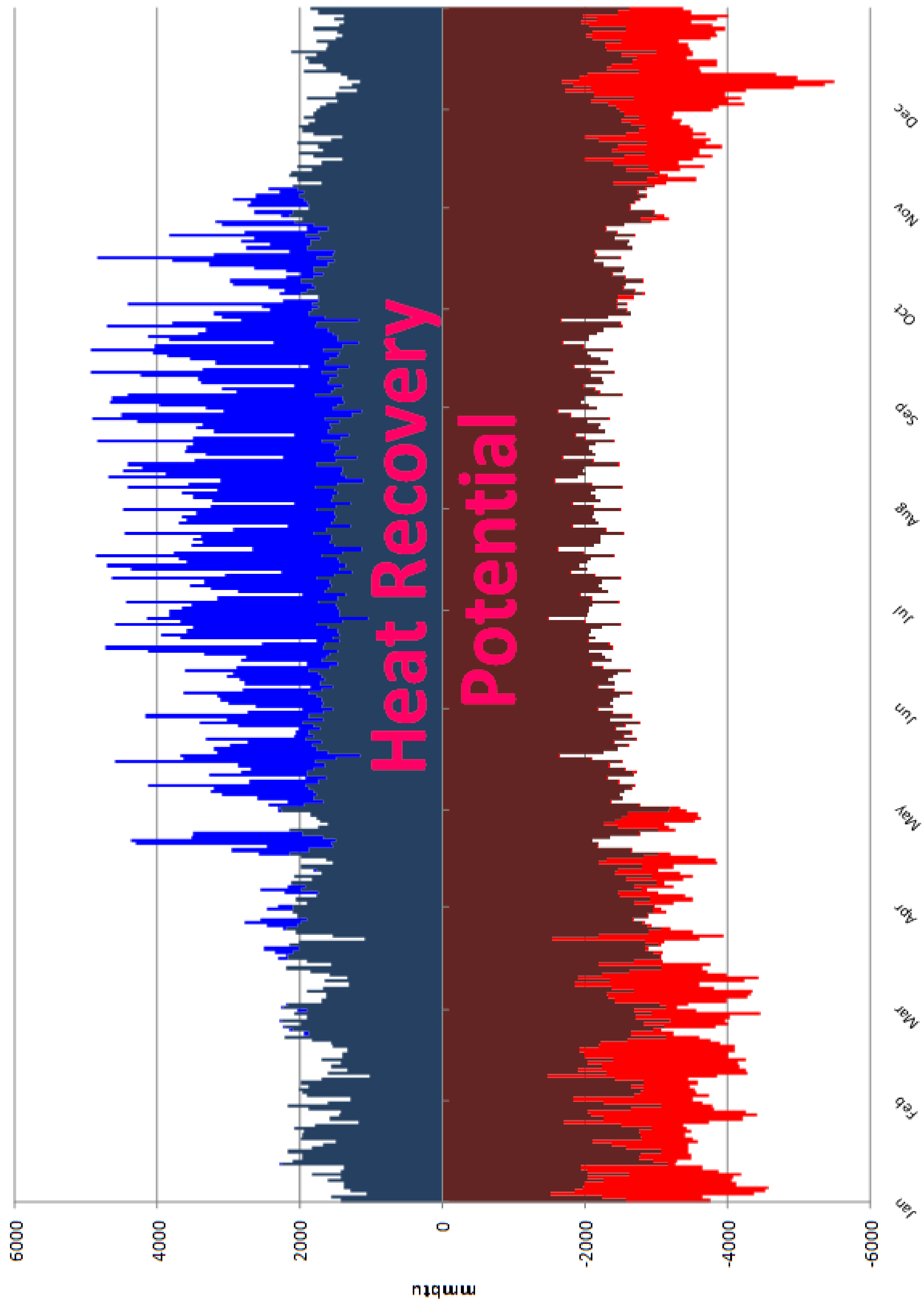
Spring/Fall





Winter

Figure 6-4 Annual Heat Recovery Potential



power plant options, not one new power plant option to the existing power plant fleet. When society is collectively investing capital in new energy supply systems (thermal or electric), it is prudent to select the best new energy system option, rather than selecting the most convenient one because it offers some marginal improvement. This is especially true in the absence of a long-term plan that provides a bona fide strategy to achieve the GHG reductions required for our planet. Promoting the installation of many small new distributed gas-based generation technologies may actually undermine other strategies in the power sector, such as implementation of a renewable portfolio standard for electricity production, and/or foreclose other GHG reduction strategies, such as large central station carbon capture and sequestration.

After considering all these factors, the university concluded that diversifying campus energy sources, perfecting direct access to open energy markets, and decoupling its energy supply from the volatilities and environmental impacts of fossil fuels to the greatest extent possible offers a better long-term strategy for supporting its mission. It determined that continued reliance on natural gas as its primary energy source will greatly limit the potential for direct reduction in its GHG emissions, whereas moving to an electrically powered energy facility of similar or greater efficiency would pave the way to full sustainability through the development of sustainable electricity generation technologies.

Equipment Redundancy, Plant Space Use, and Capital Cost

A CHP cogeneration plant requires redundant boilers of equal capacity to provide backup service during scheduled or unscheduled outages. In contrast, an IC-based cogeneration or SHP boilers-and-chillers plant is modular in nature, with multiple pieces of smaller equipment rather than one large cogen unit. Therefore, instead of backing up the entire heating plant, redundancy requires only extra equipment equal to the largest individual IC engine, chiller, or boiler. This difference considerably reduces capital investment and further separates these options from a conventional CCGT cogen plant such as that currently supporting the university.

Flexibility to Adopt New Technologies

Investment in a cogeneration plant would greatly reduce flexibility in adopting potential new technologies that could reduce cost and GHG emissions for many years. For example, heat recovery, whose great potential at Stanford was only recently uncovered, cannot be rapidly adopted without decommissioning the current cogeneration plant. Conversely, the modular nature of a heat recovery–based SHP plant would provide greater opportunity to move to advanced technologies as they become available, because individual pieces of plant equipment are typically acquired and retired in staggered succession over time. In essence, one can “rotate the stock” in a modular SHP plant but not in a large, single-component cogeneration plant.

Economics and Selected System

Economic models of the different energy supply options described above were developed, and side-by-side comparisons were made of the net present value (NPV) life cycle costs. Figure 6-5 shows the comparative costs, GHG emissions, and water use of the options considered. These options were presented to the Board of Trustees thoughout 2011 until a decision was made in December 2011.

Figure 6-5 shows cost decision criteria are shown in bars. Initial capital investment in red, operations and maintenance cost in blue, the cost of purchasing natural gas in yellow, and the cost of purchasing electricity in purple. The NPV of each energy generation option is shown in the $ figure above its composite bar. Environmental attributes are shown by total GHG and water use icons.

FIGURE 6-5 COMPARATIVE COST, GHG, AND WATER USE OF ENERGY SUPPLY OPTIONS

Energy Generation Options and Descriptions

Option Category	Name	Description	Advantages	Disadvantages
Gas	On-site gas cogeneration options	These options explore burning fossil fuel on site to meet campus power and thermal needs.	Potential for low-cost long-term natural gas supply; 100% on-site power generation	Dependence of all campus energy on single fossil fuel source; lack of environmental sustainability
#1, with NPV $1,593 million	Steam option—business as usual (BAU)	Extend current cogen operation to 2050 under existing third-party agreement	Lowest direct capital and O&M costs because third party owns and operates plant	Highest overall cost, GHG emissions, and water use due to third-party overhead and profit and lowest plant efficiency
#2, with NPV $1,356 million	Steam option—new cogen plant	Install new Stanford–owned and operated combined cycle gas turbine (CCGT) cogen plant	Lower capital cost than other new Stanford-owned cogen options because includes no new hot water system; lower GHG emissions and water use than BAU	Higher overall cost than high-efficiency hot water–based IC cogen systems; only modest overall emissions and water use reductions
#3, with NPV $1,392 million	Hot water option—new gas turbine (GT) cogen	Install new Stanford–owned and operated CCGT cogen plant with hot water–based heat distribution system	Modest reductions in GHG emissions and water use over new steam-based cogen plant	No economic advantage over new steam-based cogen plant
#4, with NPV $1,399 million	Hot water option—new GT cogen with heat recovery	Install new Stanford–owned and operated CCGT cogen plant with hot water–based heat distribution system and some heat recovery	Slight emissions and slight water use reduction over standard GT cogen with hot water, due to modest amount of heat recovery possible	Higher capital cost ($579 million), higher overall cost than hot water–based GT cogen without heat recovery
#5, with NPV $1,333 million	Hot water option—GT cogen using internal combustion (IC) engines with heat recovery	Install new Stanford–owned gas-fired IC engine cogen plant with hot water–based heat distribution system and some heat recovery	Best overall gas-fired cogen option with additional modest GHG, water use, and cost reductions over GT-based cogen without heat recovery	High capital cost ($546 million); higher GHG emissions, water use, and overall cost than grid + heat recovery (option #6)

Option Category	Name	Description	Advantages	Disadvantages
Grid	Options using grid power for electricity instead of on-site cogen	These options explore combinations of grid power for electricity, an on-site thermal energy plant with optional heat recovery, and hot water–based heat distribution.	Optimality from overall economic, risk, flex-ibility, and environmental sustainability standpoints	Modestly higher up-front capital costs than retaining cogen with steam-based distribution
#6, with NPV $1,290 million	Grid + heat recovery	Get electricity from grid; install new electricity-based heat recovery plant and hot water–based distribution system	Best overall option, with rela-tively low cost, GHG emissions, and water use	Higher up-front capital cost ($474 million) than retaining existing cogen with steam-based distribution, which is financed, owned, and operated by a third party
#7, with NPV $1,371 million	Grid, no heat recovery	Get electricity from grid; install new gas boilers, electric chillers thermal plant; install hot water–based distribution system	Better option than BAU; simpler ownership and operation than cogen plants; more long-term flexibility	No real improvement over gas-based IC cogen plant, more expensive investment and less water savings
Grid + On-site PV	Grid power options with on-site pho-tovoltaic (PV) power genera-tion	These options explore com-binations of grid and on-site PV power for electricity, an on-site thermal energy plant with heat recovery, and hot water–based heat distribution.	Optimal environmental sustainability; lower capital costs	
#8, with NPV $1,276 million	Grid + 20% PV + heat recovery	Same as grid + heat recovery option but using same total capital that would be required by best cogen option to buy some on-site PV plant	Further improvement upon best overall option (grid + heat recovery) if total up-front capital equivalent to that required for best cogen option is allocated; ability to absorb PV power behind the meter	Higher up-front capital cost than base grid + heat recovery option; land use requirement
#9, with NPV $1,267 million	Grid + 33% PV + heat recovery	Same as grid + heat recovery option but allocating enough land and capital to meet full 33% California Renewable Portfolio Standard for electricity use via on-site PV	Further improvement upon best overall option (grid + heat recovery) if additional up-front capital and land are allocated; partial long-term power cost stability	Very significant land use require-ment; possibility that exports of PV power to grid would be required in some hours

Board of Trustees Approval

In December 2011, after approval by the trustee advisory board, Stanford's Board of Trustees gave concept approval to Option #6, Grid + Heat Recovery (circled on Figure 6-5) as the new base energy system for the university from 2015 to 2050. This option of an electrically based heat recovery plant with grid power offers superior economics and environmental performance, lower energy price risk, greater flexibility to adapt to changing energy technologies over time, and a clearer path to sustainability.

