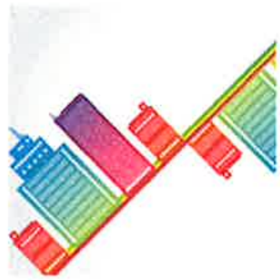
RESOURCE RESHUFFLE

Energy reduction efforts are resulting in not only a dramatic rebalancing of power sourcing but also deferred maintenance removal and hands-on learning labs in science and business academics.

By Karla Hignite



The nation's energy landscape has shown some dramatic shifts since the turn of the century. According to the 2016 Sustainable Energy in America Factbook (www.bcse.org/sustainableenergyfactbook), published by the Business Council for Sustainable Energy (BCSE), 94 percent of new power capacity built in the United States since 2000 has come from natural gas and renewable energy, with these two market sectors responsible for more than 45 percent of U.S. electricity generated in 2015.

Colleges and universities across the country are at the center of this energy transition, as more institutions have begun tackling utilities infrastructure updates on their campuses to modernize aging systems, increase efficiency, and reduce environmental impacts. As a sector, higher education exhibits trends regarding spend in the energy economy reflected in other key findings from the BCSE factbook:

- Energy efficiency investment and energy savings performance contracts totaled $13.1 billion in 2014.
- Combined heat and power (CHP) projects were up 25 percent in 2014.
- Renewable energy accounted for 20 percent of U.S. energy consumption in 2015—up 57 percent since 2008. During this same time frame, wind and solar capacity have quadrupled.

READ AN ONLINE EXTRA

To learn about Vanderbilt University's move to a natural gas cogeneration system, read "Coal-free Conversion" in *Business Officer Plus* at www.nacubo.org.

Yet, those general data points don't tell the story of *how* institutions are forging ahead with their energy transitions. As higher education leaders active in remapping their campus utilities infrastructure can attest, it may take the better part of a decade to fully shift gears with sourcing and system strategies. Likewise, no single solution exists for every campus, or even on a *single* campus, since updates to the built environment for many colleges and universities have been bolted on during several decades in ways that make a seamless energy transition unlikely.

"It's only logical that if you begin with different infrastructure, different energy sources, and different relationships with your utilities, the same solution won't make sense for every campus," says Fred Rogers, vice president and treasurer of Carleton College, Northfield, Minn. "In our numerous planning exercises, we found that some of the engineers we hired tended to want to figure out a universal solution that we could apply comprehensively. Others wanted to develop a unique solution for the one building they were working on. We had to keep in mind, and remind our engineers, that what would work for 80 percent of our buildings might not be the best approach campuswide," says Rogers. "For many, this isn't going to be a single swing. You have to balance efficiency and cost effectiveness for different components across your campus."

What is also true is that many campuses are at a life-cycle stage where an aging physical plant has become increasingly expensive to operate and maintain. For instance, despite the efficiency of steam-generated systems—which have been a staple on many campuses—more institutions are making the transition to hot water because of the substantial labor and operational expense required to clean and maintain steam plant components. Likewise, newer technologies and approaches that promise greater efficiency argue in favor of wholesale upgrades. As one example, a combined heat and power approach generates electricity and heat using a single, integrated system, helping offset peak loads and often reducing electricity costs.

The decisions that must be made in replacing and updating campus energy systems are complex and also carry a hefty price tag. While a big capital commitment, improvements to keep your campus humming along at optimal efficiency for the next several decades can also address long-standing deferred maintenance needs. Furthermore, the opportunity to introduce new energy supplies and technologies can help your institution mitigate power supply risk, reduce emissions and operating costs, and make significant gains in energy efficiency and conservation. Among the lessons learned from campus leaders interviewed for this article: Setting the stage for your next energy era requires a comprehensive review, a broad team of expertise, and the fortitude to continue fine-tuning your final approach.

Leaders are Carleton College spent nearly eight years vetting ideas to determine what would best meet campus energy needs for the next 30-plus years.

MAKE EDUCATED PROJECTIONS

"If your campus has been around for 100 years or more, chances are at some point your institution had a system for burning coal and a central plant to contain the ash in one location," says Rogers. That was true for Carleton, now 150 years old. Overhauling the college's energy infrastructure has entailed remapping a legacy central steam system from 1910.

