COGENERATION SYSTEM

INTRODUCTION

New Mexico State University currently provides a number of necessary utilities to the main campus such as electrical power, steam, and chilled water among others. It was brought to the attention of the NMSU facilities staff in the 1990's that significant energy savings could be had by combining 2 or more of these utilities on the production level. After thorough review, the University made the decision to invest in a natural-gas fed turbine to create electrical power on site while using the inevitable waste heat off the back end of this unit to assist in providing both steam and chilled water production from the central utility plant.

COGENERATION SYSTEM DESCRIPTION

In its current configuration, the central utility plant houses a Solar Taurus-60 natural gas-fed turbine, capable of generating 4650 kW for distribution to campus. In accordance with the nature of a turbine such as this, only about one third of the energy put into the system in the form of natural gas comes out the other end in the form of electrical power. One third of the energy input is lost completely through inherent inefficiencies of the system. The remaining third of energy input is exhausted out the back end of the turbine in the form of extremely hot air. This energy is capable of transforming liquid water into steam that can be used to offset the cost of steam production from conventional boilers.

The University has installed a Nebraska S2.5 series heat recovery steam generator (HRSG) on the back end of the turbine to perform this very task. When the turbine is running its full load, the HRSG is capable of producing up to 22,400 lbs/hr of usable steam at 100 psi and 337°F. In the winter months this steam is used to supplement the boiler manifold to offset natural gas costs. In the summer months the steam is used to provide all of the steam demand from campus, allowing the boilers to sit idle, and the remaining steam is used to operate one of two Carrier 16 JT-150L double effect absorption chillers, designed to operate at a rate of 9.25 lbs/ton for a total of 1570 tons each. Currently the absorbers operate at a rate of roughly 15.5 lbs/ton for a total output of about 1200 tons each, when operational. The significant de-rating of these machines is attributed to their prototypical origin.

The cogeneration system generates utility savings largely from the difference in energy costs between purchased electricity from El Paso Electric (EPE) and purchased natural gas from the City of Las Cruces (CLC). At the time of installation, natural gas prices were foreseen to stay below $5/Dth for a significant time. At this price of natural gas, there would be no reason to ever turn down or shut off the turbine except for maintenance reasons, as it would cost less in overall energy usage compared to the additional gas and/or electricity needed to produce the steam or chilled water that the HRSG would provide. However, gas prices in recent years have fluctuated between $6/Dth and $10/Dth and in the summer of 2008 prices soared to nearly $13/Dth. According the NMSU cogeneration model of operation, if gas prices reach $9.25/Dth it would only be cost effective to run the turbine during on-peak electrical hours when purchased electricity on EPE rate 26A costs $0.12/kWh compared to the off-peak rate of $0.06/kWh. If gas prices reach $16/Dth it becomes most cost effective to shut the turbine off completely.

