Global District Energy Climate Award Application
The Pennsylvania State University Energy at Penn State

Introduction & Summary

- 35% reduction in greenhouse gas emissions by 2020.
- 20% reduction in overall energy usage over the next 10 years.
- $60 million investment in energy savings over 5 years.
- 60% of a $2.7 billion capital plan dedicated to renovation and retrofitting aging campus infrastructure.

These are inspirational goals for an institutional behemoth and an academic powerhouse. The Pennsylvania State University (PSU) educates 98,000 students, stewards 23,000 acres of land, and services 32 million square feet of buildings.

Penn State has a comprehensive approach toward planning and building high-performance projects that are sustainable and provide for an increased return-on-investment. Since 1997, University-wide, Penn State has added 4.5 million square feet of building space. At the same time, we have reduced our greenhouse gas (GHG) emissions to below 1997 levels. More than 1 million square feet of this new space is for high-technology buildings including our new Millennium Science Complex, laboratory space for Chemistry and the Life Sciences, and new Business, Law, and Forestry Buildings, all of which achieved LEED certification.

Penn State has reduced its campus greenhouse gas emissions by 18% since 2005 and has set an ambitious new reduction goal of 35% by 2020. This will be accomplished, in part, with an expansion of the University's combined heat and power (CHP) and its district energy system. In 2011, a combustion turbine and heat recovery steam generator (CT-HRSG) was installed at Penn State's East Campus Steam Plant (ECSP) to modernize the facility and cogenerate 30,000 lb/hr of steam and 7MW of electricity. A ductburner increases the HRSG capacity to 117,000 lb/hr.

This operational change has reduced the University's coal consumption as well as increased on-site electricity production. In combination with the West Campus CHP plant, the East Campus CT-HRSG cogenerates steam and electricity serving more than 200 buildings at University Park. Penn State's District Energy system produces 100% of campus steam needs and about 20% of campus electrical needs. In 2011, Penn State's system operated at 72% efficiency. When completed, Penn State's system will operate at better than 80%—more than twice the efficiency of the electric grid.

Energy Overview

Penn State uses a lot of energy at University Park while supporting the academic and research missions of Penn State. Our large campus serves 45,000 students, 12,000 employees, and countless visitors every day.

It uses the equivalent amount of electricity every year as 25,000 average size U.S. homes. Students use energy in the residence halls taking showers, charging their laptops and cellphones, and in other campus buildings while attending class or studying. Dining halls staff use energy to prepare meals and wash dishes. Faculty use energy while teaching classes and conducting research through the operation of fume hoods, lasers, autoclaves, computers, and

freezers. Staff use energy while conducting their work, by operating their computers and other equipment, and commuting back and forth to work. The athletic department uses energy for athletic events, such as volleyball and wrestling events at Rec Hall, soccer games at Jeffrey Field, baseball games at Medlar Field, and football games at Beaver Stadium.

Energy is used in our buildings for heating, air conditioning, and lighting. From the operation of low-end buildings like the College of Agriculture dairy barns to high-end research facilities like the Millennium Science Complex, the University Park campus consumes $26M of energy every year from an annual electric bill of $14M dollars and an annual heating bill of $12M dollars. Extensive utility systems are in place to serve the energy needs of the campus. Electricity is distributed throughout the campus by a system of underground and overhead lines from 4 Allegheny Power substations.

Our biggest energy need in the summer is for cooling. Prior to 1999, cooling was provided by individual building chillers. Beginning in 1999, we started to build an underground Campus Chilled Water System that delivers chilled water produced in three centralized chiller facilities to buildings. We generate chilled water using electrically driven chillers. This system currently serves 72 buildings.

Because this centralized system is much more efficient than cooling buildings individually, plans are in place to add ten more buildings to the chilled water system. The long-term plan is to add most buildings to this network as individual building chillers need to be replaced. The other major system in the University's energy profile is the campus combined heat and power (CHP) and district energy system.

District Energy at Penn State

Penn State operates a district energy system. District energy is a system for distributing electricity and heat generated at a centralized location. Heat is often produced as steam in combined heat and power (CHP) plants. The West Campus Steam Plant (WCSP) and the East Campus Combustion Turbine-Heat Recovery Steam Generator (CT-HRSG) cogenerate steam and electricity serving more than 200 buildings on University Park Campus. Penn State's district energy system produces 100% of campus steam and 20% of its electricity. The CT-HRSG increased onsite power generation to 25% and reduced coal consumption by 20,000 tons and replaced with 600,000 decatherms of natural gas to reap significant GHG reductions. At an average efficiency of about 70%, Penn State's district energy system is more than twice as efficient as a typical utility power station.