When rethinking your utilities infra-structure, you first have to reflect on how you got where you are today and then review your existing needs and priorities and how your campus works day-to-day with current loads, suggests Rogers. "The real challenge comes in trying to anticipate future growth for your campus and make educated projections about the kinds of spaces you may need and the best and most reliable energy sources available decades into the future, even though no one can predict those things with certainty," cautions Rogers.

Leaders at Carleton spent nearly eight years vetting ideas to determine what would best meet campus energy needs for the next 30-plus years. From the time of initial discussions about utilities infrastructure changes to formulating a concrete master plan, the college pledged its commitment to a climate action plan, then welcomed a new president and launched a new strategic plan. All this influenced the final outcome of the college's energy path, notes Rogers.

Carleton's $30 million-plus energy overhaul calls for replacement of all central heating capacity and much of its central air conditioning infrastructure. In broad strokes, the plan encompasses three main components.

Deal with domestic water. Replace steam-heated domestic hot water heaters with gas-fired hot water heaters to generate hot water for all dorms and campus buildings. "This allows us to turn off our central steam plant during the summer months when the heating load is non-existent but when we still need domestic hot water," notes Rogers. "More importantly it prepares us for the future when we decommission the central steam plant."

Coordinate heating and cooling with new construction. Build a large ground-source heating and cooling system in conjunction with Carleton's new science complex that will heat and cool nearly the whole campus, including the new buildings. Because the geothermal system will connect to both the heating and the air conditioning systems, it can literally add, remove, and repurpose heat as needed to balance heating and cooling loads within the science buildings and other connected loads, explains Rogers.

Move from steam to hot water. Carleton's plan calls for converting the remainder of the college campus heating distribution system from steam to hot water and incorporating a CHP system that will generate both electricity and heat. At that point the college can decommission entirely the legacy central steam boilers, notes Rogers. The system will then be augmented by a 1.6 MW wind turbine and the small solar photovoltaic and thermal arrays already installed on the campus.

Another core component of Carleton's plan includes building a hybrid distribution system that utilizes both standard 180-degree hot water and lower temperature 120-degree hot water. Both are much cooler than the 330-degree steam now used to distribute heat around the campus. "This will allow us to accommodate a variety of energy sources going forward, including solar, thermal, and other possible future technologies," says Rogers. The higher-temperature of steam requires combustion—typically from fossil fuels, he explains. "If you want to maintain flexibility, you have to operate at temperatures that can support alternative energy sources.

TO RESHUFFLE ENERGY RESOURCES

- Make educated projections.
- Maintain flexibility.
- Keep pace with space.
- Maximize and optimize resources.
- Think futuristically.
- Focus on performance.

"Defining and developing our system has taken years to work out because it is complex and has required an iterative process," says Rogers. "With these improvements, we are building an energy infrastructure that should reduce central plant carbon emissions by 80 percent and total campus carbon emissions by 30 percent over current levels," says Rogers. The college will also gain the capacity to strategically heat sections of the campus from the most efficient source and to share heating and cooling loads, enabling scaling and load balancing to be much more efficient, notes Rogers. These and other changes in the works will also position the college to accommodate a variety of energy sources and technologies going forward.

MAINTAIN FLEXIBILITY

"For any comprehensive utilities infrastructure upgrade, flexibility is a major concern," says Jack Colby, assistant vice chancellor for facilities operations for North Carolina State University, Raleigh. "Historically, institution leaders made these kinds of system investments with the expectation they would be operational for 40 or 50 years without much in the way of reinvestment," notes Colby. "This new energy economy requires keeping constant watch over the volatility in energy markets and the emergence of new technologies and approaches."

Nearly a decade ago, leaders at NC State began discussing how best to address $25 million in central utility plant deferred maintenance, including several 60-year-old boilers that routinely failed. The need to ensure plant dependability, expand capacity in response to projected campus growth, and reduce energy consumption to meet state mandates made clear the scope of the challenge, says Colby. "Our initial study focused on boiler plant renovation with replacement and upgrade of various units. As we moved through the process we determined that a cogeneration approach, together with the district energy system, could provide a financially attractive alternative that addressed our renewal needs without taking capital funds from other needs," says Colby.