Options #8 and #9, which add some amount of on-site PV power generation to the base energy supply system selected, were determined to be destination choices with superior environmental and economic benefits as long as the conceptual economics could be verified and land use challenges for them could be resolved. In energy system planning it was also determined that some amount of on-site ground source heat exchange (GSHE) might be possible to augment the base heat recovery scheme. Based on the two positive preliminary PV and GSHE feasibility studies the Board also directed that additional studies of these options be conducted in parallel to implementation of the chosen new base heat recovery system. During this approval stage, the official name of the program became Stanford Energy System Innovations (SESI).

The construction cost of SESI, without the PV or GSHE options, is $438 million. This includes conversion of the campus energy distribution system from steam to hot water and associated building-level conversions, construction of the new heat recovery plant and the new high-voltage substation, and other system improvements (see Figure 6-6). The balance from the total capital cost shown on the bar chart ($474-$438=$36 million) represents other related costs such as accelerated depreciation of stranded assets at the existing CEF to be demolished as part of the SESI program.

Benefits for Stanford

Financial Benefit and Payback

The $474 million capital investment is significant, but it is lower than that of most other options. There is no "do nothing" option because the existing CEF is near the end of its useful life and a replacement is required. The BAU option had the lowest capital investment ($153 million), but it also had the highest overall long-term cost, much greater emissions and water use, and inflexibility to change with future technologies.

In addition to better environmental performance, SESI also provides significant life cycle cost savings, ranging from $43 million to $109 million, over all the other base energy system options while offering one of the lowest up-front capital costs. In fact it will save Stanford $303 million over the next 35 years compared to the BAU scenario.[1]

Environmental Benefits

Key environmental benefits of the SESI program include:

- **Input and Output Savings—Carbon and Water**: When SESI's replacement CEF comes on line in 2015, current campus carbon emissions will immediately be cut in half and sit at 50% below 1990 levels. While SESI will provide this almost instantaneous huge reduction in carbon emissions, its flexible electricity-based energy supply system also creates a path to a fully sustainable energy supply via green power generation and procurement. Having recently achieved Direct Access to the California electricity market, Stanford is now exploring opportunities for a more economic and environmentally sound electricity portfolio to allow it to continue down the path toward energy sustainability. Reduction in water use will also be significant. Since the majority of the waste heat from the chilled water loop will be reused instead of being discharged out of the evaporative cooling towers, campus potable water use will be 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.
- **Higher System Efficiency:** Due to the significant recovery of waste heat and lower heat distribution line losses via hot water distribution as compared to steam, the new combined heating and cooling energy system will be 70% more efficient that the existing CHP plant.

1 Option #1 BAU NPV $1,593 million – Option #8 "Grid + Heat Recovery" NPV $1,290 million = $303 million relative gain

- **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 155 buildings to get them ready for hot water. In the process, those buildings are receiving efficiency improvements. The carbon and water reduction calculations account for the overall energy efficiency improvements in the built environment.

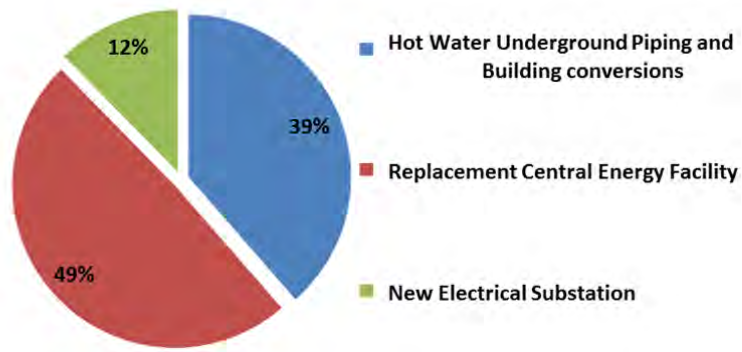
Social Benefits

Key social benefits of the SESI program include the following:

- **Improved safety:** Keeping the campus community **safe and informed** is of the utmost importance at all times. Steam systems pose more injury and safety concerns than hot water systems. The replacement of the legacy steam system reduces the risk of facility damage and public and staff injury from system leaks or failures. The Department of Land, Buildings & Real Estate 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.

- **Campus engagement:** SESI also has set a precedent for campus involvement with major capital improvement projects. Determination of the vision and principles for this multi-year initiative integrated input and leadership from **all stakeholders on campus** (staff, students, and faculty), while maintaining steady communication with Stanford leadership (the executive cabinet and the Board of Trustees) from 2009 to 2012. Faculty and leadership played an active role in making major social and environmental impact decisions throughout planning. For example, to test and prioritize the many GHG reduction options available, a long-term campus energy model was constructed and various scenarios were developed to determine which solutions satisfied 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 for review by the university administration. Subsequent reviews with more detailed analysis were held with the Board of Trustees in 2009, 2010, and 2011, and two faculty advisement committees participated in this phase of the project (President's Blue Ribbon Taskforce in 2008 and 2009 and Board of Trustees Energy Advisory Committee in 2010 and 2011). Over the entire course of SESI planning and implementation to date, more than 25 faculty members and 100 students have been involved through student groups and departmental queries. This is truly an all-campus project that has solicited, welcomed, and benefited from faculty and student input throughout the years.

Figure 6-6 Breakdown of SESI costs



- **Campus-wide education:** SESI has been a steady source of **education** for Stanford students and community members. Not only were students involved during its planning, student and campus community outreach has been extensive during its implementation. 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 why the campus is taking a leadership role with SESI, as well as to coordinate the scheduling of the pervasive construction. The campus community has been extremely supportive despite the short-term inconvenience of 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 that shows the current and future construction zones and project progress. Additional educational resources include a popular educational video overview of SESI and a SESI-focused Energy Seminar, hosted in fall 2012 and attended by students, staff, and faculty and community members.

Chapter 7: Implementation of a Comprehensive Plan

As the earlier chapters have demonstrated, a comprehensive energy and climate plan at a growing institution must consider three key energy components: (1) demand-side management via new construction standards, (2) demand-side management via efficiency programs for existing buildings, and (3) supply-side solutions. The plan must also take a holistic, long-term approach rather than considering only short- or intermediate-term strategies and goals. Building design, energy infrastructure, and energy supply decisions that must be made over the coming decade will be long lived, and their planning horizon must be at least as long as the life cycle of the investments to be made.

Moreover, even adept infrastructure planning is incomplete if it yields only incremental improvements, even if those are very significant. Until systems and human behavior are transformed enough to achieve sustainability the challenges will remain, and incremental improvements will just buy time.

The Stanford Energy and Climate Plan recognizes this and not only provides very significant incremental improvements but also enables a future of true energy sustainability. Converting campus energy systems from a fossil fuel base to an electricity base opens a clear path toward sustainability through renewable electricity generation. Conversely, absent scientifically based national and international plans and policies that might allow for a limited amount of fossil fuel combustion within the planet's atmospheric ecosystem, there is little confidence that the cumulative individual impacts of even "efficient" fossil fuel systems, such as new cogeneration plants, are sustainable. It is for these reasons that Stanford University has developed an Energy and Climate Plan that moves the university off local gas-fired energy production and onto an even more efficient electricity-based system.

Implementation of this plan will not stop with the projects and programs outlined herein, but will continue through the pursuit of economical and sustainable technologies. As Stanford uncovers and develops sustainable electricity supplies or makes significant further advancements in demand-side management, this Energy and Climate Plan will be revised periodically.

Implementation Under Way for All Three Strategies

Demand-Side Management via New Construction Standards

Chapter 4 has summarized some of the key results of new efficiency standards for new construction and major renovations on campus. Past success at exceeding federal, state, and local performance standards has helped evolve the market towards higher-performing buildings. Many of these standards have been updated to include the energy and water use best practices that Stanford has been implementing for many years. By focusing on practical, cost-effective technologies and operating strategies, Stanford will continue to lead by example in new construction practices. The new, high-performance buildings on campus will reduce baseline GHG emissions by 10% (see Figure 7-2).

Demand-Side Management via Existing Building Efficiency

Chapter 5 has shown how energy-saving strategies will continue to decrease consumption in existing buildings. Recent experience illustrates this. Total energy use increased 9% from 2001 to 2012 due to new construction, more energy-intensive research, and more people and electricity-using equipment in existing buildings. However, energy intensity (energy use per square foot) has decreased about 10% since 2001. The successful water and energy efficiency programs in existing buildings will continue to serve the university and appreciably reduce utility costs and GHG emissions. Areas for future growth and development include the following.

Continuation of Programs that Reach and Appeal to All Campus Stakeholders

- Identify new and/or underserved "markets" on campus. As new research or facility use practices change user activity, identify and market new efficiency program offers. Similarly, as new technologies become available, identify cost-effective niches for their deployment on campus.
- Ensure reliable sources of funding for maintenance/expense projects as well as capital improvement projects, and communicate the availability of funds to campus stakeholders. Any project manager or building manager must be aware of, and confident in, the availability of efficiency funding when scoping future infrastructure projects. Stanford must maintain a campus perception that it is easy and normal to build energy efficiency features into all building projects (whether small or large).
- Collaborate with stakeholders across campus to identify projects with energy savings potential. This includes collaboration among sustainability programs such as water, energy, and waste management.

Pursuit of New Technology

- Investigate demand management. Minimizing spikes in energy use helps control costs by avoiding high utility demand charges and lets HVAC systems operate in more efficient ranges of their performance curves.
- Continue to deploy "smarter" monitoring and control systems within campus buildings. This helps ensure buildings operate with the most efficient schedules, set points, and control strategies. Upset conditions are identified sooner and fixes can be deployed rapidly, reducing wasted time and energy and improving occupant comfort.

Integration of Energy Demand and Energy Supply

With good visibility into the performance of each building and a thorough understanding of its energy-using systems, active steps can be taken to adjust its energy time of use. This demand side of the campus energy equation can help maximize the efficiency of the supply side, and vice versa. For example, daily demand from buildings can be forecasted, and CEF operation can be scheduled to maximize the efficiency of energy production. Conversely, if temporary upsets hamper the efficiency of the CEF, the buildings can alter their demand in a prescribed manner to provide temporary load relief.

Even though many large and notable energy efficiency projects have already been completed on campus, the future still holds great opportunities to save energy as new technologies emerge and the costs of old technologies decrease. Energy and GHG savings realized from efficiency projects for existing buildings are expected to be about 20% of baseline each year (see Figure 7-2).

Supply-Side Solutions

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

Hot Water System 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 instead of steam for heating. 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.

The piping construction work is being carefully sequenced in multiple phases to minimize disruption to campus life (see Figure 7-1). 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.

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 (see photos).

Campus Outreach

The SESI program is the most pervasive utility-scale construction project in campus history. The DPM and the Office of Sustainability launched a comprehensive outreach effort and met with over 30 campus departments and entities to coordinate the scheduling and timing of the phased construction.

