Executive Summary
Comprehensive Energy Master Plan (CEMP)

Purpose Statement

This project was initiated based on the Purdue Board of Trustees approved resolution of February 2011 that requested that Purdue administration “engage in planning designed to identify and meet the long-term energy needs on the West Lafayette Campus over the coming years.” In support of this resolution, Burns & McDonnell was selected to work with Physical Facilities to develop a Comprehensive Energy Master Plan (CEMP).

The purpose of the CEMP was to develop a strategic framework for campus-wide energy management and a fiscally sustainable plan for the production, distribution and demand (PD&D) of all utilities serving the Purdue University West Lafayette Campus including: potable water, chilled water, steam, and electricity. The CEMP aligns with the mission and vision of the University’s New Synergies and Sustainability strategic plans and incorporates input from Purdue stakeholders and external consultants. The integrated planning process that was followed resulted in the formulation of a strategic framework for making fiscally sound and sustainable choices regarding energy production, distribution and demand that will serve the University for years to come.

The overarching goal of the CEMP was to assess the current status of Purdue’s operations and develop a solid plan for the near-term that is aligned with future long-term campus energy requirements. Our intent is to implement several of the recommendations contained in the CEMP that will improve operating performance and position the campus for a more sustainable future from both fiscal and environmental viewpoints.

The key findings and recommended actions resulting from the study are summarized in this document. Due to the dynamic energy landscape, the CEMP will need to be revisited as time progresses, requiring periodic updating to keep it current. Burns & McDonnell’s complete report is attached to this executive summary as an exhibit.

Production, Distribution & Demand Background (Wade Utility Plant)

The Wade Utility Plant (Wade) was designed and built in 1960-1962 with Boiler 1 being commissioned in 1962. Boiler 1 is a coal fired boiler rated for 200,000 lb per hour (PPH) and is still in operation today. From 1962 through 1967, Wade served as a seasonal plant and the Power Plant (currently referred to as the North Plant) located immediately south of ENAD, served as Purdue’s main utility plant.

In 1967, Boiler 2, another 200,000 PPH coal fired boiler, came on line along with Turbine Generator #2 (nominal 10 Megawatt capacity) at Wade. At that time, Wade became the primary source of the steam for campus with the North Plant serving as a seasonal back up.

From the late 1960s through 1974, several steam fired absorption and centrifugal chillers were added at Wade, with the largest chiller 6 being added in 1967. This 6250 ton chiller was added in conjunction with the approval of Wetherill Chemistry Building to handle the load of Wetherill being the first 100% outside air (no-recirculation) building on the West Lafayette Campus.

Boilers 3 & 4 were added to Wade around 1974. Both of these were designed to run on fuel oil. As the price of fuel oil skyrocketed above the price of coal, it was decided to retrofit Boiler 3 as a dual fuel boiler to burn natural gas and fuel oil, and Boiler 4 went off-line.

A coal fired fluidized bed boiler, Boiler 5 (200,000 PPH) was commissioned in 1991 and Turbine Generator #1 (nominal 30 Megawatt capacity) was brought on-line in 1994.
Two 2000-ton electric driven chillers were added to Wade in the late 1990s. The Satellite Chiller Plant located in the northwest area of campus was built in the early 2000s and since then five 2,000-2,700 ton electric driven chillers have been installed with the sixth one scheduled to come on-line in 2012.

Boiler 7, a natural gas boiler rated at 200,000 PPH, is currently being installed at Wade at the site of the original Boiler 4.

As of the end of Fiscal Year 2011, Purdue Utilities supplies and distributes ~100% of the heating to campus with steam (13.5 million gross square feet) and 100% of the cooling with chilled water (11.8 million gross square feet) and electric cooling and generates 40-50% of the electricity consumed but provides 100% of the campus electrical distribution (16.4 million gross square feet).

Within the next year, the last available location within Wade to add heating production will be filled with a new natural gas boiler and the last location for adding cooling production to the Satellite Chiller Plant will be filled with a new chiller.

Purdue staff members have been focused on reducing the energy usage of campus facilities and have already employed energy saving strategies with short implementation periods that are anticipated to yield high levels of return on investment. In addition, Purdue’s internal investigations indicated that potential for energy savings still exists on campus. As more and more buildings with significant increases in high-energy use labs, research, and data centers have being added to the campus, the capacity of the infrastructure requires expansion. In addition, the operating costs to produce and distribute energy to the buildings also are growing.