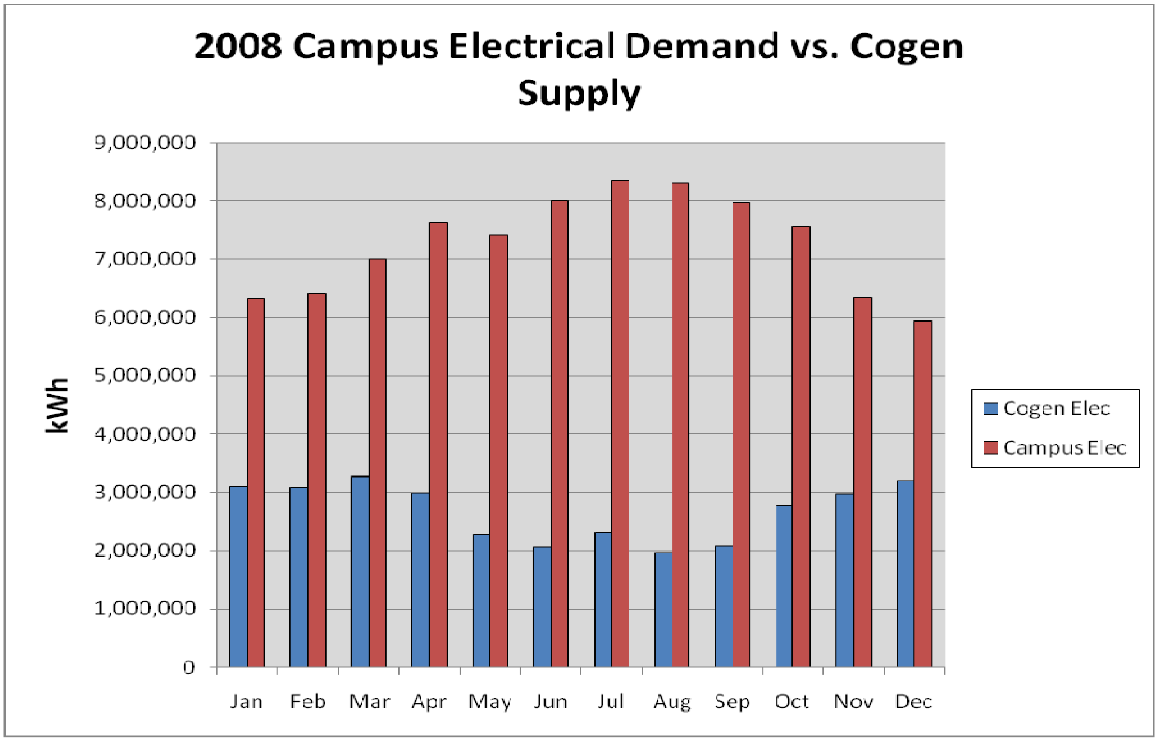
According to this model of operation, in 2008 the turbine would have only been running during on-peak hours in the months of May, June, July, and August. However, there is an additional element in the cogeneration system that restricts optimized operation. The NMSU data center requires a relatively consistent 2.5 MW of electrical power to provide continuous operation of the University's data center. In the event of a power outage from EPE, it is considered unacceptable to allow any disruption in continuous power to this facility. There is currently a battery bank serving as an uninterruptable power supply (UPS) to the corporate data center mainframe and a separate UPS serving the research data mainframe. These UPS systems serve as an electrical power filter to level out potentially dangerous spikes in continuous power supply and in a conventional configuration would be able to supply backup power in the event of a power outage until the emergency standby generator powers on completely. In the existing configuration, these UPS systems only serve as a power filter due to the fact that there are no standby generators at this facility. The contingency plan in case of a power outage is to continue to run the cogeneration turbine at a minimum dictated by the power demand of the data center. In the event of an outage, a fiber optic sensor determines a drop in supply power from EPE and begins to route power from the turbine in parallel until supply completely switches over to the turbine. Because this process can happen within 5 cycles, the data center never notices the outage. Due to the current configuration of power supply to the data center, NMSU facilities staff is not able to shutdown the turbine completely when called for by the operational model. Because of this, when gas prices peak the designed energy savings of the system are not being met.

The turbine itself has just recently been replaced with a new one according to the designed maintenance schedule at the beginning of 2009 and the turbine and HRSG systems are operating adequately in producing electrical power and steam for consumption by the main campus.

ELECTRICAL LOADS

According to 2008 data, electrical load demand peaks in the summer at about 15,700 kW, largely due to chilled water production and distribution. Due to atmospheric conditions, the cogeneration turbine is able to peak at around 4500 kW, able to provide the campus with a third of its required power demands so long as natural gas prices remain attractive. Figure 1 below illustrates difference in campus demand and central plant production on a monthly basis for 2008.

