



Stanford Energy System Innovations

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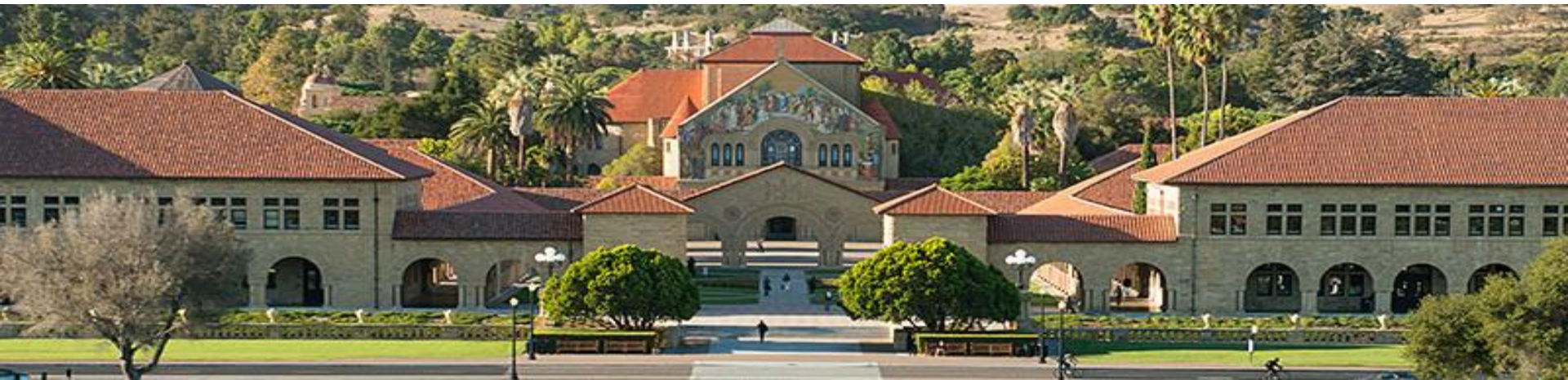
Department of Sustainability & Energy Management

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Sustainability at Stanford: Research and Action

The Initiative on Environment and Sustainability (Since 2003)

Interdisciplinary Research: The Initiative boosted interdisciplinary research and teaching in all seven of Stanford's schools, as well as in interdisciplinary institutes, centers, and associated programs across campus.



Sustainable Stanford (Since 2007)

Institutional Practice of Sustainability: University-wide effort to reduce Stanford's environmental impact and preserve resources through innovation and best practices.

Energy & Climate Plan Vision

Support Academic Mission

- Successor for Cardinal Cogeneration
- Expansion for research and academic programs



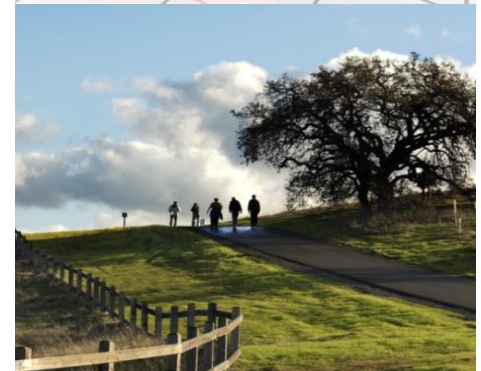
Maintain Economic Viability

- Increase efficiency
- Protect against resource cost increase



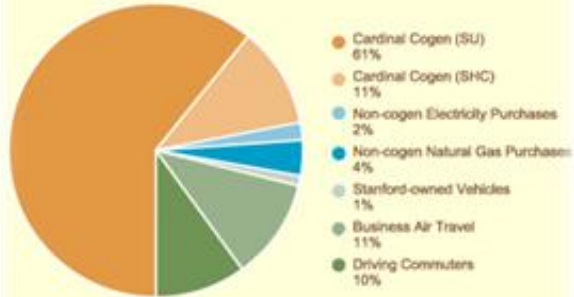
Lead Sustainability By Example

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



Balanced Approach to Energy Management

Emissions Inventory
(metric tons CO₂)



Energy
Conservation in
Existing
Buildings



Energy Efficiency
in New Building
Design



Energy Supply

Aggressive Energy Conservation



Existing Energy Conservation and Efficiency Initiatives

- Retrofit Programs
- Energy Conservation Incentive Programs
- Monitoring, Recommissioning, High Efficiency Equipment
- Advanced building controls

Benefits

- Energy retrofits save more than **39 million kilowatt-hours** of electricity per year. This is equal to 19 % of the university's current annual electricity consumption.
- Cumulatively, these projects have led to over **\$4 million in savings** for the university per year.



Advanced New Building Design



Leslie Sun



Astrophysics



Spilker



LKSC



Lokey Stem Cell

2000

Sustainable Guidelines

2005

SU Energy Goals 30/25

2010

SCC GBO

2015

2013 T24

Global Ecology

Y2E2

Huang

Knight

Neukom

Shriram



Transformation of the Stanford Energy System



Stanford Energy System Innovations (SESI) is a new sustainable energy program designed to meet the energy needs of Stanford and lead by example. The project transformed the campus energy supply from one based on fossil fuels, to an electrically powered system.