Implement now, save later. But with no state funding available for a major utilities improvement, the level of expenditure required pointed toward an energy services contract as the most feasible way to finance a project of this scale, notes Colby. "This approach would

allow us to renovate the plants now and leverage utility savings to pay the debt." The $19 million improvement—part of a larger $61 million energy services performance contract—would improve reliability, provide capacity for growth, and improve efficiency.
Over the course of two years the university added two 5.5 MW combustion turbines and a heat recovery system. The extensive upgrades to the Cates Utility Plant used parts of the previous building and the same footprint to conserve resources and preserve space. In operation since 2012, the new natural gas-fired 11 MW CHP plant is already paying off with more than $4.5 million in annual avoided costs, an increase in electrical generation efficiency from 38 percent to more than 72 percent thermal efficiency, and an 8 percent reduction in greenhouse gas emissions, says Colby.

In addition to eliminating a whopping $19 million in deferred maintenance, the new system introduces redundancy in the electrical supply, provides greater reliability for summer peaking, and allows for campus growth. A side benefit of the new CHP system is its black-start capability, says Colby. "If we were to lose grid power, we could power a portion of the campus on our own."

NC State's energy strategy has also made possible the development of a smart micro grid at the university's Centennial Campus, a hub for student and faculty research that includes advanced research and demonstration on smart micro-grid technology and implementation. Installation of another cogeneration plant on the Centennial Campus will allow for a doubling of its current four million square feet of space dedicated to academic and corporate collaboration on technology and other cutting-edge research efforts, notes Colby.

Anticipate rapid changes. Because the energy sector is evolving much more quickly today than in decades past, institution leaders must educate themselves about energy markets so that they can help their institutions make the best decisions about infrastructure improvements for the long term, argues Colby. This learning curve includes getting comfortable with energy forecasting. "You have to be willing to accept a certain amount of volatility and risk in terms of energy markets and fuel costs," says Colby.

At NC State, leaders are prepared for natural gas prices to increase by a factor of three. "When we first started our studies, natural gas was at $8 per dekatherm. Now it is around $2 per dekatherm, but it could go the other way again," says Colby. "All these potential fluctuations impact how a project will respond." That alone is reason to remain vigilant and continually assess how you may need to adapt, argues Colby. "Even before we pay off the debt on our contract—which currently projects a 17-year payback—we will begin asking where we should go from here."

KEEP PACE WITH SPACE

As for many community colleges, enrollment increases during the Great Recession squeezed resources at Raritan Valley Community College, Branchburg, N.J., beyond seats in classrooms. RVCC's enrollment rose from about 6,000 in 2005 to 8,000 today, peaking at about 8,600 in 2011, according to John Trojan, RVCC's vice president of finance. "Not only did the college have to move quickly to expand academic space, but we also had to ensure our utilities infrastructure could handle the increased heat and power requirements."

> **NC State's energy strategy has also made possible the development of a smart micro grid at the university's Centennial Campus, a hub for student and faculty research.**

The energy landscape changed dramatically for RVCC in 2007 when it fired up its new high-efficiency cogeneration CHP system. Previously all electric and gas used by the college was provided from local utilities, with the majority of the campus powered by electric chillers and gas-fired boilers, explains Trojan. The new system burns natural gas to create 65 percent of the electricity the college needs on a daily basis to power its campus and to run its plant, which also makes use of waste heat to generate hot and chilled water. This heat recovery component allows RVCC to eliminate its use of approximately 200,000 gallons of fuel annually. The $14.5 million project, which received a $1 million incentive grant from the New Jersey Office of Clean Energy, is saving the college about $400,000 annually in avoided utility costs and has enabled the college to better manage its energy consumption, says Trojan.

Phased implementation. While the college reviewed options for solar and geothermal, gas-fired cogeneration was deemed the best and most cost-competitive option for meeting campus growth needs, which included a projected 50 percent increase in academic space, notes Trojan. The initial phase of the project entailed replacing all the underground piping—about three miles—for hot and cold water distribution from the central plant. This corrected significant areas of corrosion and water leakages. Once fixed, RVCC's water costs dropped by nearly one-third, an indication of the poor condition of the 40-plus-year-old piping, notes Trojan. With the leaks fixed, the college is now also better able to maintain building temperatures.