Figure 1 – Campus Electrical Demand vs. Cogen Supply

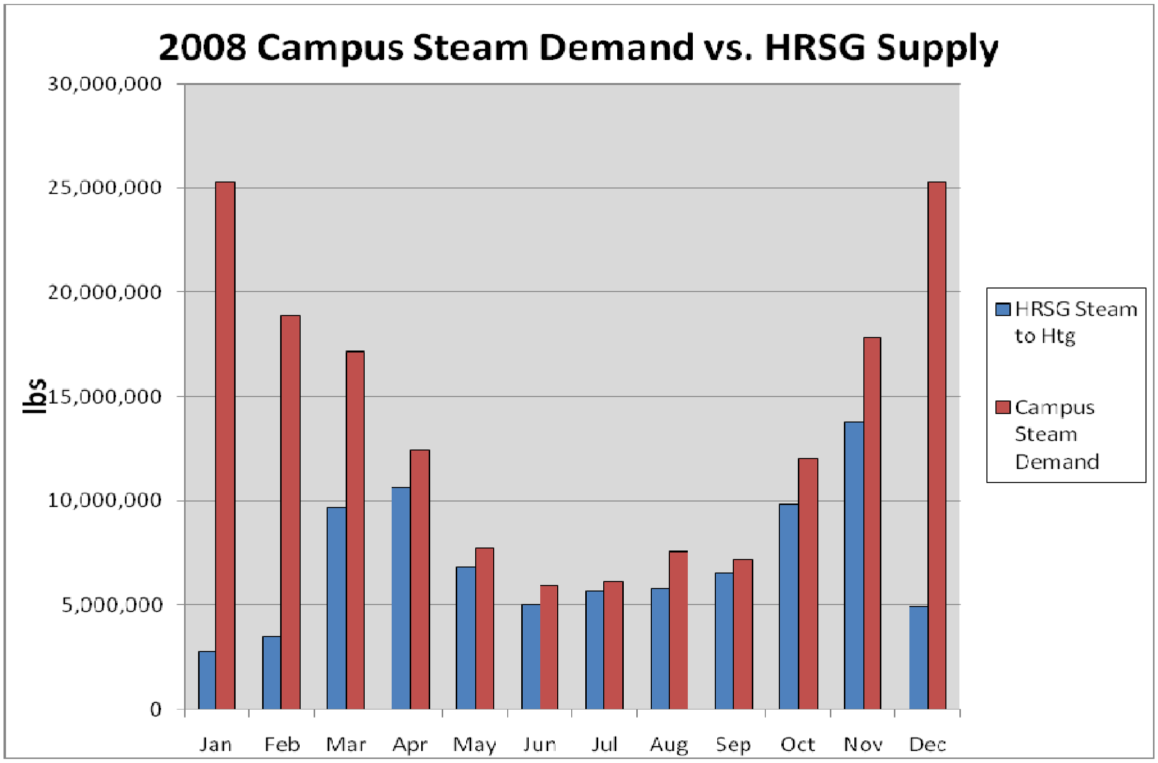


As seen in Figure 1, the campus consumption peaks in the summer mostly due to chilled water production, but the central plant turbine bottoms out during the summer due to the rise in natural gas prices. Aside from unattractive gas prices, it appears that the turbine is able to provide a relatively stable base supply of 3,000 MWh each month. In total for 2008, the cogeneration turbine was able to provide the main campus with roughly 32,000,000 kWh out of a total consumption of 87,000,000 kWh.

STEAM LOADS

According to historical data, the campus demand for steam peaks at approximately 65,000 lbs/hr. This occurs, as expected, in the winter months for the purposes of space heating. The HRSG, while the turbine is running at full, is able to peak at roughly 23,000 lbs/hr, providing about a third of the total steam demand during peak conditions and being able to provide all of the required steam during summer months as campus steam demand bottoms out. Figure 2 below represents the monthly production values of dedicated heating steam from the HRSG compared to the total campus demand.