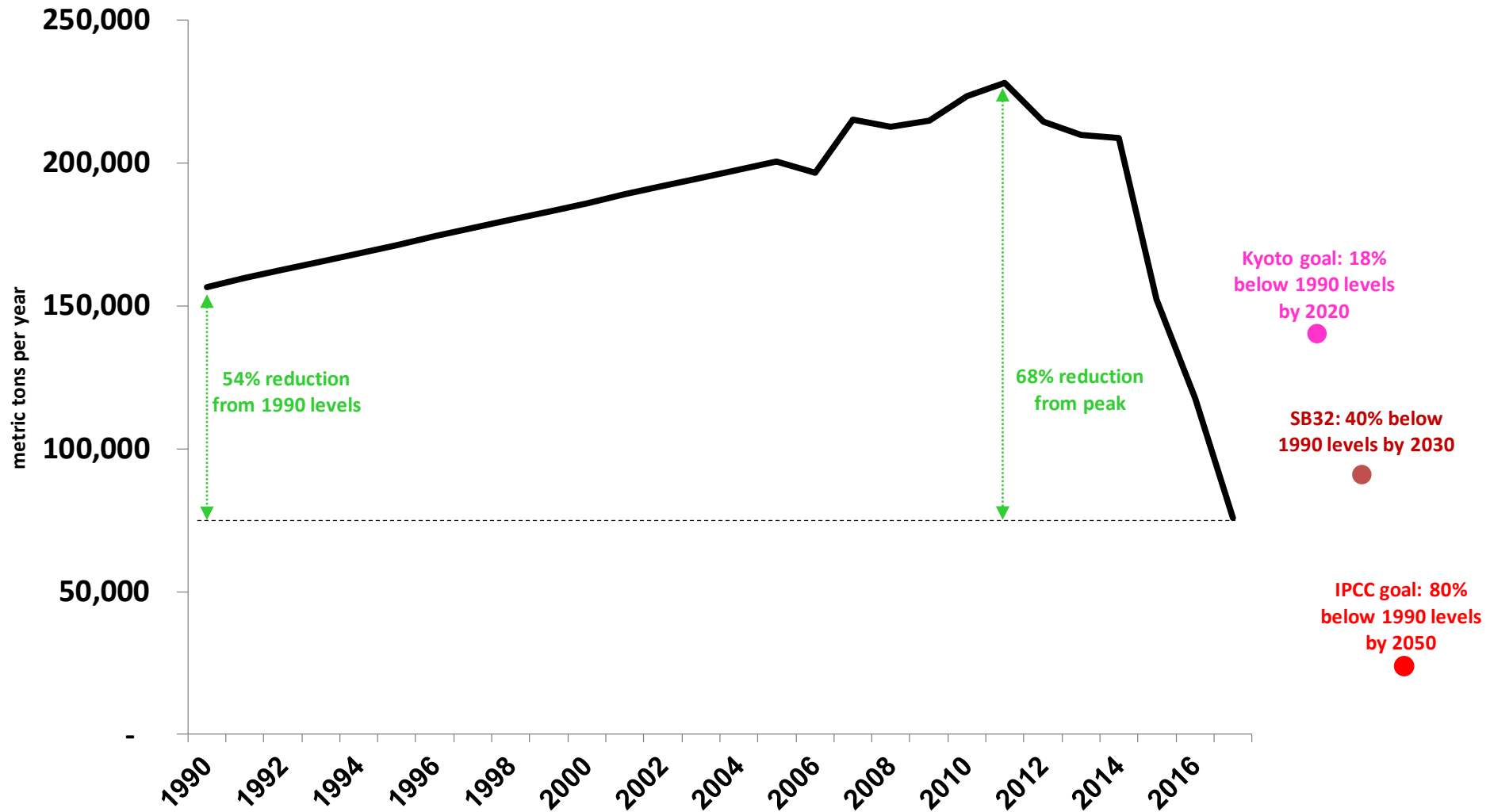
Benefits

- Reducing campus greenhouse gas emissions by **68%**
- Reducing campus drinking water use by an additional **15%**
- Saving **\$450** million over Business As Usual over next 35 years
- Supplying **65%** of our electricity from renewable sources