The second phase included installation of a gas-fired reciprocating engine that generates 1.4 MW of electricity, coupled with an absorption unit that converts exhaust engine gases to either cool or hot water. Currently about 80 percent of RVCC buildings are hooked into the campus CHP loop, with the remainder powered directly from the utility or by solar. This is more the result of circumstance than capacity, notes Trojan.

Unexpected solar panel support. In 2010, RVCC became one of several institutions benefiting from a county-funded renewable energy program paying for the installation of solar panels on select buildings. On RVCC's campus, this includes a 465kW solar parking lot canopy to power its arts building and child-care center. The college does not own or operate the panels but buys the generated electricity at a significantly reduced rate as part of a 15-year purchase agreement. The electricity generated from the array covers most of the total power usage for the two buildings, notes Trojan. Once the purchase agreement is complete, RVCC would have the opportunity to bring these buildings online with the central plant.

Separately, the college is in the midst of doubling its science facilities space. While the new space will be looped into the central plant, the existing science facility would require a substantial conversion to connect to the central plant's hot and chilled water loop. Currently it maintains a direct connection to the local utility, explains Trojan. "The good news is that we now have power options and capacity for any new spaces," says Trojan.

MAXIMIZE AND OPTIMIZE RESOURCES

In concert with its keen focus on energy efficiency and conservation, energy supply is a key strategy of the energy and climate plan at Stanford University, Stanford, Calif. Nearly three decades ago, when Stanford moved to cogeneration, that represented a significant shift in campus energy technology. Now the university is once again in a position to lead, rethinking the energy supply landscape with an innovative approach centered on maximizing the use of its own waste heat. In the process, Stanford is dramatically lowering its reliance on fossil fuels and reducing greenhouse gas emissions and water consumption, notes Joseph Stagner, Stanford's executive director of sustainability and energy management.

For 28 years—from 1987 to 2015—Stanford operated a natural gas–fired CHP district energy system, with steam and chilled water distribution systems providing virtually all electricity, heating, and cooling to its buildings. While efficient, the gas-intensive system was the source of 90 percent of the university's emissions and consumed 25 percent of its potable water supply. With Stanford's contract to purchase

> **In 2010, Raritan Valley Community College became one of several institutions benefiting from a county-funded renewable energy program paying for the installation of solar panels on select buildings.**

energy from this plant ending in 2015, and with the plant nearing the end of its useful life, an opportunity emerged for the university to re-evaluate its energy supply and infrastructure.

Review all options. "When we set out in 2008 to update our utility master plan, we wanted to entertain every possible energy system out there and bring the best knowledge about each to the table so that we could determine which would best serve Stanford for the next 30 years," says Stagner. The university began by forming multiple sustainability working groups on energy to explore options. Each group of faculty, staff, and students included facilities and engineering expertise. "For each system proposed—nine total—we essentially did a deep dive to understand what it would entail; how it would serve the university's power, heating, and cooling needs; and how it would advance Stanford's energy and climate goals," says Stagner. In addition to extensive internal peer review, the findings from each group were vetted by external consultants.

Among the options reviewed, and the most expensive, was to continue with an updated version of the university's current CHP plant, notes Stagner. What ultimately emerged as showing greatest potential was a system featuring separate heat and power that would make use of Stanford's significant levels of waste heat. To test the hypothesis, Stanford engineers compared the simultaneous delivery of heating and cooling from its existing cogeneration plant over all hours of the day throughout the year. "This revealed a large overlap in the heat we were producing—nearly 75 percent—and a major opportunity for improving efficiency and cost savings in energy production," says Stagner.

Another benefit: Since a heat recovery system could be powered by renewable electricity, the university could further reduce its reliance on fossil fuels. Equipped with the possibilities for completely rethinking the university's power infrastructure, leaders began sketching the groundwork for what would become the Stanford Energy System Innovations project (see sidebar, "Energy Supply Innovation").