The SESI website launched in the summer of 2012. It provides

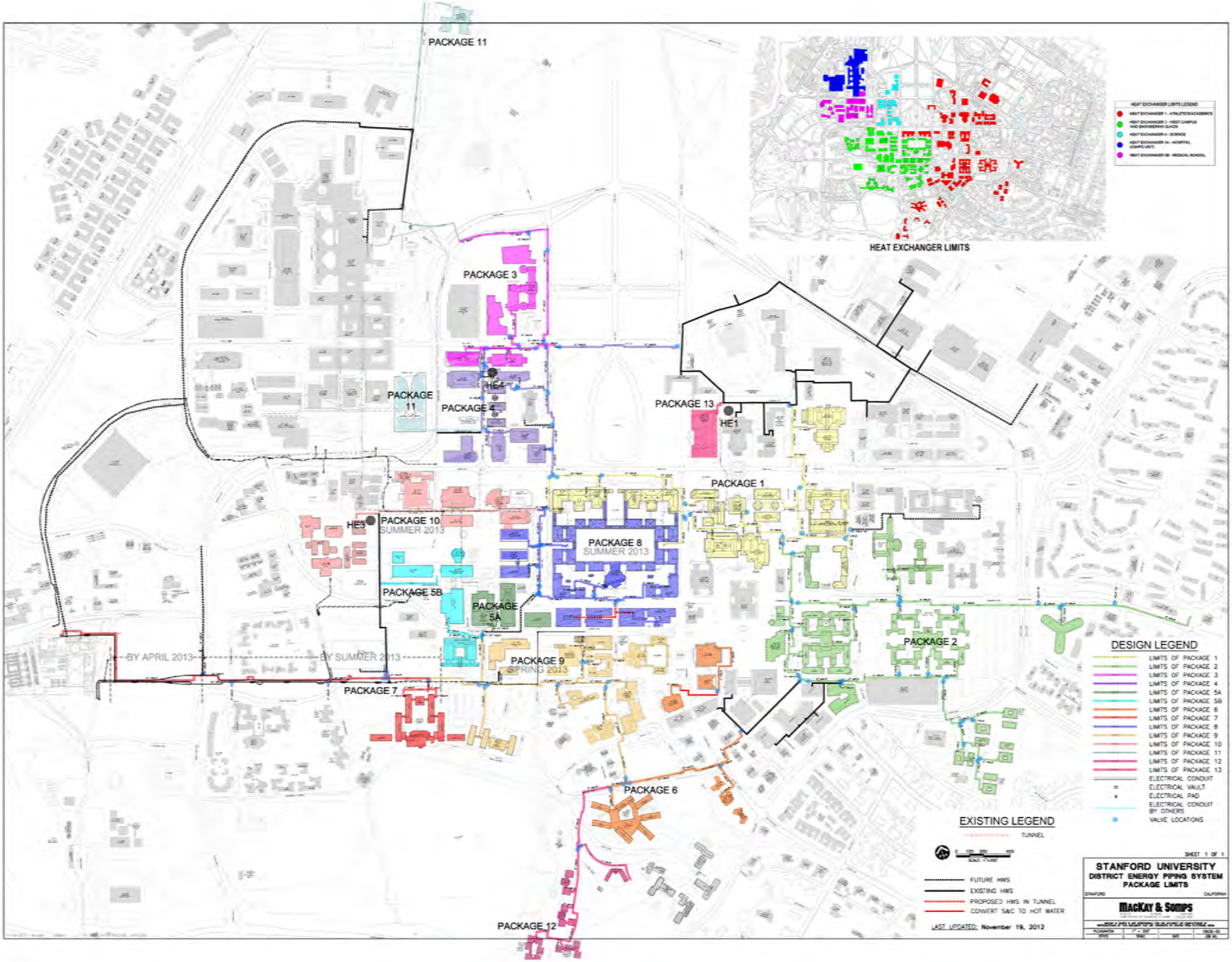
Photo: piping installation in progress along Serra Mall.

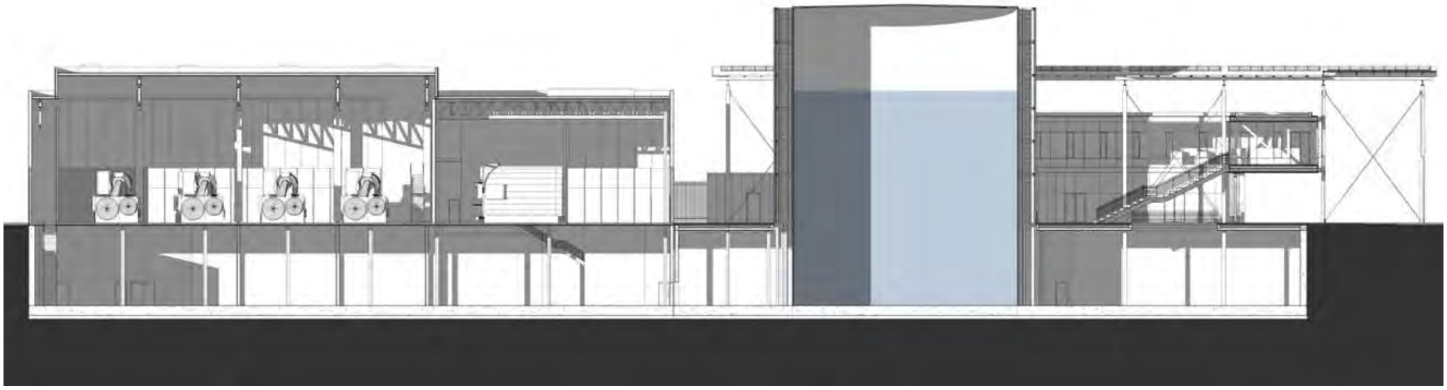
an avenue for interested community members to learn about the program and follow the construction on a real-time, interactive campus map that shows the current and future construction zones and project progress. It also includes links to related articles, an updated climate action video, and project fact sheets.

Looking Ahead

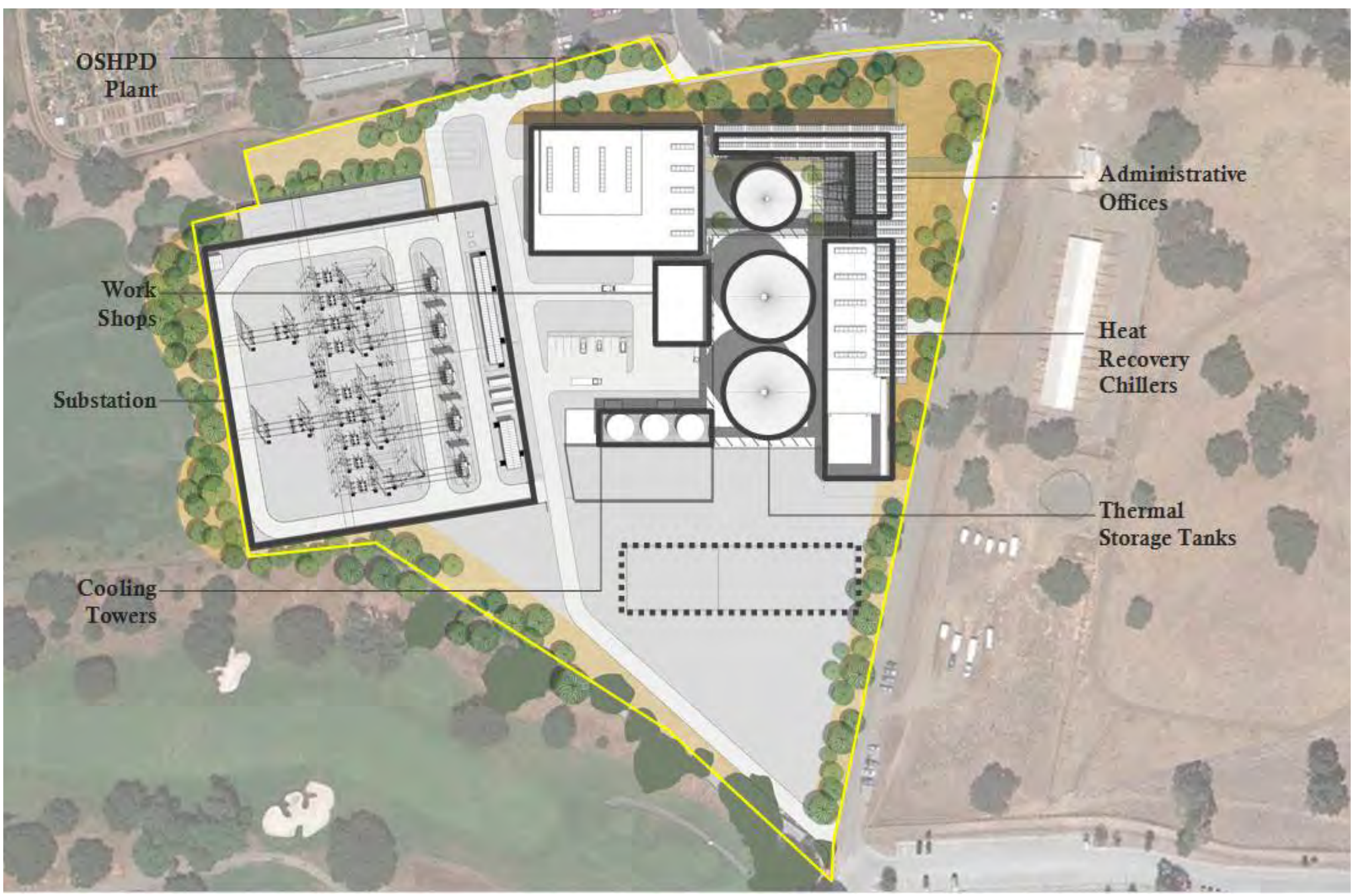
Additional potential major enhancements to the campus energy system are being studied. These include on-campus PV power installations as well as a GSHE system to complement the core heat recovery process based on the chilled water system. Project additions with concept approval that are now under final feasibility study include installation of four to seven MW of on-site behind-the-meter PV power generation; installation of a GSHE system, and installation of a new 60kV high-voltage transmission line connecting SLAC, Stanford, and the City of Palo Alto to strengthen the local transmission grid. These studies are expected to be completed in late 2013. 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.

Figure 7-1 Hot water piping conversion map





PHOTOS: NEW CENTRAL ENERGY FACILITY RENDERINGS AND SITE PLAN



Summary View: Emissions Reduction at Stanford

Chapters 4, 5, and 6 discuss options and strategies for managing the three energy components described above. However, the three must be consolidated into an overall plan that adeptly balances investment among them to optimize overall results in managing capital and operating costs, as well as GHG emissions.

Figure 7-2 compares Stanford's expected long-term GHG emissions under the Energy and Climate Plan to state and international goals. By 2015, Stanford expects to reduce its emissions by 50%, about 25% below the level mandated by California's Executive Order AB 32.[1] The figure shows three wedges.

1. **DEMAND-SIDE MANAGEMENT VIA NEW CONSTRUCTION STANDARDS:** Stanford's new-building standards adopted in 2007 require new and significantly renovated buildings to be 30% more energy efficient on average than current energy code requirements (see Chapter 4). This wedge represents savings from constructing new facilities to this standard.
2. **DEMAND-SIDE MANAGEMENT VIA EXISTING BUILDING EFFICIENCY:** This wedge represents the GHG emissions reductions from continuance of the energy efficiency and conservation programs for existing campus buildings (see Chapter 5). These include minor noncapital improvements to buildings and equipment, improvements in how buildings are operated, and impacts of occupant behavior. This wedge also reflects emissions reductions that can be "mined" from Stanford's existing stock of large buildings through comprehensive study and major capital retrofits with state-of-the-art HVAC systems and other energy-efficient technologies. Tackling each building as a whole (rather than piecemeal) will maximize energy use reductions, which can be on the order of 30–50%.
3. **SESI:** This wedge represents the reduction in energy cost and GHG emissions expected from the heat recovery option described in Chapter 6. If heating demand drops less than is expected, a greater percentage of the potential heat recovery on the supply side can be realized to make up the difference.