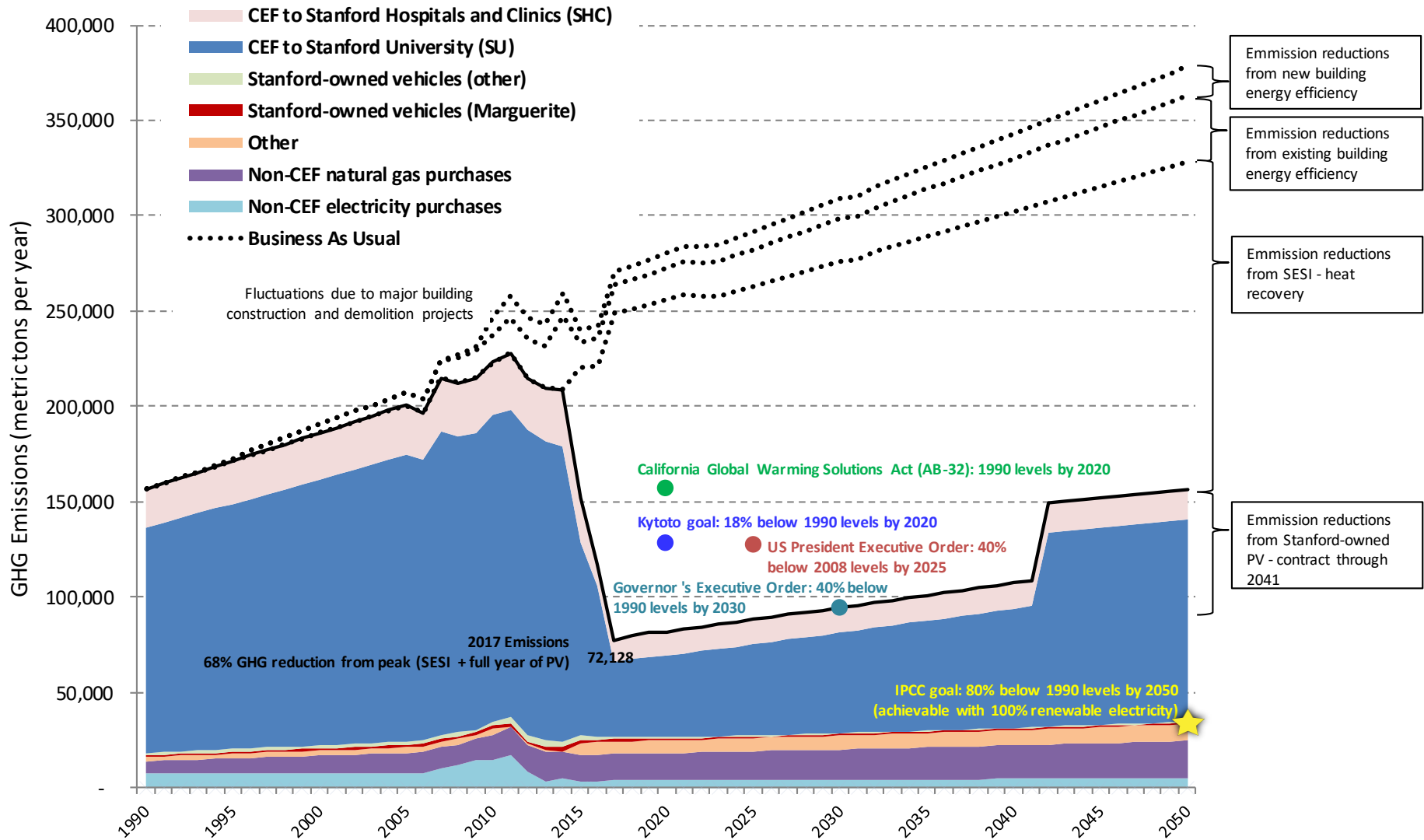


Benefit to Complete Energy Management: 68% GHG Reduction

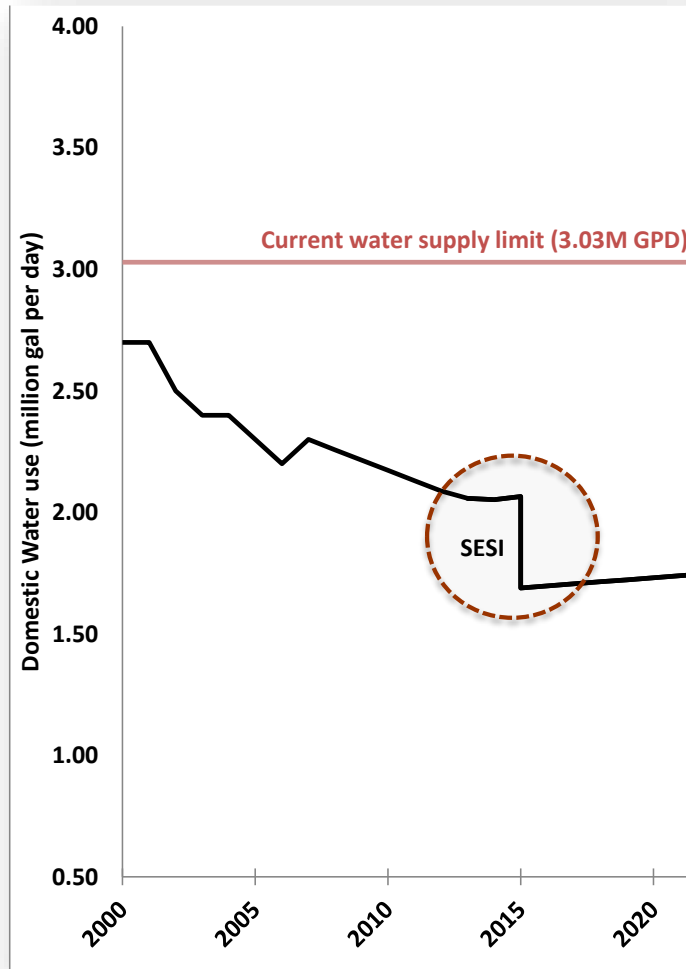
Stanford University Greenhouse Gas Emissions