West Campus

The West Campus Steam Plant consists of four 1960s-era coal-fired boilers and one 1947 coal boiler converted to natural gas. These produce superheated, high-pressure (240 psig) steam for turbines that operate pumps, fans and electric generators. Low-pressure (13 psig) turbine exhaust steam is delivered to campus for heat and process. Pressure reducing stations reduce high-pressure steam to medium pressure (150 psig) for delivery to buildings further away from WCSP. Two 1930s vintage backpressure steam turbines rated at 2.5 mW and 3.5 mW generate electricity to serve Penn State's emergency power needs as well as provide low-pressure steam to campus. These turbines produce approximately 6% of Penn State's total power needs.

- Steam Capacity: 350,000 pounds per hour
- Electric Capacity: 6 mW
- Plant Efficiency: 50% - 70%

A project to replace the two back-pressure steam turbines with new more-efficient units has been initiated. This project is expected to reduce the amount of vented steam as well as increase the amount of electricity produced.

- Project costs compared to estimated savings show less than 5.5 year payback.
- Electric generation increased 19,500,000 kwhs annually.
- The new turbines decreased steam losses by 35,000,000 pounds annually.
- Annual GHG reduction is estimated at 10,800 $MTCO_e$
- The annual energy savings is about $1.6 million.

East Campus

Penn State's East Campus Steam Plant initially consisted of two 1970s-era natural gas\oil boilers producing saturated, high-pressure (220 psig) steam. Pressure-reducing stations reduced high-pressure steam to medium pressure (150 psig) for delivery to buildings further away from ECSP. In 2011, a combustion turbine and heat recovery steam generator (CT-HRSG) was installed at Penn State's East Campus Steam Plant (ECSP) to modernize the facility and cogenerate 30,000 lb/hr of steam and 7MW of electricity. A ductburner increases the HRSG capacity to 117,000 lb/hr. The CT-HRSG required a $20 million up-front capital investment.

- Steam Capacity: 350,000 pounds per hour
- Electric Capacity: 7 mW
- Plant Efficiency: 80%

The East Campus CT-HRSG Project

The initial purpose of the East Campus CT-HRSG project was to support essential services, meet increasing campus demands, and provide a shelter-in-place facility. However, it quickly made economic sense to use this combined heat and power (CHP) as the base load to the existing East Campus plant to produce highly efficient (near 85%) energy in the form of steam and electricity. The CT-HRSG expanded the University's CHP operations and its district energy system. Along with low-carbon energy production and hydropower, all are now critical elements in the pursuit of the 35% GHG emissions reduction goal.

With the current low cost of natural gas, this machine is now a baseload machine. This operational change has reduced the University's coal consumption as well as increased on-site electricity production. University Park now cogenerates approximately 20% of its power needs.

Multiple projects have been initiated to upgrade systems to reclaim condensate, insulate pipes and fittings in manholes, fix leaks in condensate pipes, install newer technology (desuperheater, pumps, etc.) and improve water treatment. These projects will improve overall plant and utility system efficiency.

The CT-HRSG provides 20% of the campus electricity, thus avoiding the purchase of less-efficient (25%) electricity from a grid with nearly 50% coal generation. By using waste heat, the CT-HRSG produces 31000 pph of steam without duct firing, thus reducing the need for burning of fossil fuels such as coal or natural gas at 70% efficiency.

The process is easily replicable, and the addition of a CT-HRSG at the WCSP would enable the plant to utilize the steam turbine generators to have a true Combined Cycle Plant and further improve the overall efficiency.

The East Campus CT-HRSG project has reduced our historical reliance on coal, lowering emissions nearly 50%, including greenhouse gases, which contain dangerous levels of CO2 and NOx. After the expansion, coal truck deliveries (which impede both vehicular and pedestrian traffic) dropped from 3,250 to 1,600 per year.

The expansion allows for the University to provide shelter in case of an extreme emergency. New technology provides safety, reliability and efficiency to campus operations and assures the surrounding community that the University is making decisions to improve the quality of life and the environment. The successful expansion demonstrates the viability of future, higher-efficiency co-generation—which means even cleaner air in the community.

Penn State encourages student and faculty access to the site and data as part of a living laboratory for its energy and engineering schools.