Applicable discoveries. Since embarking on its heat recovery system, university leaders have been in conversation with other campuses across the country doing their own math to learn of their potential heating and cooling overlap. In all cases, the data have consistently shown as much as a 50 percent or greater overlap in heating and cooling regardless of regional climate, notes Stagner. "Heat recovery for domestic heating and hot water service has potential application anywhere that cooling systems collect and discard heat from buildings or processes."

Stagner believes Stanford's new system represents a transformational energy supply model for other colleges and universities and demonstrates how heat recovery and renewable power are the keys to economic and sustainable energy. He points to findings by groups like the International Energy Agency and the United Nations Environment Programme that espouse the kind of building heating and cooling technologies modeled by Stanford's system as providing real potential on a global scale for meeting the world's energy requirements in a sustainable fashion.

Bankable results. Substantial amounts of heat recovery or the use of ground-source heat exchange may also be possible in many other district energy systems and yield surprising results when considering long-term life-cycle costs, argues Stagner. "A number of institutions may already have the basic infrastructure in place to make these additional changes and transform their energy supply." His challenge to institution leaders is to do their homework. Stanford's heat recovery system was in the midrange of proposals considered to replace the university's expired cogeneration plant, and it had the lowest life-cycle cost of all options on the table, notes Stagner. "This will pay Stanford back many times over in the coming years."

THINK FUTURISTICALLY

In 2006, the administration at West Chester University, West Chester, Pa., decided to proceed with a student housing upgrade to replace several vintage 1960s-era dormitories with modern suite-style residence halls. An initial review found that the buildings slated for demolition represented 35 percent of the load on West Chester's 50-year-old coal- and oil-fired central steam plant. This revelation prompted the university to widen its review to other buildings with HVAC systems more than 25 years old, says Mark Mixner, vice president for administration and finance.

Stanford University's new system represents a transformational energy supply model for other colleges and universities and demonstrates how heat recovery and renewable power are the keys to economic and sustainable energy.

The study, initiated by West Chester's former Executive Director of Facilities Management Greg Cuprak, indicated it was both feasible and cost-effective to convert these buildings from steam heating with electric chillers for air conditioning to a geo-exchange HVAC system, says Mixner. This approach—with anticipated operational savings exceeding $1 million per year—would also provide a path for upgrading obsolete heating systems.

After further examination, university leaders established a plan to convert more than 25 buildings to geo-exchange in phases over a period of 10 to 13 years, with projected savings in the range of 40 percent for heating and 20 percent for cooling. Among the long-term benefits of this program was the expectation that the university could eventually shut down the steam plant, thereby eliminating the purchase of 7,000 tons of coal and 200,000 gallons of fuel oil per year, along with all associated emissions, notes John Lattanze, energy projects manager. "The replacement of fossil-fuel energy sources with a renewable energy source was very compelling."

Decision time. According to Christopher Fiorentino, West Chester's interim president, the university faced an immediate decision point of either reinvesting heavily in a past-generation campuswide heating system or proceeding on a new energy adventure. Despite the potential risk involved, the utility savings and the positive environmental impact ultimately tipped the balance in favor of the geo-exchange project, notes Fiorentino.

The decision to convert about half of West Chester's campus to a geo-exchange heating and cooling system allowed leaders to focus on how to serve the remaining campus inventory. "We chose to install natural gas-fired boilers to heat the balance of our buildings. As future buildings undergo their life-cycle mechanical system renovations, we anticipate that each building on campus will eventually be served by the geo-exchange system," says Mixner.

In fact, West Chester's ambitious move into geo-exchange energy for nearly 50 percent of campus buildings and the corresponding switch to heating the remainder through high-efficiency natural gas-fired boilers allowed the university to decommission its coal-fired boiler plant in 2014. To date, the new system is operating with 47 percent greater efficiency than the previous system.

Energy central. The key design component responsible for these efficiency gains is the central distribution system that allows sharing of wells between buildings with different uses. This design reduces the demand on the well field, which in turn reduces the number of wells needed by 30 percent, notes Lattanze. The ability to exchange heat between buildings also increases overall efficiency, since different buildings require peak heating and cooling during different times of the day. Likewise, a redundant system allows the multiple heat pumps, water pumps, well-field sections, and even buildings to provide heating or cooling in the event of a partial power system malfunction, explains Lattanze. From a risk-mitigation standpoint, the university's dual feed source of electric power, along with the emergency power generators located throughout campus, help address any wide-scale electrical disruptions, he adds.