Benefit: Greenhouse Gas Reduction



Benefit: Additional 18% Potable Water Savings



History of Conservation

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

With SESI, Stanford saves an additional 18%.

Stanford reduced its water consumption by 39% in 15 years.

Program Elements

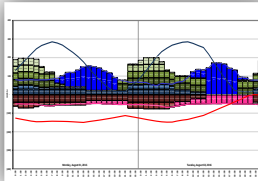
Heat Recovery
(District level application)



New Thermal System
(Steam to hot water)



Advanced Optimization Tool
(Patented)



Renewable Energy Portfolio
(Purchased electricity)



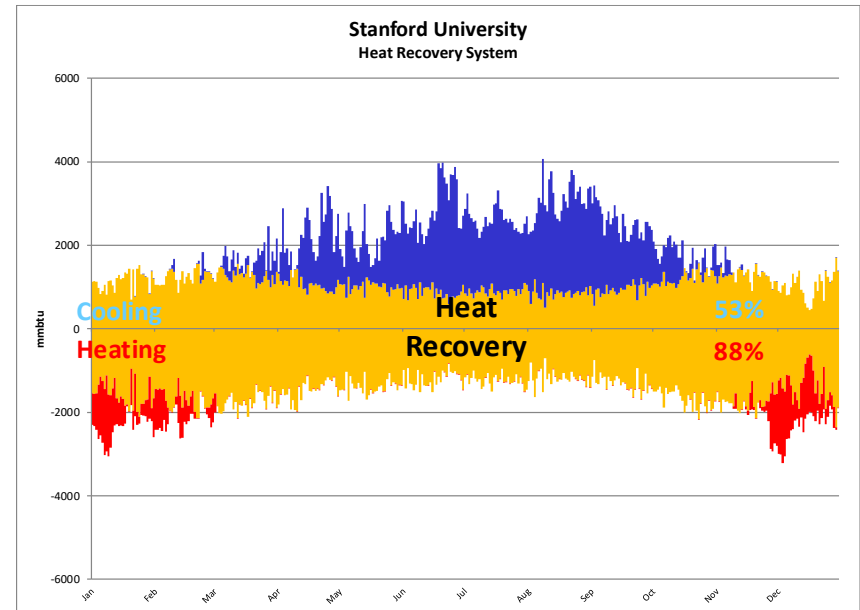
High-voltage substation
(New)



Lasting Benefits

- Energy savings
- Water savings
- Increased system efficiency
- Flexibility to adapt to new technologies
- Increased safety
- Reduced operations cost
- Improved services reliability

Innovation: District Level Heat Recovery



- Large scale deployment of heat recovery – 70% heat recovery potential
- Combining best heating and cooling technologies in Europe and North America

Global Potential for Heat Recovery

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

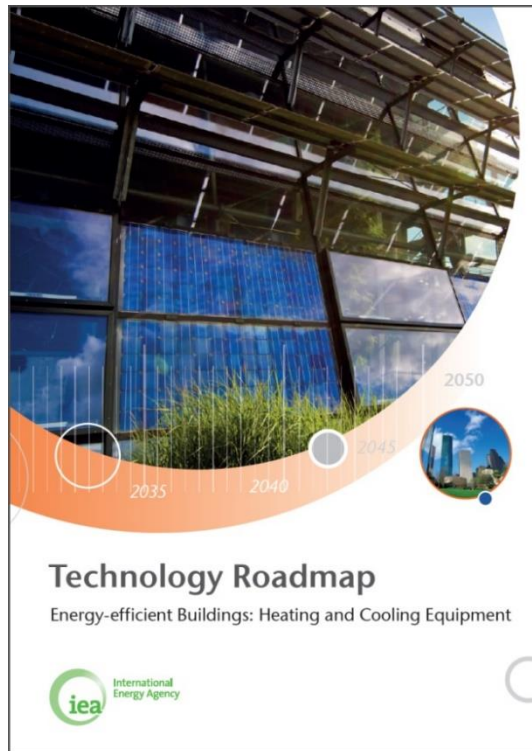
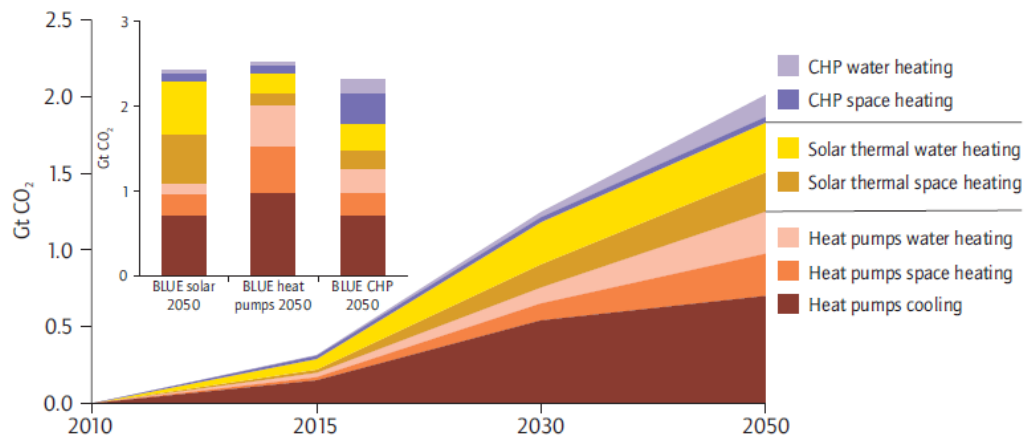