1 A separate planning process is under way to develop options for reducing emissions from the transportation sector, which is not part of the Energy and Climate Plan.

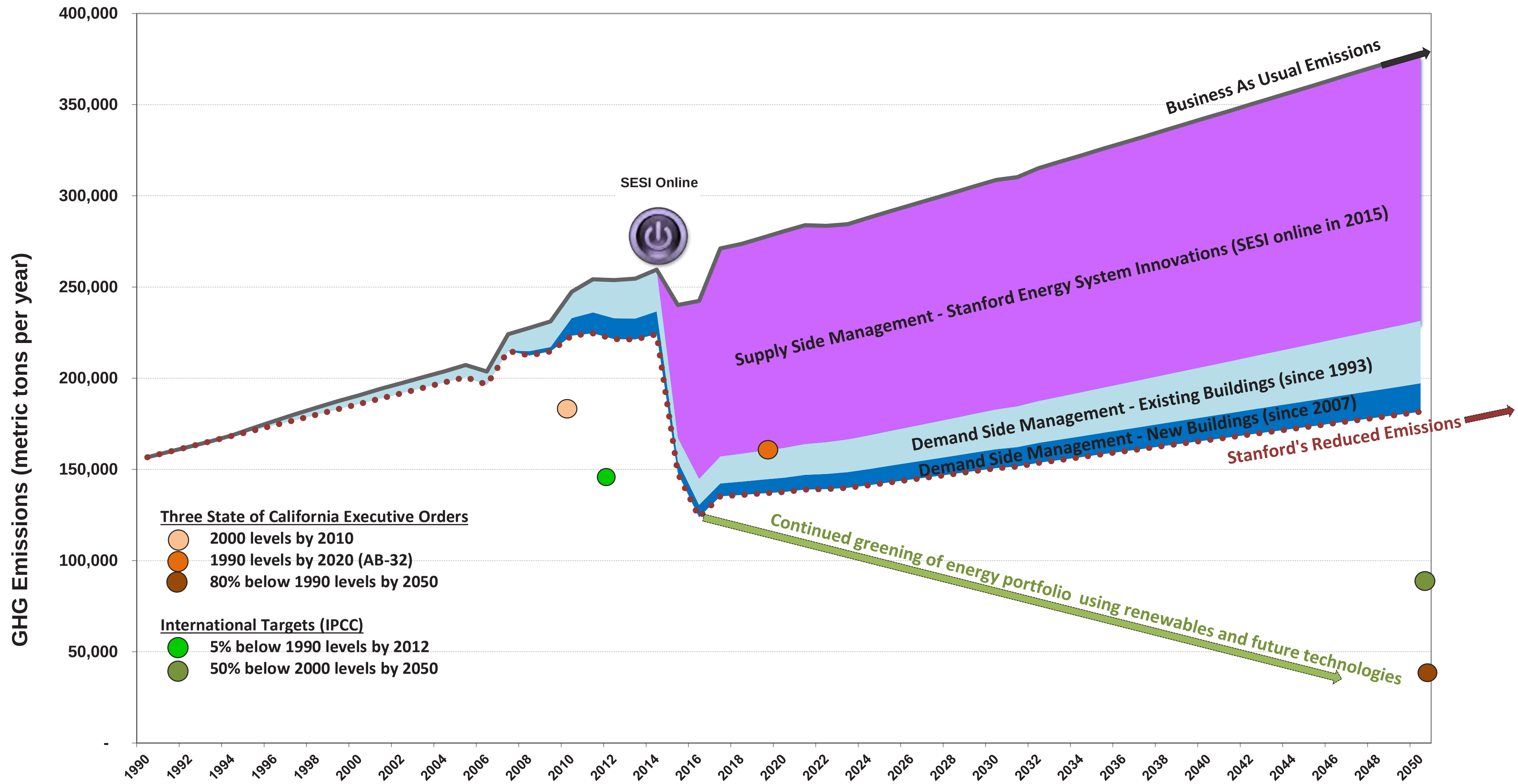
Final Thoughts

Growth Outpaces Energy Conservation. Demand-side energy efficiency and conservation improvements are vital but insufficient for significant emissions reduction because they will be outpaced by campus growth. Significant changes to campus energy supply strategies are essential for reducing cost and GHG emissions below the 2000 baseline.

Substantial Emissions Reduction is Not Possible with Fossil Fuel in the Picture. Providing a stable and affordable long-term energy budget requires decoupling from a reliance on fossil fuel and minimizing external control over Stanford's energy supply as much as possible. As outlined in Chapter 6, technologies and costs for energy production have changed, and CHP or cogeneration is no longer a superior option for meeting campus electricity and thermal loads. Instead, a Stanford–owned and operated SHP scheme coupled with heat recovery will reduce long-term cost and allow flexibility for further efficiency improvements, incorporation of new technologies, and additional forms of renewable electricity and thermal energy generation.

More Investment in Renewable Energy is Needed. The long-term benefits of direct ownership of or long-term equity in renewable energy generation (if executed adeptly) far outweigh the costs. Like many of today's renewable energy plants, hydroelectric power plants in the last century faced significant hurdles to construction, including high up-front capital costs and longer-term paybacks, intermittency and seasonality of power generation, remote sites, lack of existing transmission access, environmental and regulatory issues, and so forth. However, those facilities continue to provide the lowest-cost and cleanest power of any type of electricity generation far beyond their expected life cycle. They are coveted generation resources in today's electricity portfolio and are not easily acquired from their current owners, nor are new sites for such facilities plentiful.

Figure 7-2 Emission Reduction Wedges and Targets



The development of many other forms of renewable power generation faces the same hurdles, but offers the same long-term benefits, as hydroelectric power. Only those forms based on capital components with an extra-high cost or limited life cycle that cannot competitively repay their initial investment, such as today's PV power options, are limited in long-term potential. Once renewable energy sites based on simpler technologies (such as wind, geothermal, and solar thermal power) are developed, they may last for centuries and, with only modest capital renewal, pay for themselves many times over while providing clean, economically stable sources of energy.

Additional development of on-site or off-site renewable energy supplies may be desirable to reduce long-term costs, stabilize operating budgets, and allow top-tier emissions reductions. Investigations are well under way to identify the optimal renewable energy generation sites in California via the Renewable Energy Transmission Initiative and other efforts. Acting early, while optimal sites are available, may increase the long-term advantages of renewable power, stabilize campus energy costs, and increase the cumulative reduction of GHGs in the critical period between now and 2050. Stanford will continually monitor the development of affordable renewable energy supplies within reasonable transmission range of campus and be prepared to take advantage of any opportunities that may be presented.

Stanford Should Remain Vigilant on Carbon Instruments Development. Given unknown costs and regulatory uncertainty, carbon instruments are not a primary building block of Stanford's Energy and Climate Plan at this time. While a solution using carbon instruments may be theoretically possible, it involves considerable risk because the long-term availability, quality, and cost of these instruments are unknown and highly speculative. Instead, diversifying campus energy sources, perfecting direct access to open energy markets, and decoupling university energy supply from the volatilities of fossil fuel markets to the greatest extent possible offer a better long-term strategy for supporting the university mission. If carbon instruments are certified via a regulated cap-and-trade scheme, Stanford will consider them at that time (see Appendix A).

Appendices

Appendix A: The Role of Carbon Instruments

The emissions reductions from resource efficiency and conservation are well understood. Less defined but still requiring special attention is the emerging role of carbon instruments. This appendix provides background information and Stanford-specific context for the implementation of California's cap-and-trade program and various instruments in the carbon market that may be part of the university's emissions reduction approach in the future.

Due to the rapidly evolving market and mechanisms for these instruments in California and nationwide, our findings suggest that they should not play a significant role in Stanford's Energy and Climate Plan at this time. While the emissions reductions from Renewable Energy Credits (RECs), offsets, and allowances can be measurable, and therefore can reduce emissions on a global basis, considerable financial, regulatory, supply, and perception risks are involved in making them major building blocks of immediate emissions reduction planning and implementation at Stanford.

Carbon offsets appear to offer the greatest potential as a tool for implementing AB 32 in California and the Western Climate Initiative (WCI) region. RECs and carbon allowances are less promising. Stanford will be regulated under the new cap-and-trade program and will need to weigh the potential costs of carbon as a purchaser of outside electricity or as a producer of its own cogeneration-based power.

This appendix outlines general findings from literature on carbon instruments, interviews with carbon instrument vendors, and the proposed draft regulation for AB 32, adopted in December 2010.

Definition and Description of Various Carbon Instruments

Renewable Energy Credits

RECs are verifiable credits purchased from a provider that produces or procures power solely from a renewable energy source (solar, wind, biomass, or geothermal). Also referred to as "green tags" or "green certificates," RECs have gained popularity among individual consumers and businesses for supporting an emerging green power market. Benefits from RECs are generally referred to as "environmental attributes" and may include reductions in the air pollution and particulate matter that would have been generated by burning fossil fuels. The electricity and environmental attributes can be sold as "bundled" products in retail green power programs, or they can be sold separately. In other words, consumers can continue to purchase electricity from their existing supplier and "green" it by supporting a renewable energy source of their choosing (WRI, 2006). RECs thus allow customers greater flexibility in greening their electricity.

One REC represents one megawatt hour (MWh) of renewable electricity generated and delivered somewhere on the power grid. Theoretically, each MWh of clean renewable electricity results in one less MWh of dirty power.

Carbon Offsets

A carbon offset, also referred to as a Verified Emission Reduction (VER), represents the reduction of one ton of GHG carbon equivalent (CO_2e) through activities that retire GHG emitting sources or capture GHGs from the environment. Examples of these activities are methane capture, sustainable forestry, and fuel switching. Companies use VERs to "balance" emissions of GHGs produced in one place by procuring GHG reductions from somewhere else. They usually do this after attempting to reduce emissions and if there are no available clean substitutes.

The California Air Resources Board (CARB) has adopted methodologies for quantifying carbon offsets under AB 32. These include methodologies for forest projects (adopted in October 2007) and for local government operations, urban forestry, and manure digesters (adopted in September 2008).

Many organizations sell offsets, but the lack of formal regulation of this market means that all offsets are not equal. In the past few years, the carbon offset industry has made these instruments more transparent. However, additional standardization of reporting methodology will benefit both buyers and sellers. (See Legitimacy Requirements for RECs and Offsets, below).