Convincing calculations. While the use of geo-exchange energy and high-efficiency gas-fired boilers in place of steam improves local efficiencies, the university is currently evaluating the overall increased use of natural gas and electricity versus the elimination of coal and oil, says Lattanze. West Chester's electrical use has actually increased due to the powering of geo-exchange distribution pumps and heat pumps. Even so, expansion of the geothermal system and the purchase of renewable energy credits currently contribute to the university's carbon-neutral initiative to become a zero-emissions campus by 2025.

For this $50 million project, West Chester received a substantial amount of funding—$26.6 million total—through a variety of grants and state appropriations. Mixner suggests that for any institution pursuing an energy infrastructure overhaul, a campus utilities master plan is a must. "This step is extremely helpful for securing grants to aid your process. Attaching a technical document that shows you have done your homework—and that all you need are the resources—presents a convincing argument in an application."

FOCUS ON PERFORMANCE

> **For any institution pursuing an energy infrastructure overhaul, a campus utilities master plan is a must.**

In fact, the need for a researched campus utilities master plan as the first step for discussing your energy infrastructure strategy is something on which everyone agrees. Stagner argues that institution leaders should revisit this plan at least every five years to consider how well existing systems are performing and to review other options on the horizon. Topping his list for rethinking an institution's energy supply is a transition that ensures cost savings, reduces risk with reliable and predictable energy sourcing, and offers flexibility to adapt as institution needs and technologies change.

"The flexibility of a system to adopt new technologies and fuel sources must be factored into your risk equation," stresses Stagner. He argues in favor of greater reliance on electricity, which by its nature provides flexibility because it can be generated by multiple fuel sources, including most renewables, says Stagner. For Stanford, switching to a 25-year power purchase agreement for solar-generated electricity provides the institution with a fixed price that is not only less expensive than natural gas but also offers greater price stability and predictability and moves the university toward its emissions-reduction goals.

Also critical is for an institution's chief business officer and chief procurement officer to be involved from the start of the planning process, argues Stagner. "Both these individuals have a keen interest in life-cycle cost assessment, so it is important for them to understand how a particular energy system is likely to perform over time." What your institution has done in the past doesn't matter, says Stagner. "This isn't about maintaining an energy system simply because it's what is already in place. You have to ask whether something radically different might serve you much better for the next 30 years," says Stagner. "Important to bear in mind is that your campus utilities are as integral to the performance and efficiency of your built infrastructure as any other component."

Rogers agrees there is a hierarchy of questions to resolve. For business officers, financing is always a concern, he admits. Yet, Rogers cautions against focusing too early on how these projects get paid for. "That presumes you already know what you need to do, which requires a more complex series of questions." In addition to researching the practicalities of various energy sources for your campus, you must be clear on your priorities, says Rogers. "Are you pursuing lower costs; looking to decrease your carbon profile; trying to solve a problem for a new building, an old one, or your entire campus?," posits Rogers. "Each of these will drive you in certain directions, and funding sources may differ depending on what you decide to pursue."

Because of the long-term nature of overhauling your campus energy infrastructure, it takes a champion to see the work through from start to finish, cautions Rogers. "As a chief business officer, you also have to be willing to ask a thousand questions, because while the technical nature of these changes may not be in your wheelhouse—the trade-offs and out-of-the-box thinking may require more iteration than the engineering team will initially have patience to explore." Buckle in, suggests Rogers, because something as critical as resetting your energy infrastructure won't be quick or easy, but it can contribute immensely to the long-term viability and performance of your campus.

KARLA HIGNITE, New York City, is a contributing editor for *Business Officer*.

^ Top

JUMP START ON SUSTAINABILITY

The big boost in energy efficiency provided by Raritan Valley Community College's cogeneration plant, important in so many ways for reshaping the institution's power grid, has itself become a catalyst for enhancing sustainability campuswide, notes John Trojan, RVCC's vice president of finance. Among these efforts are continuous rounds of lighting upgrades; water conservation efforts that include rainwater collection and a green roof and green wall; integrated pest management; an organic garden; activation of student sustainability clubs and projects; and multiple curricular opportunities, including an environmental studies liberal arts program.