Figure 7: Heating and cooling technologies' contribution to CO₂ emissions reduction (BLUE Map and alternative scenarios)

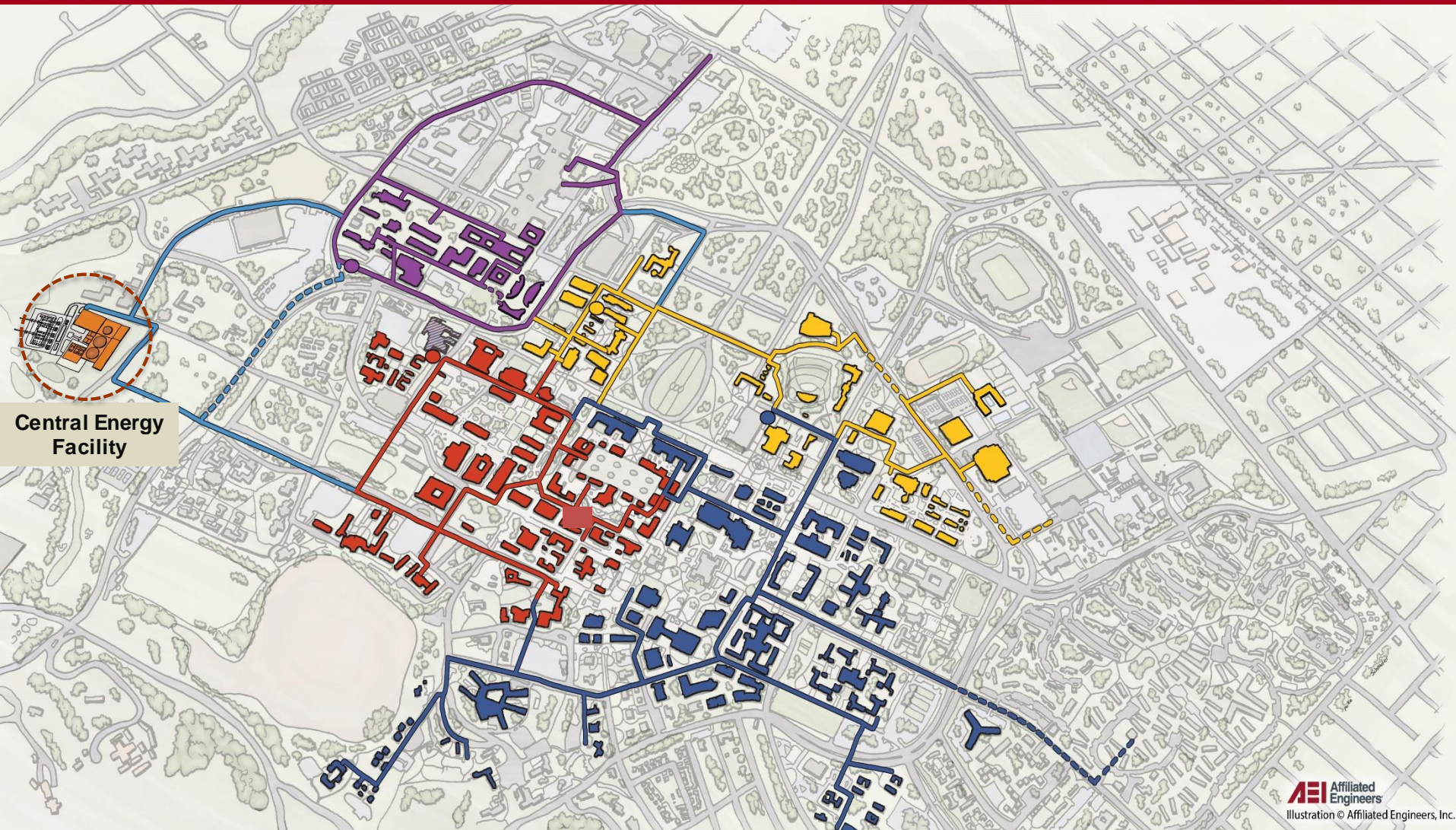


Note: Excludes the impact of improved building shells on reducing heating and cooling loads.