Reducing Greenhouse Gas Emissions—35% Reduction by 2020

In 2006, Penn State developed a reduction goal and strategy to achieve a 17.5% reduction in GHG emissions by 2012. This goal was accomplished with the 11/12 fiscal year inventory 18% below the 2005 baseline inventory. This reduction was achieved though initiatives in energy conservation, efficiency, green building design and procurement of renewable power. The 2011 installation of the CT-HRSG at the ECSP resulted in a significant drop in coal consumption at the West Campus Plant (coal truck deliveries dropped from 3,250 to 1,600 per year) and an increase in on site electricity generation.

The 17.5% reduction was based on a foundation of energy conservation but was supplemented with the purchase of renewable energy credits. The new goal of a 35% reduction by 2020 will continue to be anchored with conservation efforts, but will be supplemented with an increased level of combined heat and power (CHP), low-carbon energy production, and hydropower. On the sustainability.psu.edu site, visitors can toggle through the GHG emissions reduction strategies to see where our emissions would be through no mitigation or with any combination of strategies.

These goals are Penn State wide and include emissions at Commonwealth Campuses. This aggressive goal takes into account planned growth under LEED for new buildings, continued investment in the Energy Savings Program, increased onsite electric generation with another CT-HRSG and the continuation of the conservation and awareness efforts through the Sustainability Institute. Additional strategies include energy savings as a result of Major Maintenance and Capital Renewal projects and a “Greener Grid” resulting in lower emissions attributed to purchased electricity.

The strategy for 2020 and beyond will further integrate and increase the use of the suite of renewable technologies continually developing.

Eliminating Coal

The largest new strategy is the elimination of coal at the West Campus Steam Plant. This plan includes the purchase of 2 new efficient natural gas-fired boilers to replace two of the 1960’s era coal-fired boilers. An additional project to replace the two 1930’s era back pressure

steam turbines with 2 new ones sized based on the campus low pressure steam load will increase efficiency through increased onsite electricity generation as well as reduction of the use of pressure reducing valves throughout the steam system. The natural gas conversion will be completed by 2016.

Penn State's Office of Finance & Business officially adopted "environmental stewardship" as one of the Key Initiatives of its 2002–2005 Strategic Plan, and an Environmental Stewardship Key Initiative Committee identifies "specific actions and objectives aimed at conducting the University's business in a manner that demonstrates a commitment to environmental stewardship and moves the University toward sustainable practices." The first LEED requirement on all new buildings and major renovations was established in 2004. The University's Energy Conservation Policy (AD64) was instituted in 2009 to lower the University's energy consumption, reduce expenditures on energy, and support greenhouse gas reduction goals. These goals are based on the reduction of energy consumption through increased efficiency, conservation and awareness as well as programs in sectors other than energy.

Penn State has a comprehensive campus Utility Master Plan that incorporates future growth for the demand and supply of energy. Penn State commissioned an Energy System Master Plan in 2007 for University Park that spanned 30 years. It incorporated plans for growth from the Facilities Master Plan and Capital Plan and developed life-cycle costs for different options for the upgrade or replacement of the existing power plant. This plan was updated in 2009 due to significant increases in electric rates and fuel costs as well as anticipated environmental regulatory changes. Although the option for a new plant using waste coal and back pressure steam turbines for energy production had the lowest life cycle cost, the University did not act upon this option and continued to operate with existing equipment. Many energy savings projects were completed that reduced the campus steam load to allow the extension on existing equipment.

The University continued to study and discuss options for modernization and compliance with upcoming regulatory changes while addressing the age and capacity of the campus steam plants, the long-term cost implications and the University's commitment to meeting its sustainability goals. After considering all variables, the University determined that the most viable solution to continue to heat the campus is to convert the University's coal-fired steam production systems to burn natural gas.

Using natural gas provides a higher certainty of compliance with the impending clean-air regulations and the installation of new natural gas boilers will accommodate planned growth. Analysis shows that it will cost less to modify the plant to burn gas than to continue to burn coal. Truck traffic to the plant will be reduced. The switch to gas will allow the University to renew its aging fleet of boilers and position the plant for future enhancements. In addition, using natural gas will reduce the direct production of greenhouse gases. Design for this large project is underway and construction is expected to be completed by 2016.

Monitoring Consumption

Penn State is continuously monitoring all of its resource usages. Energy usage is the largest contributor to Penn State's emissions profile. Our primary environmental focus is on the reduction of energy consumption through increased efficiency, conservation, and awareness as well as programs in sectors other than energy.