Legitimacy Requirements for RECs and Offsets

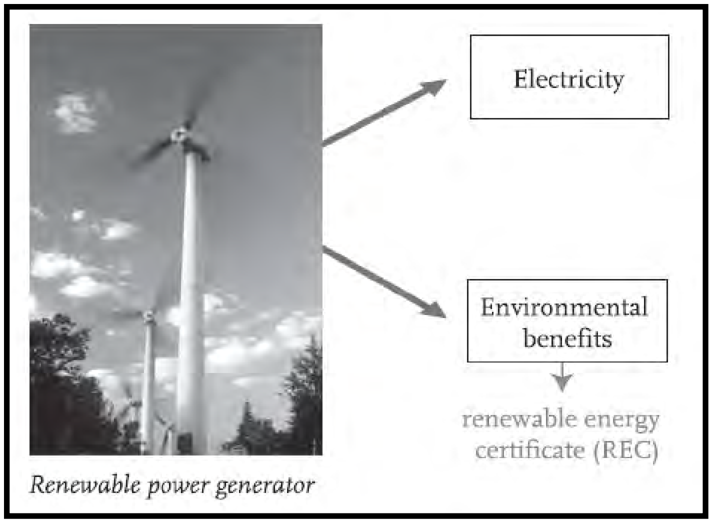
RECs and carbon offsets are market products that reduce emissions on a global basis. They must meet the criteria outlined below. Much of the controversy associated with them originates from the failure to justify meeting one or more of these criteria.

- **REAL:** The GHG reductions must represent actual emission reductions that have already occurred.
- **ADDITIONAL:** The GHG reductions must be beyond those that would have happened anyway or in a business-as-usual scenario.
- **PERMANENT:** The GHG reductions must be permanent and ideally backed by guarantees if they are reversed (for example, the GHGs are re-emitted into the atmosphere).
- **VERIFIABLE:** The GHG reductions must result from projects whose performance can be readily and accurately quantified, monitored, and verified.

Emissions Allowances

Under a state- or region-wide cap-and-trade program, allowances represent the total emissions allowed under a cap, denominated in metric tons of CO_2e, for a given entity during a specific compliance period. Essentially the currency for emissions trading, allowances enable facilities “to adjust to changing conditions and take advantage of reduction opportunities when those opportunities are less expensive than buying additional emissions allowances” (Scoping Plan, 2008). Allowances are fundamentally different from RECs and offsets in that they grant the "right to pollute" rather than being direct agents of emissions reduction. Allowances reduce overall emissions as the total number of allowances decreases over time.

Figure A-1 RECs-Two Products Generated by Renewable Power (WRI)



California Regulation AB 32 – Cap-and-trade Implementation

California demonstrated national and international leadership in climate action in 2006 by passing AB 32, authored by Fran Pavley and Fabian Núñez. AB 32—the Global Warming Solutions Act of 2006—requires that the state’s global warming emissions be reduced to 1990 levels by 2020. In December 2011, CARB released the final regulation implementing a cap-and-trade program to meet this goal. It sets up the framework and requirements for trading to ensure cost-effective emissions reductions. The program became effective on January 1, 2012, with the first allowance auctions to be held in August and November 2012.

Cap and trade is one of the key measures California will employ to reduce its impact on climate change. The California cap-and-trade program is meant to link with those of partner WCI jurisdictions to create a regional market system.

Reporting

Emissions reporting will be the backbone of the California cap-and-trade program. Data from mandatory reporting help establish the starting allowance budget and rules for distributing allowances. The entities and facilities subject to reporting in WCI jurisdictions are those with annual emissions of at least 10,000 metric tons CO_2e. California's mandatory reporting began in 2009 for 2008 emissions. The WCI Reporting Committee is developing reporting requirements, including quantification and verification methods.

The Cap

The cap represents the total GHG emissions permitted from all sources in the cap-and-trade system during a given compliance period. The cap level strongly affects what allowance price will prevail and, therefore, the need for cost containment options. The cap in AB 32 covers about 85% of California's emissions (industrial facilities and electricity by 2012, commercial and residential fuel consumption and transportation fuels by 2015). The allowances will be auctioned in the carbon trading market, rather than sold to the entities, in an effort to minimize corruption.

The first compliance period began on January 1, 2012. Compliance periods will be three years in duration (e.g., 2012 to 2014, 2015 to 2017, and 2018 to 2020). The initial cap was set in 2012 at 2% below the emissions forecast for 2012. The cap will decline by 2% in 2014 and by 3% annually from 2015 to 2020.

The Trading

The program started in 2012 for about 600 of the state's largest GHG emitters (primarily industrial sources and electricity generators), along with electricity imports. By 2015 it will include emissions from fuel combustion for transportation (e.g., gasoline, diesel, ethanol), and at stationary sources that fall below the threshold for direct inclusion in the program (e.g., residential and commercial natural gas combustion) by covering the suppliers of fuel to these sources.

At the start of the program, a minimum number of allowances will be allocated or auctioned off, depending upon the entity. Entities can buy and sell allowances via a market mechanism to meet their allowance requirements during each three-year compliance period. CARB has established clear rules for emissions trading, monitoring, and enforcement.

Capped sectors will be allowed to procure a limited number of high-quality offsets to cover a portion of their emissions reductions. Unlimited allowance banking is allowed to provide flexibility and reduce compliance costs.

Allowances (Permits to Emit)

Covered entities in a cap-and-trade program must obtain sufficient allowances to account for the GHGs they emit. Every year, as the GHG cap declines, fewer allowances will be issued, thus ensuring that emissions also decline.

- Buying and selling allowances establishes a price for each ton of GHG emissions that reflects the cost to participants of reducing emissions by that amount. The flexibility provided by trading allows for continued growth by individual sources while guaranteeing that total GHG emissions for capped sectors do not increase.
- At the end of a compliance period, each covered entity will be required to surrender allowances equal to its total GHG emissions during that period. CARB will then permanently retire these allowances. Failure to surrender sufficient allowances will result in significant penalties: the entity would have to provide four additional allowances for every ton of emissions not covered in time.
- Once an entity holds an allowance, it can (1) surrender it to comply with its obligation under the regulation: (2) bank it for future use; (3) trade it to another entity; or (4) ask CARB to retire it. Because allowances can be traded—that is, bought and sold— they have a significant economic value, whether they are allocated free of charge or initially acquired at auction.
- Large industrial facilities will initially be given free allowances but later forced to purchase allowances via an auction. Allowances for both the industrial and the electric sectors will initially be set at 90% of average recent emissions. Every year, capped industries must provide allowances and offsets for 30% of the previous year's emissions. At the end of the three-year compliance period, the industries must have enough allowances and offsets to cover the rest of their emissions over that period.

Cost of Allowances: CARB estimates that the price of CO_2 will be \$15/$MTCO_2e$ to \$30/$MTCO_2e$ in 2020. Under the proposed cost containment mechanism, allowances would be made available at reserve trigger prices of \$40, \$45, and \$50/$MTCO_2e$ in 2012, escalating 5% per year to \$60, \$67, and \$75/$MTCO_2e$ (respectively) in 2020. These prices are subject to fluctuation based upon behavioral, technological, and political factors.

Offsets under the Cap-and-trade Program

While allowing some offsets provides benefits, limiting their use assures that a majority of the required emissions reductions occur at entities and facilities covered by the cap-and-trade program. Consequently, offsets and allowances from other systems may cover **no more than 49% of the required reduction**. This translates to no more than 8% of a given facility's compliance obligation. This is a special area of attention for CARB and consistent with WCI policy. (CARB Webinar, December 2008).

Offsets must come from emission reduction projects in the United States, initially from projects in forestry, urban forestry, dairy digesters, and destruction of ozone-depleting substances. A framework is in place to eventually allow international projects.

The CARB Scoping Plan briefly mentions RECs in the context of Renewable Energy Portfolio (REP) standards for investor-owned utilities, but it does not provide for use of RECs in the cap-and-trade mechanism.

CARB will work with WCI partners and within the rulemaking process to establish an offsets program without geographic restrictions (e.g., one that allows offsets from the developing world). The criteria for offset credits must be stringent enough to ensure the overall environmental integrity of the program. One concept being evaluated would limit offsets to those from jurisdictions that demonstrate performance in reducing emissions and/or achieving GHG intensity targets in certain carbon-intensive sectors (e.g., cement), or in reducing emissions or enhancing sequestration through eligible forest carbon activities in accordance with appropriate national or subnational accounting frameworks.

Risks and Uncertainties of Carbon Instruments

Cost

The relatively low initial cost of RECs and offsets compared to capital improvement projects makes these mechanisms attractive alternatives in the set of GHG reduction options available today. Regardless of the cost ranges discussed below, it is important to note a fundamental characteristic of RECs and offsets: **unless the purchasing entity owns (funds and operates) the projects retiring the carbon in the atmosphere, RECs and offsets are a cash outflow to the entity and do not provide direct ownership or management capability.**

The prices of both RECs and offsets vary based on quantity and the duration of the contracts with different vendors. The average price can vary from \$30 to \$60/ton. This establishes a market reference for internal Stanford GHG reduction projects.

Figure A-2 (above) shows the price per ton of emissions reductions for on-campus projects. All projects "below the line" represent net economic benefits to Stanford. Projects "above the line" have a net cost.

While capital is a limiting factor, using Stanford's budget to invest in long-term efficiency projects that generate net savings is a priority, followed by investing in projects with a net cost but great emissions reduction potential. Stanford's budget is more effectively spent on capital projects with long-term net economic benefits than on annual operating expenses for offsets.

Varying Standards

Many organizations sell offsets, but the lack of formal regulation of this market means that **all offsets are not equal.** Organizations and vendors use different standards to guarantee the quality of their offsets in this voluntary market. Some examples are the following:

Clean Development Mechanism (CDM) Standards: A flexible compliance mechanism of the Kyoto Protocol, CDM supports offset projects in developing countries. Sanctioned as a way for governments and private companies to earn carbon credits, CDM-produced offsets, which can be traded in a marketplace, must meet stringent standards with strict "additionality" requirements (see Legitimacy Requirements for RECs and Offsets, above). Nevertheless, loopholes in the carbon credit protocols/standards have caused undesired market behavior.

Voluntary Gold Standard: Developed by a group of nongovernmental organizations, the Gold Standard is designed to be more stringent than CDM standards. For example, it does not certify sequestration projects that are difficult to accurately quantify. It requires third-party monitoring and verification of projects and includes strict "additionality" requirements.

Green-e Standards: Run by the U.S. nonprofit Center for Resource Solutions, Green-e sets standards and verifies renewable energy projects in the United States.