In fact, Trojan credits the dramatic reductions in greenhouse gas emissions associated with the college's utility infrastructure changes as what paved the way for RVCC to become the first community college to sign an environmental stewardship memorandum of understanding with the Environmental Protection Agency in 2009, pledging to significantly reduce RVCC's carbon footprint. Through various initiatives, including purchasing 100 percent wind energy for the remainder of its electricity needs, the college has already reduced its greenhouse gas emissions by more than 50 percent since 2005. More recently, RVCC was the only community college selected by the state of New Jersey to forward its application to the Department of Education's Green Ribbon Schools program, which was expanded for the first time for 2016 to allow postsecondary institutions to become recognized for taking a comprehensive approach to greening.

^ Top

ENERGY SUPPLY INNOVATION

After four years of research and planning and three years of construction, the Stanford Energy System Innovations (SESI) project became operational as of April 2015 via a new district heating, cooling, and electricity system designed to meet Stanford's energy needs through 2050. It includes a dedicated off-site solar farm; conversion of the heat supply of all university buildings from steam to hot water; and a heat recovery loop that captures nearly two-thirds of waste heat generated by the campus cooling system to produce hot water for the heating system.

Reusable heat. "The opportunity for heat recovery is huge and is key to the efficiency of Stanford's system," says Joseph Stagner, executive director of sustainability and energy management. How it works is that waste heat—normally released into the atmosphere via cooling towers—is collected from buildings through a chilled-water loop and captured at the central energy facility. Here it moves to a new hot-water loop that then distributes heat to the buildings that need it. Where this differs from cogeneration is that it productively uses heat naturally generated by the system rather than heat supplied by combustion, explains Stagner. "Simply put, the reason this works so well is because it requires far less energy to move heat around than to create it from scratch. Instead of discarding our heat, we essentially give it a U-turn and send it back out to other buildings that need it."

Grid makeover. Stanford's new central energy facility includes three large water tanks for thermal energy storage and a high-voltage substation that receives electricity from the grid and provides interconnections to the campus grid in 10 locations to increase capacity and reliability. The transition to this new energy system also called for switching the heat supply of all buildings from steam to hot water. That entailed converting 22 miles of steam pipelines to hot-water pipelines across the campus and upgrading 155 buildings to connect to the new piping. As each section of the campus was completed, a series of regional heat exchangers were installed to convert steam from the existing cogeneration plant to hot water at a district level. Once the entire campus was converted, the regional heat exchange stations were removed and the old steam distribution system was decommissioned.

Sun power. At the time the university was preparing to implement the new system in 2011, the economic pro forma assumed buying electricity from the university's local utility and paying 10 cents per kWh. "Instead, we chose direct access for 20 percent less with an investor-owned utility," explains Stagner. In April 2015, Stanford entered a long-term power purchase agreement to build an off-site 73 MW solar photovoltaic (PV) plant that by 2017 will supply 50 percent of Stanford's electricity for at least the next 25 years, says Stagner. An additional 5.5 MW of solar PV will be installed at 15 sites on campus and start generating power later this year. In total, 65 percent of all campus electricity needs will be renewably sourced, with more than half of campus electricity needs being met by on-site and off-site solar, says Stagner.

Energy intelligence. The highly complex, yet repetitive, operations of the central energy facility warranted a computerized model that can automate much of the day-to-day functionality. A "model predictive control" software system developed by Stanford monitors plant equipment and predicts hourly campus heating and cooling loads and grid electricity prices 10 days in advance to steer the system to optimal efficiency, says Stagner. The model factors in weather, cost of electricity and natural gas, thermal capacity, and equipment availability.

Payoff. SESI is set to save Stanford more than $420 million in operating costs over the next 35 years, in part by essentially cutting in half the total energy required to operate the campus, says Stagner. Currently Stanford's heat recovery system meets more than 90 percent of the heating load on campus and has reduced total campus water consumption—normally needed to produce heat—by 15 percent. The new system is also 70 percent more efficient than the former CHP plant because of the ability to reuse waste heat. That efficiency, combined with Stanford's sizable investment in solar electric generation, is expected to reduce campus emissions approximately 68 percent from current levels.

^ Top