Figure 2 – Campus Steam Demand vs. HRSG Supply

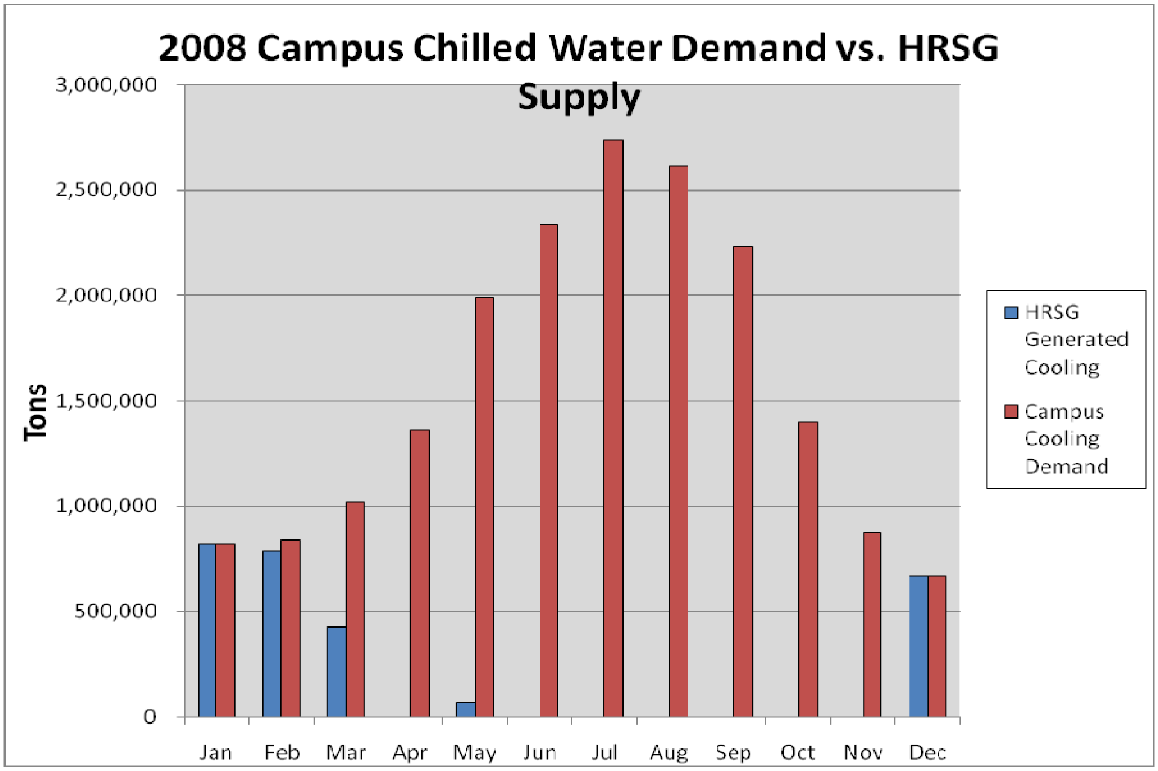


As seen in Figure 2, the campus steam consumption peaks in the winter for the puposes of space heating and bottoms out in the summer to serve as mostly terminal reheat energy. The HRSG steam supply nearly matches the campus demand in the summer and shoulder months of the year, but bottoms out in the winter when it should be at its peak. This is due to the fact that the electrical chillers were shut down during this time in 2008 and the absorbers were forced into use, consuming most, if not all of the steam produced by the HRSG. This particular year was somewhat of an anomoly and in typical operation the HRSG would be able to provide its full steam load to campus for heating. Aside from this anomoly, it appears that the HRSG is capable of providing nearly 14,000,000 lbs of steam for heating, if demanded, on a monthly basis. In total for 2008 the HRSG was able to provide about 85,000,000 lbs of steam out of a total campus consumption of about 163,000,000 lbs.

CHILLED WATER LOADS

According to historical data, chilled water loads peak at about 6600 tons in the late summer months. While the HRSG is constantly supplying steam to campus for heating, leftover steam can be used in the summer months to create chilled water via the 2 absorption chillers. Chilled water supply from the HRSG is able to peak at roughly 1200 tons to supplement the electrically driven compressor type chillers. Figure 3 below represents the capacity for the HRSG to provide cooling versus the total campus consumption of chilled water on a monthly basis for the year 2008.