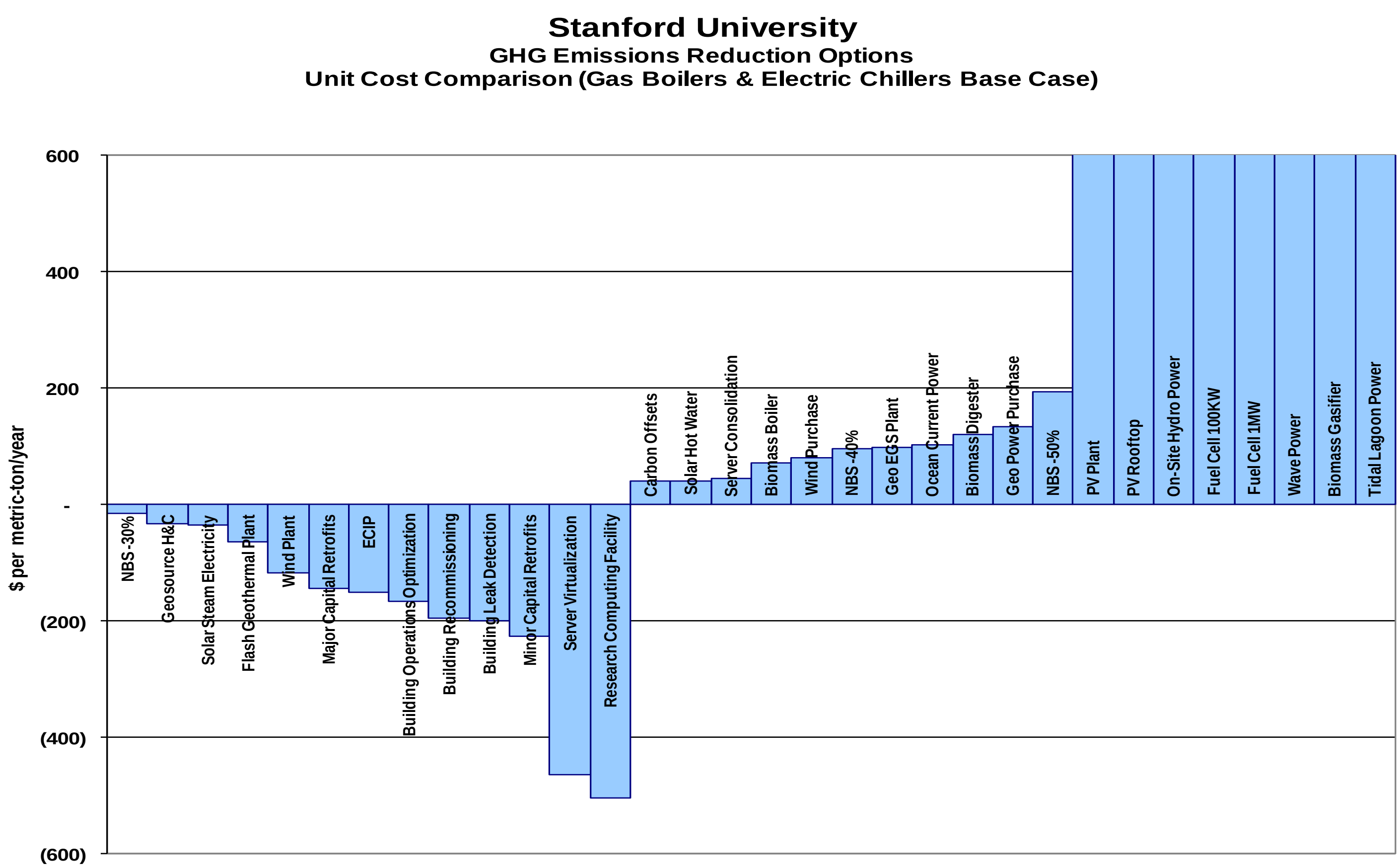
California Climate Action Reserve Protocols: The CCAR launched Climate Action Reserve in 2008, bringing order to the voluntary carbon market to assure high degrees of environmental integrity, transparency, accuracy, and accountability in that market. The reserve is likely to play a strong role in implementation of cap and trade under AB 32.

In the past few years, the carbon offset industry has improved the transparency of these instruments. However, additional standardization of reporting methodology will benefit both buyers and sellers.

Entangled Regulations

Significant uncertainty surrounds the interplay between California and federal regulations and how that impacts the definition and use of different carbon instruments. Federal activities are expected to accelerate, and the federal Clean Air Act authority may soon mandate a federal carbon tax. While CARB hopes that the interplay between California or WCI cap and trade and a carbon tax will be smooth, at a minimum it will impose administrative and reporting requirements and possibly a sizable financial responsibility on regulated institutions.

Figure A-2 Stanford University Emissions Reduction Options



In addition, at a state level, the operational placement for carbon instruments has not been fully determined. RECs are currently seeking certification to count as allowances in the carbon cap-and-trade market in California. Regulatory experts speculate that state or national regulatory schemes will supersede the current voluntary market for RECs. Similarly, recognition of voluntary reduction or offset methodologies under the AB 32 implementation plan does not in any way guarantee that the resulting offsets can be used for other compliance purposes.

Perception

Carbon offsets are popular concepts, having gained recognition and support in the media as a tool for individual action. However, offsets are still defined in broad terms to refer to any effort to reduce GHG emissions, and their use will greatly benefit from the clarity provided by the AB 32 implementation process. Perhaps the biggest perception issue with offsets is that they involve annual cost without the security of infrastructure improvement that the beneficiary entity can manage and monitor. In addition, offsets suffer from the public perception of "buying one's way out" of making needed changes to infrastructure.

Implications for Stanford University

STANFORD UNIVERSITY WILL BE REGULATED UNDER AB 32. CARB has imposed reporting emissions thresholds of 25,000 $MTCO_2e$ for any entity and 250,000 MT for any power generation facility. Because Stanford procures power from Cardinal Cogeneration (owned and operated by General Electric) and the current Scope 1 and 2 emissions exceed 250,000 $MTCO_2$, the university will be regulated.

ALLOWANCES WILL NOT BE FREE. Stanford will not be given free allowances for carbon because the proposed regulation gives "free allocation" only to the manufacturing industry, not to university CHPs.

THERE IS NO CAP ON HOW MUCH GAS STANFORD CAN BURN; STANFORD WILL JUST HAVE TO BEAR THE INCREMENTAL ALLOWANCE COST. Cap and trade does not limit the amount of CO_2 that a covered source can emit. However, Stanford will always have incentive to reduce emissions because it will simply cost more to emit more over time. The expectation underlying the cap-and-trade program is that efficient installations will always be better off than inefficient ones, creating an incentive to be greener. The instrument has not and will not set a legal limit to how much fuel a regulated entity can burn or use, Stanford will just need to be prepared to pay to procure allowances at an estimated price of \$10–\$30/ton of CO_2. In essence, the environmental stewardship question is intertwined with economic prudence. The regulation is designed to make emissions incrementally expensive.

THE COST ESTIMATION FOR ALLOWANCES PER THREE-YEAR COMPLIANCE PERIOD IS:

total Scope 1 and 2 emissions in $MTCO_2e$ x \$ allowance cost
= 200,000 $MTCO_2e$ x \$15 to \$30
= \$3 million to \$6 million

STANFORD'S LONG-TERM STRATEGY SHOULD FOCUS ON GREENING ENERGY SUPPLY TO THE MAXIMUM EXTENT. Cap and trade is only one of the AB 32 regulatory instruments. The REP standard requires 33% of renewable energy in the state's fuel mix. The Low Carbon Fuel Standard and the California Advanced Clean Cars Program account for more than 150 million cumulative metric tons of reductions. Going towards "green" is a cheaper long-term strategy because the combination of cap and trade and REP is designed to systematically introduce a carbon price to fossil fuel purchase and use, thus ultimately reducing that use.

"Cap and trade is a market-based mechanism, not a direct regulation. We are not trying to say, 'You should do this,' as is the case with direct regulation. The expectation is that the market will adjust to a low-carbon economy and the entities that adopt quickly will come out as winners." – CARB staff

Stanford's energy planning horizon is 2050, well beyond AB 32's planning horizon. But the effect of the regulation will hold, national regulation may be coming, and both are likely to be designed to help drive investment into activities that result in lower GHG emissions.

IF DONE RIGHT, EARLY ACTION WILL NOT HURT THE UNIVERSITY. Entities that have demonstrated reductions prior to the initiation of the cap-and-trade program could be eligible for allowance value. This would incentivize early reductions, which would reduce cumulative emissions.

AB 32 has a bias for cogeneration, but higher efficiency is all the better, and many of the terms for CHP regulation are yet to be defined. The main reason AB 32 favors cogeneration is that the grid will have a carbon tax. Much remains to be determined on timing, quantity of allowances, and the use of natural gas.

Gas price projections are uncertain, but gas will not be cheap. Cap and trade covers electricity and large stationary sources starting in 2012. In the second compliance period (~2015–2017), transportation fuel and natural gas for residential and commercial use will also be covered, and gas prices will be subject to a carbon adder.

Recommendations for Stanford Regarding Carbon Instruments

Given the annual costs and regulatory uncertainty, RECs, allowances, and carbon offsets should not be treated as fundamental building blocks of Stanford's Climate Plan. RECs and offsets should be viewed as complementary to a robust and actionable GHG reduction plan founded on infrastructure and programmatic improvements that support individual action to serve the campus in the long term. RECs and offsets are to be used to fill the gap between on-site projects and a specific GHG goal. If Stanford does decide to enter this market, here are some recommendations for possible scenarios in which these mechanisms can add value to Stanford's emissions reduction goals.

Research: One of Stanford's interdisciplinary environmental institutes should engage in a steady but minimal annual investment in some carbon instruments (most applicably offsets and RECs) to monitor how the market is evolving. This could be a student-managed project.

Public Relations: RECs and offsets have gained an increasingly positive image in the business world for offering some option to consumers and businesses who want to make a contribution to the emerging green market and accept the risks associated with the purchase. Stanford should develop a policy for academic and operational departments and their special events to allow and acknowledge purchase of RECs, if the activities have potential to create a positive PR opportunity.

Programmatic Incentive for Individual Action: Stanford should continue to consider purchasing RECs and offsets for specific sources of GHG emissions that cannot be fully mitigated by infrastructure improvements. For example, departments could offer a subsidy to commuters to purchase offsets for commuting; such a program could encourage students and employees to participate in the process voluntarily and alter their commute behavior.

The following steps are recommended if Stanford purchases RECs or offsets for research or to complement other emissions reduction programs:

- Stay current with the carbon emissions market (both regulations and pricing).
- Determine the percentage of emissions Stanford could reduce through RECs and offsets.
- Determine a range (0% to 100%) of the remaining emissions from a chosen target that are currently not planned to be met by reductions from infrastructure improvement projects.
- Determine the gap between cost-effective demand or supply projects and the GHG goal, and use RECs or offsets to make up the difference.

Implement on-campus conservation and renewable energy projects that are low cost or have a positive internal rate of return.

Once the VERs and/or RECs are part of Stanford's GHG strategy, work with providers as described in the Consumer Guide to Carbon Offsets.

Appendix B: Stanford Emissions Inventory

Summary

Stanford University has committed to estimating and reporting its GHG emissions in accordance with the Climate Registry (TCR)'s General Reporting Protocol (GRP).[1] This involves estimating GHG emissions resulting from Stanford operations, compiling a GHG inventory, and reporting the inventory results via the Climate Registry Reporting Online Tool. A TCR-approved service provider must verify the completed inventory.

Figure B-1 shows the official Scope 1 and 2 emissions inventory and the unofficial Scope 3 emissions for the university, plus CEF emissions attributable to steam and chilled water deliveries to the Stanford Hospital and Clinics (SHC). Total GHG emissions (Scope 1, 2, and 3 plus SHC steam and chilled water) were about 276,500 $MTCO_2$ in 2011.

Protocols for the Emissions Inventory

In 2001, the state of California created the nonprofit California Climate Action Registry (CCAR) to facilitate voluntary accounting and reporting of GHG emissions. In 2010 CCAR transitioned its membership to TCR, a nonprofit emissions registry for North America.

The CCAR GRP required the filing of Scope 1 and 2 emissions inventories with independent third-party verification, and encouraged the filing of Scope 3 emissions as well. Stanford joined the CCAR in 2006 and used this protocol to prepare and file its GHG emission inventories through 2009. In 2010, Stanford transitioned to the TCR protocol.

Organizational Boundary

The organizational boundary encompasses all the facilities and operations that Stanford owns or controls within the geographic boundary (the state of California). Stanford reports all of the associated GHG emissions for those operations and facilities that it wholly owns or over which it has operational control.