KEY POINT: Energy-efficient and low/zero carbon technologies for heating and cooling save 2 Gt CO₂ by 2050.

2011 International Energy Agency Report

Overall Conversion of Thermal System

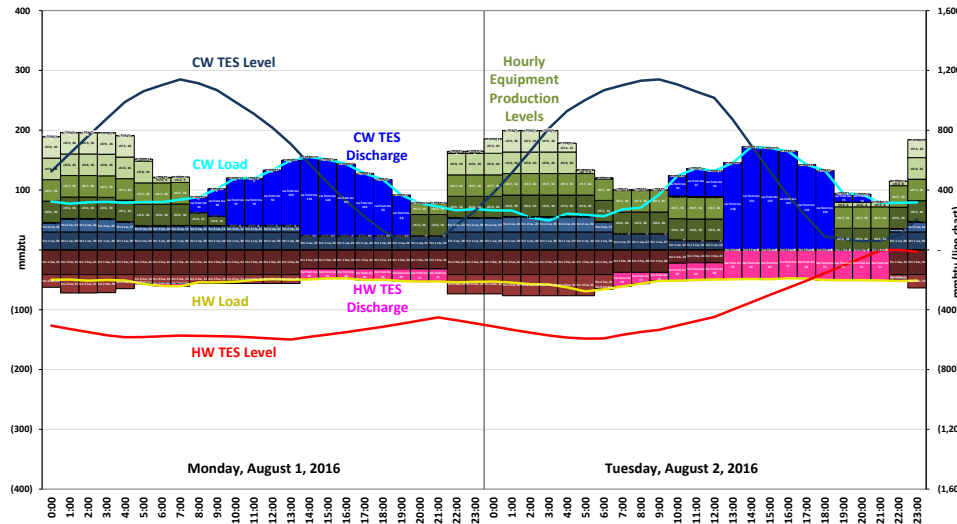


- Colors represent different phases of steam to hot water conversion
- 20 miles of new hot water pipe
- 155 building conversions

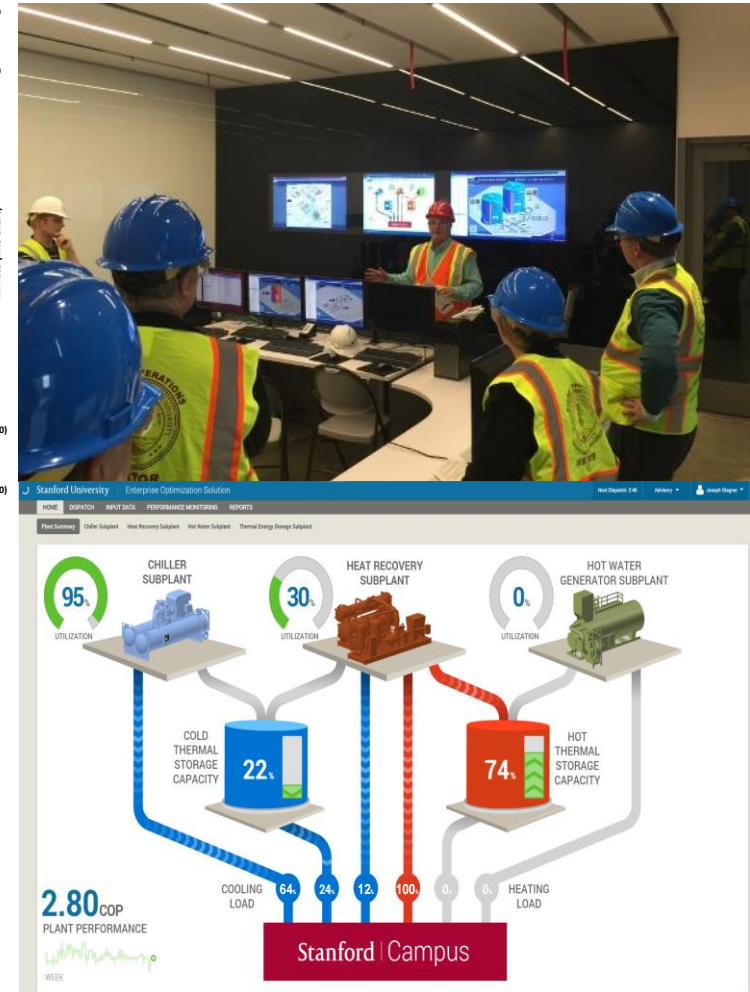
Innovation: Advanced Planning & System Operation