Production

Analysis of energy production focused on the generation of steam, chilled water and electricity to meet current and future campus energy requirements. Several options to meet the campus energy requirements were developed for both chilled water and steam. These options were then analyzed with an economic model with the final result being a ‘road map’ for Purdue to follow to meet production requirements. This plan was designed to be inherently flexible; as inputs such as environmental mandates, commodity fluctuations, or demand forecasts change, we will be able to review resulting effects on the plan model.

Steam

To serve the demands for the West Lafayette Campus, steam is currently only produced by Wade Utility Plant’s four boilers; three coal fired (#1, #2, & #5) and one duel fuel fired with fuel oil or natural gas (#3). Boiler #7 is a new natural gas fired boiler that is currently being installed at Wade. Within 180 days of #7 becoming operational, Boiler #1 will be deactivated per our Indiana Department of Environmental Management (IDEM) Wade plant operating permit.

Wade’s installed steam capacity is 750KPPH. A recognized approach is to evaluate peak steam demand against installed capacity minus the capacity of the largest boiler. This is called firm capacity. Wade’s firm capacity is 550 KPPh. Current peak steam demand is 545KPPH. Load growth over the next 10 years is expected to be 110KPPH. Coupled with Boiler #2 coming off line in 2021 due to age, new and replacement steam needs will exceed capacity by more than 300KPPH in the next 10 years.
To address the forecasted deficit in steam capacity, the CEMP recommends that Purdue University replace Boiler #1 with a Combined Heat and Power (CHP) unit by 2014. The CHP is a natural gas fired turbine, similar to a jet engine, which produces electricity and uses the exhaust heat to produce steam through a heat recovery steam generator (HRSG). This is a very efficient system that has a lower life cycle cost than a traditional natural gas fired boiler.

As other existing boilers approach the end of their useful lives, Purdue Utilities will evaluate campus steam needs and available technologies to determine the most suitable replacement. Boiler #2 is expected to require replacement in 2021, or sooner if environmental regulations dictate that it is necessary to accelerate this timeline.

**Chilled Water**

Chilled water is currently produced at the Wade Utility Plant on the south side of campus and the Northwest Satellite Chilled Water Plant on the northwest side of campus. Currently there are four steam driven chillers and two electric driven chillers at Wade. Steam driven chillers #6 & #7, 6250 tons & 3000 tons respectively, are scheduled to be replaced in 2014 and 2018. The Northwest Satellite Chilled Water Plant has 5 electric driven chillers and a final sixth electric driven chiller will be installed in 2012.

Similar to the analysis of the steam system, chilled water demand is shown here through 2021. Chilled water installed capacity will be 36,900 tons in 2012. As with steam, we evaluate peak load chilled water needs using firm capacity. Firm capacity, 2012, will be 30,600 tons. Current peak chilled water load is 31,000 tons. The expected chilled water load growth is 9,200 tons by 2021 with retirement of 9,250 tons of steam chillers #6 and #7. This identifies an additional chilled water demand of 18,450 tons over the next 10 years.

The CEMP recommends we add an 8,000 ton Thermal Energy Storage (TES) tank adjacent to the Northwest Satellite Plant. With the cost of electricity significantly higher in the day than at night, we would run the chillers in the satellite plant in the evening. During the day, we would use the chilled water in the tank to supply campus. This is a quick and cost effective way to add chilled water capacity and offset operating costs. It is also recommended that we add a second satellite chiller plant with the space to add 6 chillers for an additional capacity of 16,200 tons. By 2021 we project a need to install four 2700 ton chillers.
Distribution

Steam and chilled water distribution systems were also analyzed as part of the CEMP. Computer load and flow modeling was created for both the steam and chilled water distribution systems and Purdue provided peak building load information. These models were then calibrated to actual operating information. Once the models were calibrated, they were used to analyze the distribution systems at current conditions, 5 years in the future and 20 years in the future. The last step in the process was to create improvement options and test them in the model to represent the system performance under the conditions expected in the 5 year model.

Steam
Since steam is currently produced only at the Wade Utility Plant, a big challenge is to deliver steam to the north end of the campus without excessive pressure drop. Due to planned building growth in the next 5 years, the steam pressure at the Permanent Apartment (PA) Pit (located north of Tower Drive near Cary and Ford) is projected to fall below the level desired for satisfactory system operation. Three options were analyzed to improve the pressure at the PA Pit.

One option is recommended:
1. Increase the steam distribution system along Jischke Drive from Third Street to Tower Drive.

Chilled Water
Modeling of the chilled water distribution system indicates that supplying water from the satellite plant to the east and from the Wade Plant to the northeast portion of campus are the major stress points. Like the steam system, the chilled water system also needs improvements to meet distribution requirements during the next 5 years. The chilled water system differential pressure in the northeast portion of campus was utilized as the reference point when analyzing improvement options. Options considered focused on alleviating restrictions for flow distributed from the west side of the campus near the existing chilled water plant to the northeast corner of campus. Locating additional chilled water plant capacity in the northeast corner of campus was one of the options also considered.