Operational Boundary

Within the organizational boundary, Stanford assigns its emissions sources to categories, as described below.

Categories of Emissions and Source Identification

The GRP requires TCR members to account for emissions in the following categories:

- Direct emissions from sources owned or controlled by the member:
  - Mobile combustion sources;
  - Stationary combustion sources;
  - Process functions; and
  - Fugitive sources.
- Indirect emissions from sources that occur because of a participant's actions:
  - Purchased and consumed electricity; and
  - Purchased and consumed heat, steam, or cooling.

Stanford's self-reported operational boundary includes the following emission categories:

- Scope 1 – stationary combustion
- Scope 1 – mobile combustion
- Scope 1 – process
- Scope 1 – fugitive

1 The Climate Registry General Reporting Protocol, Version 1.1, May 2008.

- Scope 2 – purchased electricity
- Scope 2 – purchased steam
- Biogenic – mobile biomass combustion

Stanford University Emissions Inventory

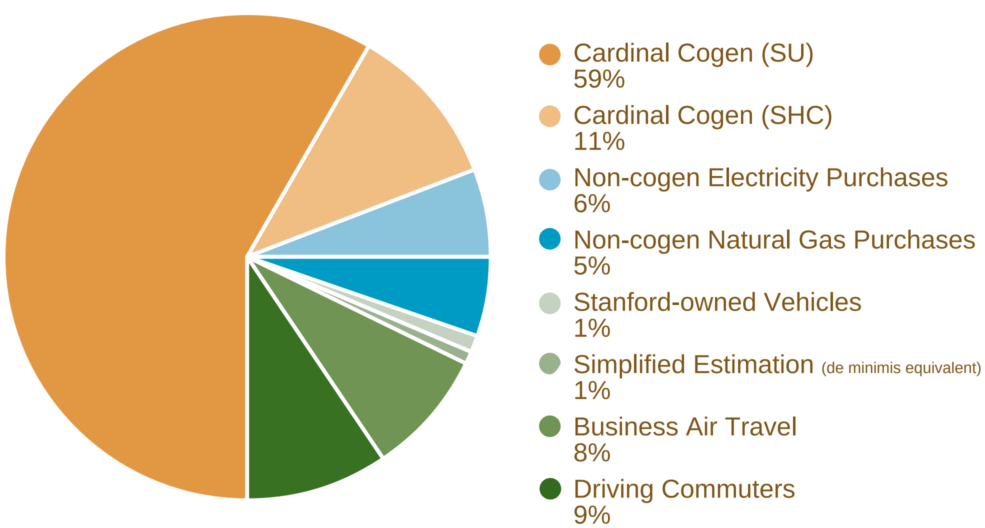
The geographic boundary for Stanford University GHG reporting is the Stanford main campus, which does not include SHC or SLAC National Accelerator Laboratory.[2] Stanford's emissions inventories from 2006 to 2009 can be viewed at http://www.climateregistry.org/tools/carrot/carrot-public-reports.html. Inventories starting in 2010 can be viewed at https://www.crisreport.org/web/guest/analysis-and-reports. Please note that the information reported below includes de minimis or de minimis–equivalent emissions.

- In 2006, Stanford's initial inventory of core Scope 1 and 2 GHG emissions (CO_2e) from the main campus totaled approximately 168,400 MT.[3]
- In 2007, Stanford's inventory of core Scope 1 and 2 GHG emissions (CO_2e) from the main campus totaled approximately 182,900 MT.
- In 2008, Stanford's inventory of core Scope 1 and 2 GHG emissions (CO_2e) from the main campus totaled approximately 180,700 MT.
- In 2009, Stanford's inventory of core Scope 1 and 2 GHG emissions (CO_2 e) from the main campus totaled approximately 182,400 MT.
- In 2010, Stanford's inventory of core Scope 1 and 2 GHG emissions (CO_2e) from the main campus totaled approximately 195,800 MT.
- In 2011, Stanford's inventory of core Scope 1 and 2 GHG emissions (CO_2e) from the main campus totaled approximately 198,400 MT.
- The campus has also prepared unofficial inventories of its Scope 3 emissions and emissions attributed to steam and chilled water deliveries to SHC from the CEF.
- Emissions of the five other GHGs identified in the Kyoto Protocol (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) were reported to the CCAR for the first time in 2009. They comprise one-tenth of one percent of Stanford's total GHG emissions.

2 SHC and the SLAC National Accelerator Laboratory are distinct organizations that do not fall under the university's operational control.

3 WRI/WBCSD Protocol

Figure B-1: 2011 Emissions Inventory (metric tons CO_2)



Emissions for 2011 per the Climate Registry General Reporting Protocol.

Campus Growth and Emissions Trends

Long-term energy demand projections were developed based on projections of campus growth in GSF and expected average energy intensity per square foot.

The actual campus GSF served by each type of energy service (electricity, steam, and chilled water) as of 2008 were determined based on actual data and planned growth information from the campus capital plan, which covers the period through 2020. For the period after 2020, three growth scenarios were developed consistent with the recently completed campus Sustainable Development Study, developed by the Planning Office.

More specifically, projections of average energy intensity per square foot were calculated by determining the overall net growth rate in energy demand over the past 20 years and dividing that by the change in GSF. These estimates were applied to the GSF projections to develop growth projections for each of the three energy services. Using these energy intensity demand projections, a forecast of future campus GHG emissions was prepared using three possible scenarios:

- Business-as-usual emissions with growth
- Emissions with growth and air travel
- Emissions with growth, air travel, and commute

For a complete list of assumptions and methodologies, please contact: Susan Vargas, Facilities Energy Management, susank@bonair.stanford.edu

Appendix C: Campus Utilities Growth Projections

A long-range forecast of campus electricity, steam, and chilled water demands was prepared using the current campus building construction schedule (for growth through 2020) and the three growth scenarios considered in the Sustainable Development Study.