Figure 3 – Campus Chilled Water Demand vs. HRSG Supply



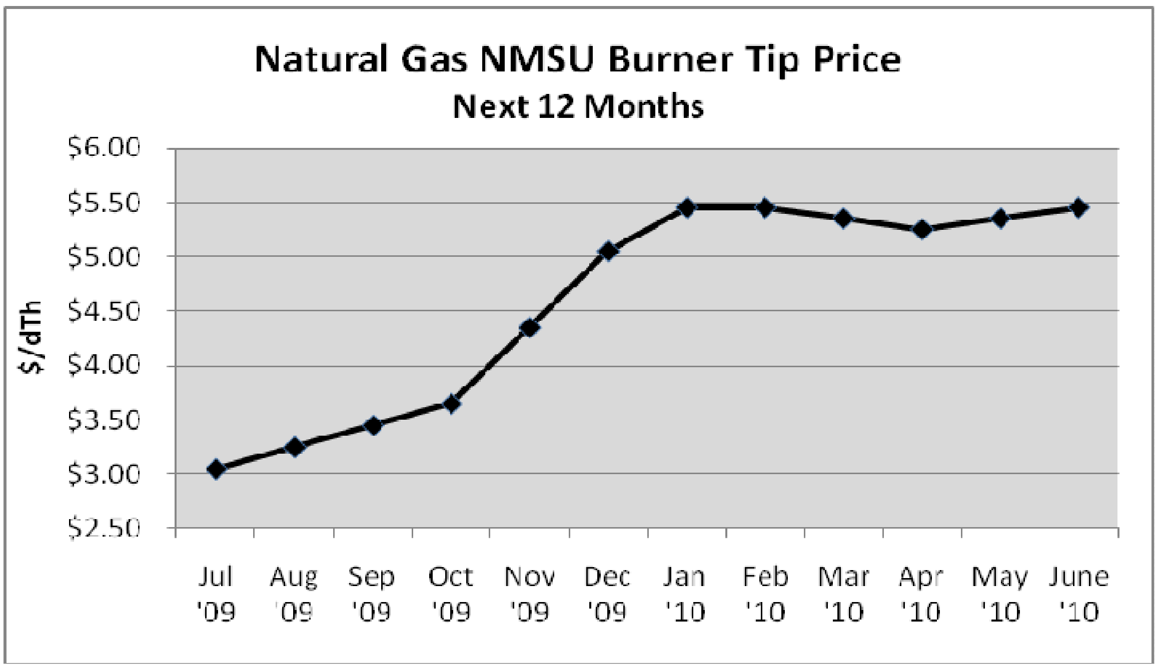
As seen in Figure 3, the campus cooling demand spikes in the summer as would be expected. However, most of the absorber cooling is performed during the winter months. This is due to the electric chillers being down in the winter of 2008, forcing the absorption chillers to steal steam for cooling in the dead of winter. During the summer months there is virtually no cooling accomplished using waste heat. This is particular to 2008 and is due to the rising gas prices during these months. Because of the high cost of gas, the cogeneration turbine was forced into running at minimum and providing the base steam load to campus. There simply was not enough steam leftover from this process to successfully activate an absorber. Typically, for the best energy savings the only time the absorbers would run is when there is enough leftover steam from supplying the campus heating demand. This would only happen in shoulder and summer months and the absorbers would be shut down for the winter. In total for 2008, the HRSG was able to provide 2,857,000 ton-hrs of cooling out of a total campus consumption of about 18,250,000 ton-hrs.