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

Central Energy Plant Optimization Model
Hourly CEF Dispatch Plan



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



Purchased Electricity 65% Renewable

Greener than California Mix: 65% of our electricity from renewable sources

Brown power from CA grid



67 MWdc, SunPower Oasis
C1 Power Plant, Single axis
tracking system, [Video](#)

4.5 MW Rooftop solar



Green power
from CA grid

Rooftop Installation 3% of Total

- 16 Stanford buildings
- 4.9 MW dc, Completed by December 2016
- One large parking structure roof top (1.9MW)
- Type: Mix of rack mounted (RMR) and SunPower Helix system



Stanford Auxiliary Library, Livermore



Stanford Auxiliary Library, Livermore

Stanford Solar Generating Station - 50% of total

- Rosamond in Kern County, CA at Holiday Ave and 150th St
- 67 MWdc, Complete by Dec 31, 2016
- Type: SunPower Oasis C1 Power Plant, Single axis tracking system
- [Video](#)



Stanford Solar Generating Station - 50% of total



Opportunities for Additional GHG Reduction

| <u>GHG Emissions</u> | <u>m-tons/year</u> |
|--|--------------------|
| 1990 (Baseline) | 157,000 |
| <i>IPCC 2050 Goal (20% of 1990 level)</i> | <i>31,400</i> |
| 2011 (Peak) | 228,000 |
| 2015 (after SESI) | 117,000 |
| 2017 (after PV) | 68,000 |
| <u>GHG reduction options</u> | |
| Increase renewable electricity from 68% to 100% | 38,000 |
| Complete bus fleet electrification | 1,000 |
| Complete car fleet electrification | 1,000 |
| Deploy ground source heat exchange | 3,000 |
| Convert rest of buildings to hot water or use sustainable combustion gas | 8,000 |
| Use sustainable combustion gas for cooking and other processes | 6,000 |
| Find alternatives to process steam use or use sustainable combustion gas | 4,000 |
| Capture emissions or find alternatives for GHG emitting research gasses | 3,000 |
| Capture emissions or find alternatives for GHG based refrigerants | 3,000 |
| Other | 1,000 |
| <hr/> | |
| total | 68,000 |


Campus Citizenship: *My* Cardinal Green



My Cardinal Green



Welcome to your gateway to participating in making Stanford a more sustainable campus. My Cardinal Green connects you with resources and opportunities to minimize your environmental impact and maximize your sustainability efforts on campus. Get rewarded for small actions that can have big results!




Welcome Lauren Hennessy!
You need 90 more points to be eligible for your incentive


10
Your Earned Points


0
Your Pending Points

REDEEM INCENTIVE


Here's What Others are Doing

 114
People on campus are working on earning points











 490
kWh per year have been saved by My Cardinal Green users

 1152
Points have been earned by My Cardinal Green users to date

Promotional Actions

 Participate in the ERP program **MORE+** ☒ VERIFY


Your Actions to Perform

| | |
|--|--|
|  Consolidate your supply shipments into 1-2 d... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |  Report leaks that you see in fixtures on cam... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |
|  Join the Commute Club next month MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |  Turn in your space heater for a Sustainable ... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |
|  Request an audit of your workstation to iden... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |  Take a First Step: Purchase recycled content... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |
|  Use a reusable or compostable K-cup to make ... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |  Remove your personal printer from your desk ... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |
|  Don't throw away any leftovers next month MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |  Take a First Step: Literally! In buildings L... MORE+ <input checked="" type="checkbox"/> VERIFY <input type="button" value="TRY ANOTHER"/> |