Figure C-1: Projected Electrical Consumption

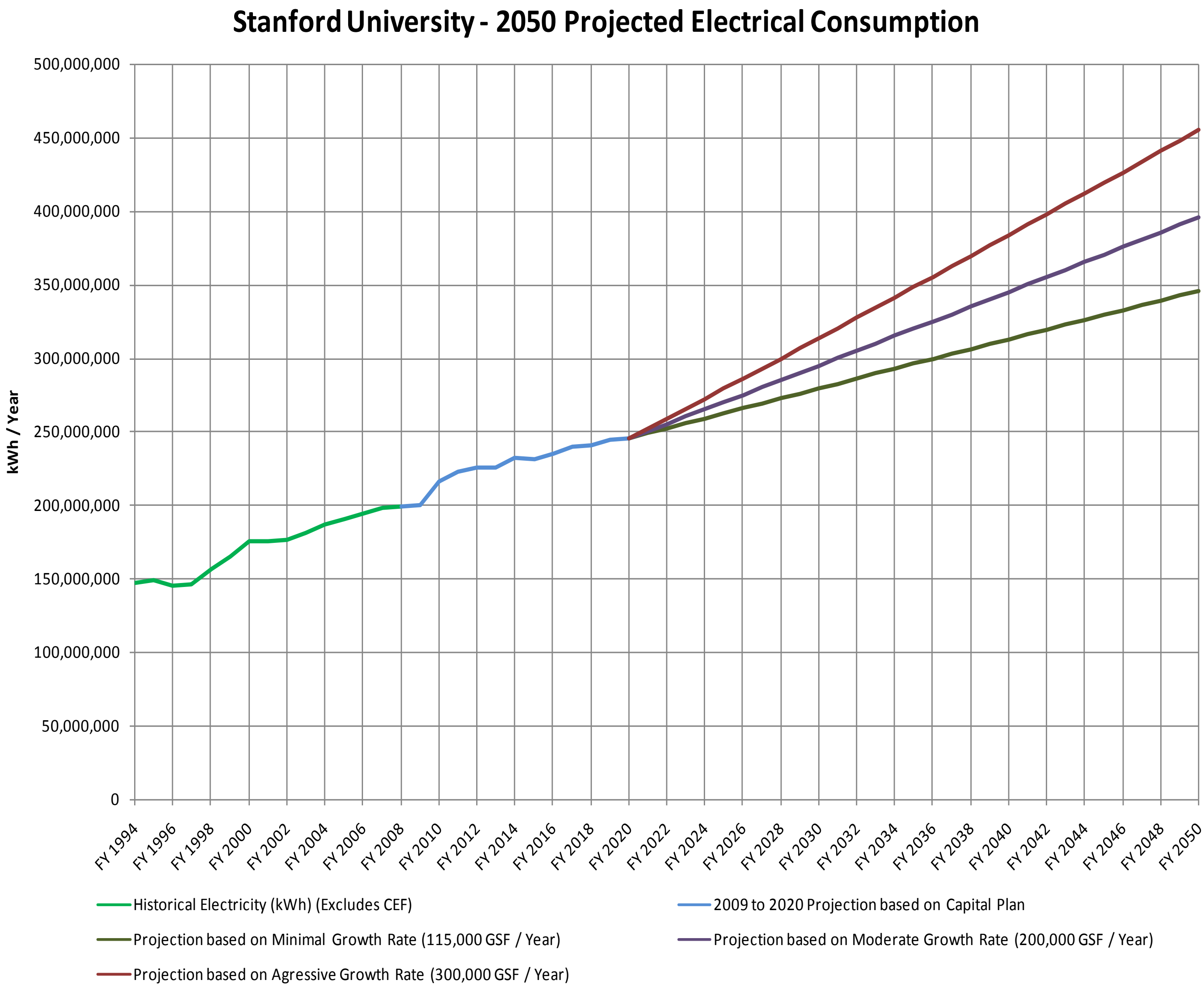


Figure C-2: Projected Steam Consumption

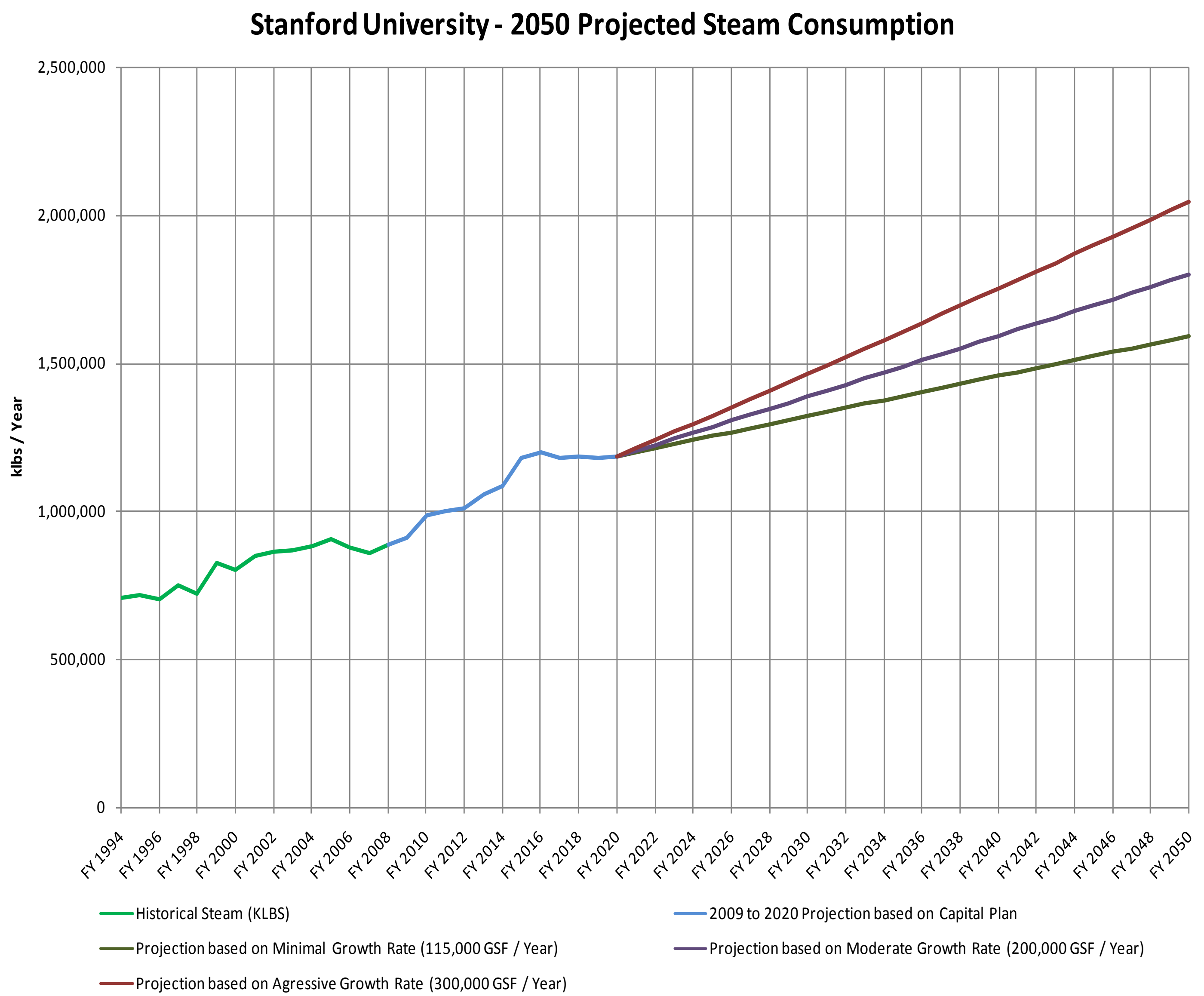
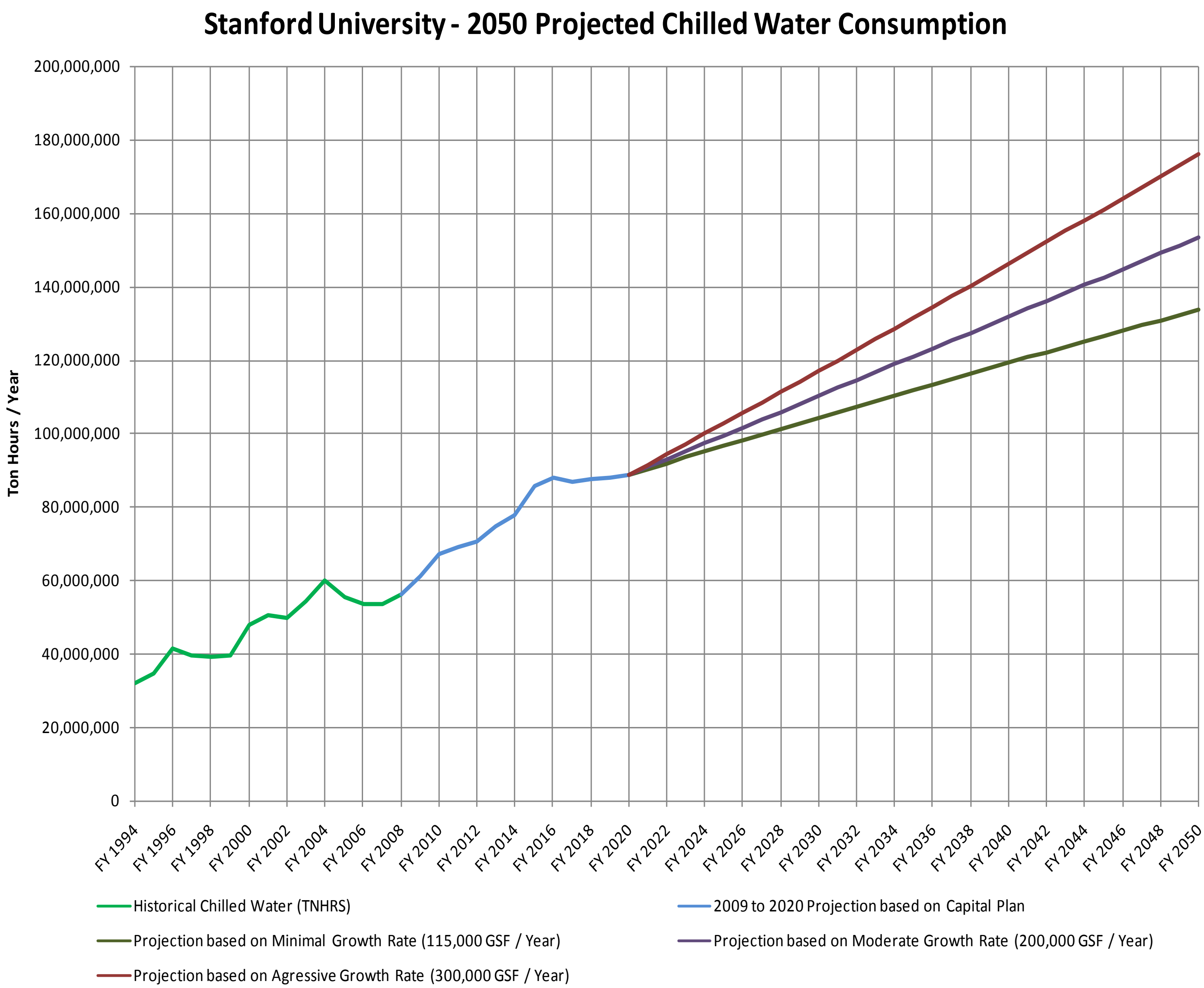


Figure C-3: Projected Chilled Water Consumption



Appendix D: Benefits of Converting Steam Distribution to Hot Water

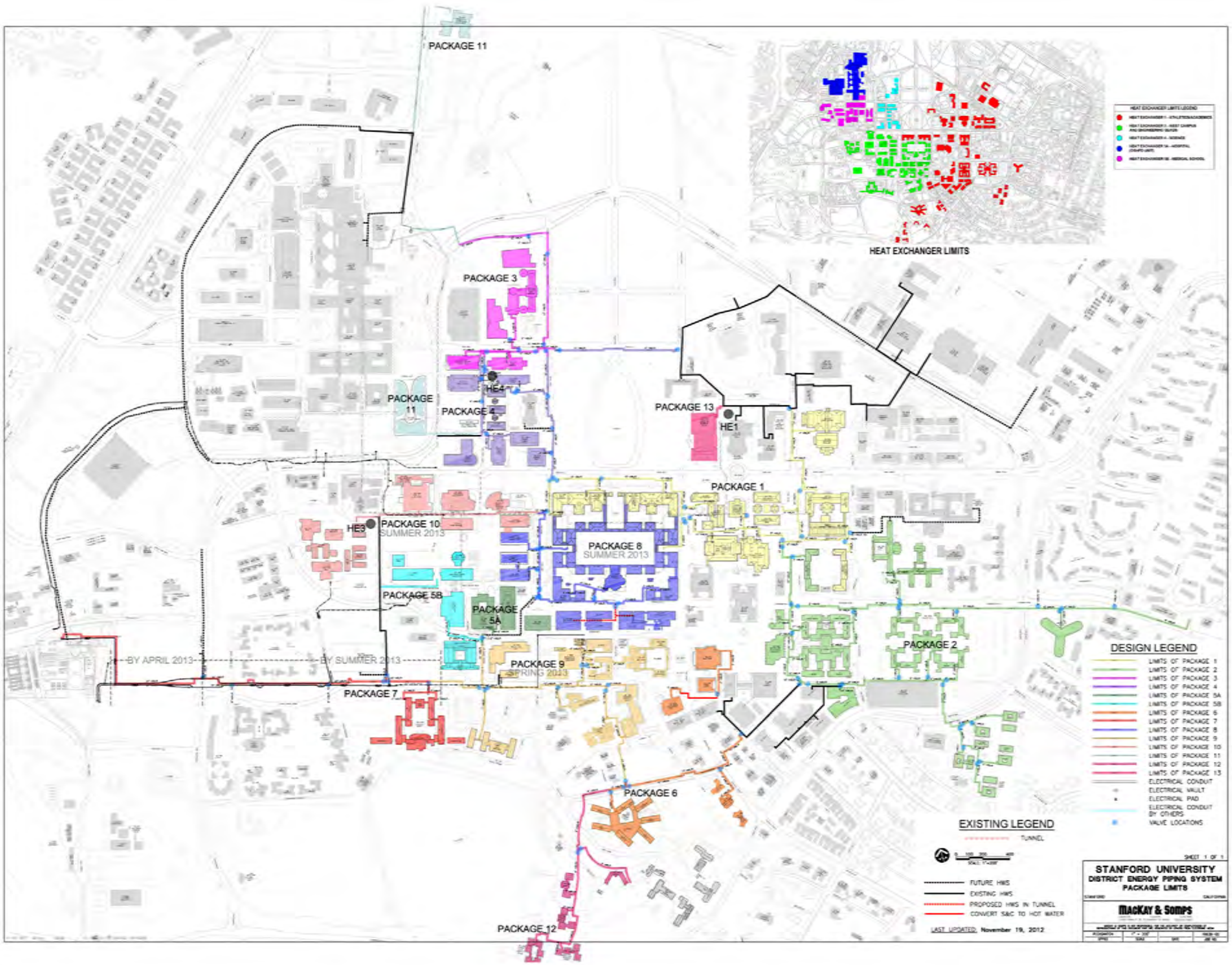
Achieving heat recovery at this scale would require a complete conversion of the campus steam distribution system to a hot water distribution system. Figures D-1 and D-2 depict one possible phasing plan for such a conversion. Additional benefits beyond facilitating the deployment of heat recovery include the following:

- Heating system line losses could be reduced from about 12% to 4%;
- Operation and maintenance cost would be much lower;
- Substantial capital costs for replacement of aging portions of the steam system could be avoided; and
- Capital costs for future system expansion and interconnection to new buildings would be much lower.

This analysis examined several case studies and analytical reports explaining the benefits of heat recovery and steam to hot water conversions, including the following:

- Industrial Heat Pumps for Steam and Fuel Savings, US Department of Energy
- Water to Water Heat Pumps, York Chiller Company
- District Heating (DH) System Optimization: Principles and Examples from US Army Studies, Roland Ziegler, GEF Ingenieur AG
- From Steam to Hot Water and CHP: University of Rochester Converts, Morris A. Pierce, University of Rochester, District Energy Magazine, Third Quarter 2007
- Efficiency of Steam and Hot Water Heat Distribution Systems, Gary Phetteplace, CRREL, U.S. Army Core of Engineers

Figure D-1: Steam to Hot Water Conversion Phasing Plan



Appendix E: Peer Review Consultants Reports

Peer review reports are available upon request. The following groups contributed reports:

2009 –Jacobs Carter Burgess

2009--Affiliated Engineers, Inc.

2010—Enginomics

2011—Black and Veatch – Economic Model

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Stanford University

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