COGENERATION SYSTEM ANALYSIS

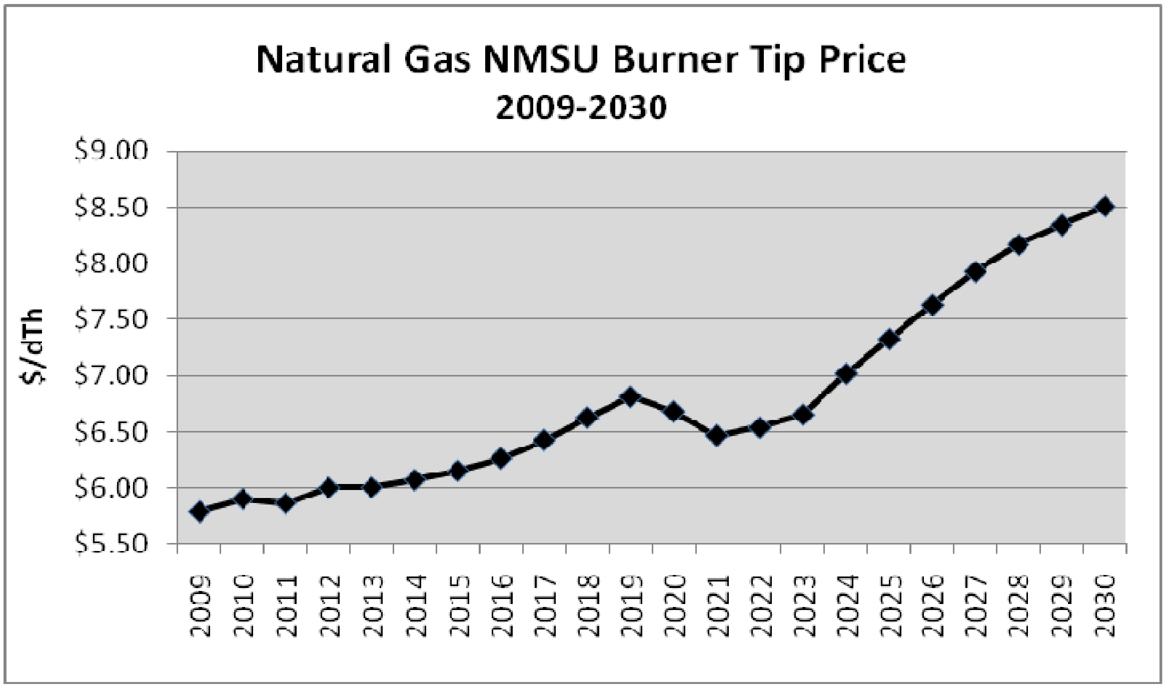
In order to obtain a comprehensive view on the performance of the cogeneration system, the highest resolution central plant data for the year 2008 was retrieved and compiled into a cogeneration operation spreadsheet. This data consists of steam, chilled water and electrical figures for 2008 and is embellished using the hourly profiling capabilities of the U.S. Department of Energy open source building energy modeling software known as eQUEST. After obtaining hourly information on all the associated systems for an entire year, an hourly profile for an average day for each month can be assembled in order to gain a complete annual profile while describing the diurnal swing of energy usage on campus. It is crucial to be able to see how energy consumption changes by the hour for the purposes of evaluating alternatives with respect to the on/off peak electrical rates as well as being able to determine what system the steam generated from the HRSG is being fed into.

Once the averaged monthly days are each compiled onto their own sheets, the spreadsheets are setup to model the operation of the turbine. The Stage 1 cogeneration model was setup to analyze the actual 2008 usage of the system and run "what if" scenarios. The Stage 2 version of the model has been significantly modified to run the theoretical operation of the turbine relative to many alternate variations including energy rates, operational hours, waste heat usage, peak shaving techniques and campus size.

The most important variables in operation of the cogeneration system are not any energy rates individually but the spread between natural gas prices and electricity prices. Henry Hub projections for natural gas prices have been utilized and adjusted to reflect NMSU burner tip prices. For the purposes of the model, monthly projections for the next 12 months have been input and can be seen in the following figure:



These prices are henceforth used to estimate the theoretical operational profile of the cogeneration system. DOE-EIA projections out to 2030 indicate a relatively steady price with a slight peak in 2019 and slight escalation in rate increase starting in 2024 as seen in the figure below:



The projected near term steady cost per decatherm allows for a safe theoretical operational projection of the cogeneration system using current monthly projections.