Rejected Actions You Can Resubmit

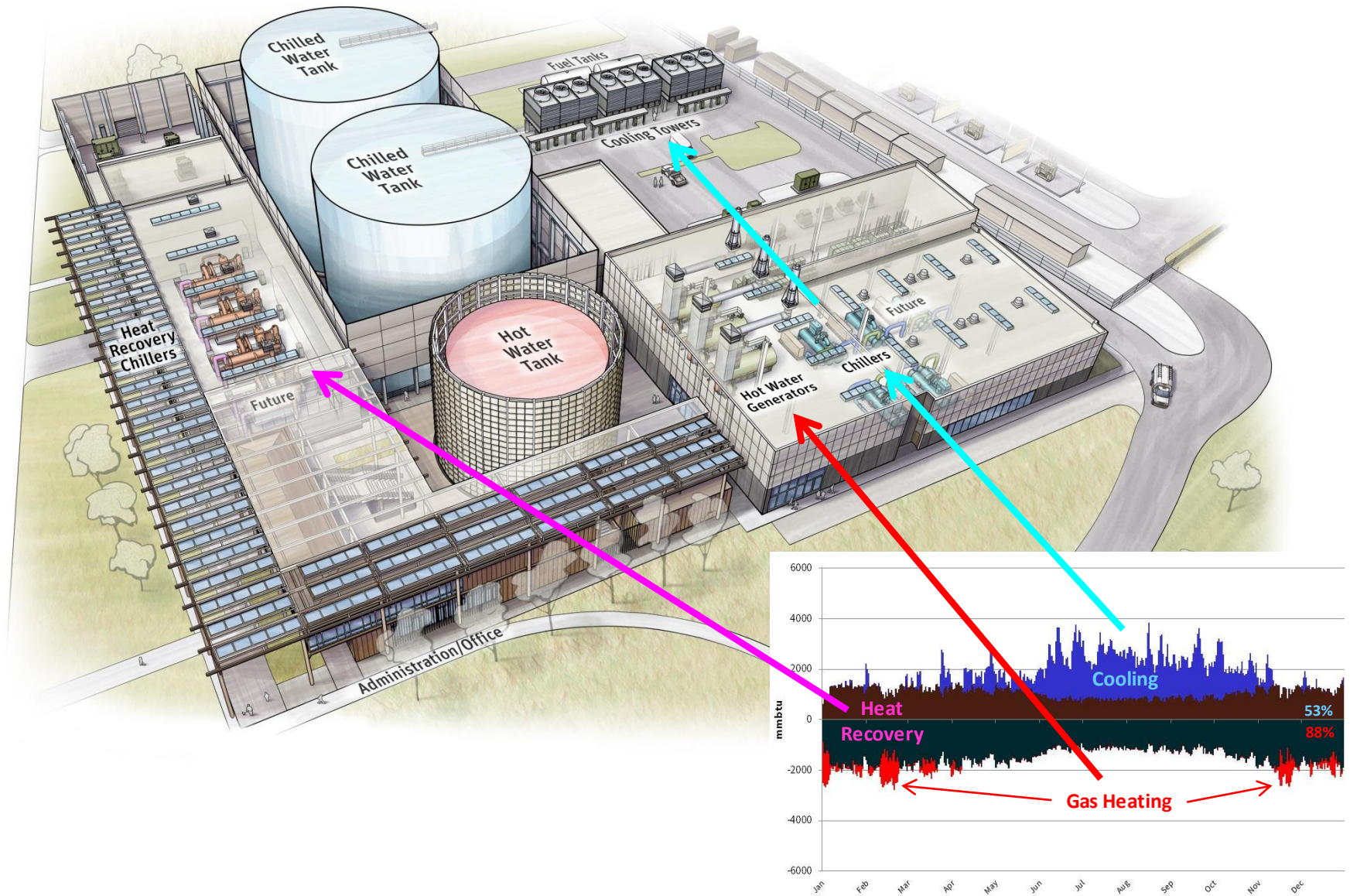
The actions in this section have been rejected by the administrator. Click "More" to view comments and suggestions for how you can successfully complete this action

Your Completed Actions

 Participation in the My Cardinal Green Pilot

5
Points Earned

Central Energy Facility – Tours Available

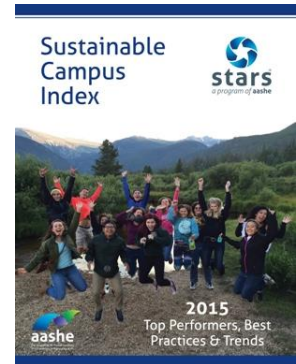


Stanford Leading by Example



Assessments and Evaluations

- **Association for Advancement of Sustainability in Higher Education (AASHE)**
 - **Platinum Rating**, highest for Overall Performance out of 800 institutions
 - **Sustainable Campus Index (in 2016)**
 - 1st for Water
 - 1st (tied) for Research
 - 1st for Buildings (Building Rating system included as highlight)
 - 3rd (tied) for Diversity and Affordability
- **Stanford Internal Building Ratings** - 135 buildings' ratings on Sustainable Stanford Map (sustainable.stanford.edu/buildings)

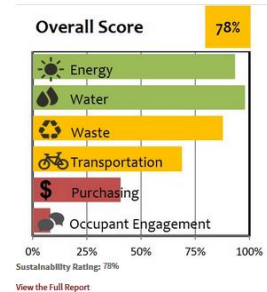


Environment and Energy Building (Y2E2)



KEY STATISTICS

Type: Low Intensity Lab
Usable Sq Ft: 171,097 sq ft
Address: 473 Via Ortega



Business Systems

- **SEM Operations, Maintenance, Automation**

Support of historian system and related infrastructure, EBS billing system, and client tools.

- **SEM Systems Integration**

Enhancement of the data infrastructure

- **Forecasting**

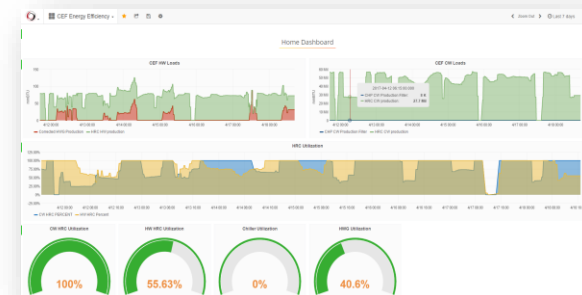
Campus demand forecasting models

- **Reporting**

Key performance metrics; 134 live building dashboards

- **Analytics**

New analytics platform implementation underway



Organization and Governance