Two options are recommended:
1. Increase the chilled water line size from the Northwest Satellite Chiller Plant east along Third Street to near Lawson.
2. Upgrade the chilled water distribution pumps in the Northwest Satellite Chiller Plant.

Demand

Prior to commencing with the CEMP, Purdue staff had implemented a number of energy savings measures both prior to and as a result of Sustaining New Synergies to reduce the energy consumption across campus. This included high payback items like lighting retrofits and instituting fume hood sash control procedures. Purdue staff believe that energy savings are still available by making improvements within campus buildings. The majority of buildings on campus and each building surveyed in this CEMP are supplied with electricity, chilled water, steam, and compressed air from central utility plants on campus. The utilities are generally not accurately metered at the building level, but the University is currently conducting a building by building program to install meters to close this gap.

Energy investigations were conducted on eight representative buildings on the Purdue University Campus by Burns & McDonnell. The eight selected facilities represent a range of building types including: Administrative, Classroom, Research/Labs, and Residence Halls. These facility types comprise the majority of Purdue’s campus building stock and provide a sampling of buildings from which to predict energy and operational performance and extrapolate those savings across the rest of campus.
The investigation of the representative facilities was initiated to develop a baseline of the energy savings potential that exists across the select campus facilities with respect to utility consumption (domestic water, chilled water, steam, and electricity). Interviews were conducted with Purdue Facility staff, existing information was reviewed and site investigations were performed on the selected facilities. The building types with the greatest energy savings potential are classroom and research/lab facilities which make up approximately 6.7 million square feet of space.

Examples of some of the recommended energy savings measures are noted below.

- Opportunities exist in selected existing labs to reduce the air change rate during occupied and unoccupied times while offering significant reductions in energy. Purdue is currently working to reduce air change rates in labs during unoccupied times.
- Space temperature set back is currently not utilized in a majority of campus locations. Rooms that have varying occupancy patterns based on academic calendar, occupancy and/or scheduled events and do not have a regular occupancy schedule have a high opportunity for energy savings. We have additional opportunities for further optimization of control sequences of mechanical systems on campus.
- Most of the campus facilities that were investigated currently utilize high flow water devices (urinals, faucets, toilets, etc). There are numerous opportunities to save water by retrofitting these fixtures with low flow devices.

**Risk Assessment of “Do Nothing” Case**

Based on our current campus systems, there isn’t an alternative source for heating or cooling the campus. Over the past few years, Physical Facilities had to reduce chilled water and steam demand by implementing curtailments. As additional buildings come on line over the next few years, a significant increase in curtailments is likely to occur. Curtailment is when the amount of steam or chilled water is reduced to facilities based on the criticality of the use of the space. For instance, labs, data centers & research space, especially involving high end computing and animals, have the highest need for properly conditioned space and therefore would be among the last to be curtailed.

For chilled water, the curtailment plan is to reduce demand by shutting down chilled water and reducing or eliminating air conditioning to a percent of athletic facilities and residence halls during peak periods. These peak periods are typically during the summer months when Housing & Food Service and Athletics sell services to organizations and individuals from outside Purdue.

For steam, the curtailment plan is to reduce demand by allowing building temperatures to drift down, and to reduce amount of ventilation air where available and practical. If additional steam distribution piping is not completed to the north side of campus to provide sufficient header pressure, Mackey, Ross-Ade and Cary Quad will likely experience operational problems in their heating systems. Failure of any chiller, boiler or associated auxiliary equipment during peak periods will significantly increase the number of buildings affected by a curtailment.

**Summary of Recommendations – Next 10 Years**

**Production**

- Chilled Water
  - Install TES
  - Build a second satellite chiller plant
  - Add electric chillers

**Steam**

- Install CHP including demolition of Boiler #1
  - Boiler #9
Distribution
Chilled Water
- Increase the chilled water line size from the Northwest Satellite Chiller Plant east along Third Street to near Lawson
- Upgrade the chilled water distribution pumps in the Northwest Satellite Chiller Plant
Steam
- Upgrade steam distribution along Jischke Dr.
- PA Pit Steam Line
Other
Chiller 6 Life Extension
- Demo Chillers 6 & 7
- Convert Boiler #2 to natural gas (2013)
- Demo Boiler #2 (2021)
- Add Recurring funding for Energy Conservation Measures

Exhibits