The first operable variable in the model is the counterpart to the gas rates, being alternates in electricity rates. El Paso Electric is current under rate negotiations to increase overall costs of electricity according to upstream inflation among other reasons. The model allows a toggle between the currently used rate 26A, the formerly used rate 26, the newly proposed rate 26 and the newly proposed rate 28. It is likely that NMSU will switch to the proposed rate 26, but rate 28, which is an interruptible rate, has been included in the model as a comparison to 26. Rate 28 is less costly by demand and by on-peak consumption charges, but incorporates the caveat of possible losing power supply. It is assumed at this point that rate 28 is not an attractive offer for the University, but it has been included in the model for future use. Therefore, all model outputs in the CD accompanying this report utilize proposed rate 26 only.

The next operable variable is the operational run time. According to the price of gas the turbine shall either be on 24 hours a day, only operating during on-peak electrical times or off completely. This can be adjusted by the year or by the month, as desired. As long as gas rates stay below $8/dTh there will be no reason to shut down the machine except for maintenance. According to the DOE-EIA projections, this won't happen until 2028, at which time electrical rates will have changed over and increased multiple times. This makes it safe to assume, for the purposes of the model, that the cogeneration system will be fully operational 24 hours a day.

Currently there are a set of buildings, including the data center, that rely on the turbine for backup power in case El Paso Electric has an outage. This set of buildings requires backup power on the order of 2.5 MW, and the model has been outfitted to be able to turn this dependency on or off but it would only take effect should the price of gas rise above $8/dTh.

One of the more important input variables in the model is the option for waste heat use from the HRSG. The model allows the user to make a choice between either two 1030 ton double effect absorption chillers or one 257 kW steam turbine and one 1105 ton single effect absorption chiller. The differences between these options are discussed further in the Chilled Water System section of this report.

Another crucial user adjusted variable is the option to install an ice storage system for the chilled water system, allowing the electric chillers to run more during off-peak hours to produce ice that is then melted during on-peak hours for an overall cheaper chilled water production. Details on this optional system are discussed further in the Chilled Water System section of this report.

The last set of variables allows the user to scroll through each phase of campus growth out to 2034 and see the results on the system as demands grow for chilled water, steam, and electricity.

According to the alternate permutations of the model and according to the EPE proposed rate 26, it appears that the most savings will be realized by utilizing ice storage along with two double effect absorption chillers to replace the currently failing absorbers at the central utility plant. In this scenario, using 2009 theoretical energy data, the annual cost of the turbine gas, boiler gas, and campus electricity sums up to roughly $8,046,000. Under this configuration the switch to on-peak only operation happens when natural gas rises to $8.75/dTh and the turbine switches off completely if the gas rates rise to $10.23/dTh. It is projected that these gas prices won't be seen until nearly 2030, so it should be safe to assume that 24 hour operation of the cogeneration system shall occur. A net present value analysis of 8 alternate permutations can be referenced in the Chilled Water System section of this report.

Included with this report is a CD containing the entire report plus an expanded set of permutations of the cogeneration model.

COGENERATION SYSTEM STRATEGIES FOR CAMPUS EXPANSION

The cogeneration system is not like the other utilities herein in that campus expansion does not require upgrading the system. However, as the campus expands and electricity consumption goes up, more options become available for demand peak shaving techniques, including the operation of the turbine, the use of HRSG steam to create chilled water or additional electricity, ice storage for chilled water (as mentioned above), or possibly the addition of a secondary generation system on campus.