Approximately 350 buildings are controlled via building automation systems (BAS). This functionality maintains customer environmental satisfaction by keeping the buildings climate within a specific range and providing lighting based on occupancy schedules as well as monitors system performance for device failures. The Central Control Systems station is staffed 24/7 and monitors alarms, remotely troubleshoots the building automation systems, and reports to the Work Control Center any situation that needs addressed by technical service staff.

Penn State uses McKinstry Enterprise Utility Management System (EUMS). This system is used to track and analyze energy and water consumption in buildings as well as energy commodity purchasing. Meter data is collected by Utility Services and transferred electronically into the system. Monthly invoice data from suppliers is entered into the system. This system also records the real-time interval data for more than 100 of the highest energy consuming buildings. The Facilities Resource and Planning department utilizes the Facilities Information System (FIS), a building and room inventory that includes space assignment, room types, conditions, and occupants for space management and planning. A comprehensive geographic information system (GIS) of land base, utilities, landscape, agriculture, and environmental datasets are maintained. These systems can work together for short and long range planning.

Saving Energy

Penn State has implemented an Energy Savings Program (ESP) that was originally based on the guidelines of the PA Guaranteed Energy Savings Program. Using a standard University Design Build/Guaranteed Maximum Price contract, Penn State awards projects to two selected firms where the entire cost of the project can be recovered through energy savings. Some projects are performed by internal technical staff, and in some cases non-ESP projects can receive funding for implementing efficient systems that were not part of the original design. These projects are capital funded. The maximum payback for these projects is 10 years including financing costs. The University has committed $55 million investment over the next five years specifically to this program.

Energy Conservation Measures (ECM) projects are smaller in size and include measures such as steam trap upgrades, low-flow water fixtures, lighting retrofits, chiller upgrades, programmable thermostats, occupancy sensors, reprogramming or upgrading control systems, system tune-ups, fuel switching, water treatment, flushing HVAC piping, building envelope repairs and re-commissioning. $3.8 million has been invested and annual investment is $500,000-$1 million.

The Continuous Commissioning (CCx) program began in 1998 and focuses on the building HVAC systems. The goals of the program are to reduce building energy usage and cost, improve indoor air quality, improve occupant comfort and reduce greenhouse gas emissions through optimizing the operation of the building systems. The average simple payback is less than 5 years. $3.8 M has been invested with a $1.4M annual savings. Annual investment in CCx projects is $500,000.

Finding Alternatives

University Park generates only a portion of its electricity needs. All other campuses purchase their electricity requirements. GHG emissions from purchased electricity are based on the fuel mix from the NERC region and eGrid subregion a campus is located in. The

Pennsylvania Alternative Energy Portfolio Standard requires that an annually increasing percentage of electricity sold to retail customers in Pennsylvania is from alternative energy sources. The current low price of natural gas, abundant regional supply and upcoming regulatory initiatives have caused a switch to natural gas at some power plants. The increase of renewables through AEPS and a move towards natural gas will reduce the GHG emissions associated with the Penn State's purchased electricity.

The University Park campus has three small solar arrays on campus. Penn State purchased Renewable Energy Credits (RECs) from 2005-2012 to jump-start GHG reductions. These funds are now used for onsite efficiency projects. A few new buildings utilize ground-source heat pumps. These systems are considered for new buildings on the perimeter of the University Park campus that do not have access to the central steam system and new buildings at Commonwealth Campuses.

In 2013, Penn State entered into a 10-year power purchase agreement with Mahoning Creek Hydroelectric Company. This new 6MW hydroelectric generating plant was built in 2013 at the existing USACE dam on Mahoning Creek located in Armstrong County, PA. Penn State will purchase all of the net electric output from the facility and retain the environmental attributes. This is approximately 8% of the University Park campus' electric purchase.

Penn State continues to investigate and pursue additional funding sources for onsite renewable installations.

The Future

Penn State has adopted a holistic approach to sustainability that embeds the concepts into everyday life in facilities. From the third-shift custodian to the President, the expectation is that all will contribute to creating a more sustainable University.

The successful expansion of the East Campus Steam Plant to include a CT-HRSG demonstrates the viability of future, higher-efficiency co-generation. Penn State's expanded combined heat and power system also ensures cleaner air for the University community and provides a resilient, highly efficient, low-carbon solution that is safe, reliable, and sustainable.

We are seizing an unprecedented opportunity to model a large-scale commitment to sustainability.