DATA CENTER BACKUP GENERATOR

Under its current configuration, the cogeneration system is more or less a slave to the power needs of the data center as well as a few other key buildings on campus. Because these facilities do not have a backup generator and because it would take too long to ramp up the gas turbine from a standstill, the gas turbine must remain operational at a minimum of 2.5 MW to serve as backup in case power from El Paso Electric goes out. With the current projections of natural gas prices, there appears to be no reason to shut down the turbine anyway, however, gas prices unexpectedly spiked in the summer of 2008 causing 24 hour operation of the system when on-peak only operation would have been more cost effective. Due to this anomalous dependency on the gas turbine by these campus buildings, the University netted an estimated negative savings of -$79,000 on gas turbine use in the 2008 year. It has been estimated with the cogeneration model that had there been a backup generator, net savings on the cogeneration operation would have summed up to about $405,000, showing a difference of over $484,000. It has been estimated that a 2.5 MW backup generator with enclosure and sub base fuel tank plus installation expenses would add up to roughly $1,020,000, giving a payback on this item of 2.1 years. It would be recommended, if the price of gas continues to spike out of proportion, to consider this option. However, if the price of natural gas stays below $8/dTh, there would not be an attractive payback on a backup generator of this nature.

PEAK SHAVING NATURAL GAS GENERATOR

In researching the option for adding a backup generator to alleviate the gas turbine from constant unconditional operation, a new generation prospect for the main campus came to fruition. The idea of the backup generator would be to sit idle until power is lost from EPE and never to run otherwise. Rather than investing in a backup generator, which would only pay for itself if gas rates continued to spike contrary to projections, investment in a peak shaving generator could have significant payback potential as well as offer some leverage for electrical rate negations. This option entails tying in a 2.05 MW engine to the City of Las Cruces 340 psi gas line near Tortugas Substation and subsequently tying in the output to the campus grid. This generator would be able to produce at a rate of 10,712 btu/kWh for a total output of 1800 kW at an elevation of 4000 feet for a total of 500 peak hours a year (according to EPE proposed rate 26). The entire cost of the equipment plus installation is estimated to be on the order of $1,414,000 and would generate a net annual savings of roughly $196,000, yielding a payback of just over 7 years. Although the equipment would undoubtedly pay for itself, from a business point of view the payback period is marginal. However, this option would grant the University leverage, especially in a time such as this while rate negotiations are active, to request a lowered minimum demand kW in return for taking some load off of El Paso Electric, as the company is currently struggling to produce enough energy for the demand they service. A lowered minimum demand would only increase the opportunity for savings by means of peak shaving and shifting techniques

STAGE 1 DEFICIENCIES

Data Center Dependency

A deficiency associated with the spiking costs of natural gas is the fact that the main data center is currently reliant on the constant operation of the gas turbine. This is due to the absence of a dedicated emergency generator at this facility. Because of this dependency, even when it becomes cost effective to shut down the turbine it must be kept online at a minimum 2.5 MW in order to provide a contingent backup power source for the data center in the event of a power outage. Not only is this costing the University excess in utility charges, the efficiency of the turbine is greatly reduced at part load. However, should the price of natural gas stay steady for the next 20 years, as projected, there should never be another time when it is economically attractive to switch the gas turbine off. Should gas projections drastically change, there is the option of installing a backup generator, as discussed above.

Lack of Demand-Based Electrical Rate

One of the most attractive opportunities in having a cogeneration system is the allowance to significantly lower electrical demand charges from the utility provider ensuring the turbine is base-loading the campus electrical demand, especially as it peaks. The rate schedule currently provided to NMSU by EPE is consumption based only with no charge for demand. EPE's currently proposed rate 26 now offers demand charges in the place of some consumption charges, opening the door to additional savings through peak shaving by the gas turbine.

De-Rated Absorption Chillers

Another notable deficiency with the cogeneration system is the functionality and efficiency of the absorption chillers. It has been reported by NMSU facilities staff that there is often one absorber down for maintenance due to various problems with the equipment. These two units were the first in a line developed by Carrier and it has become clear that they have inherited sufficient inefficiencies associated with prototypical models. Their capacity for generating chilled water has significantly reduced from 1570 tons to about 1200 tons and they do not accept a part load with ease. At this point, the NMSU facilities staff considers the machines a redundancy and places no reliance in their operability. As discussed further in the Chilled Water System section of this report, it is recommended that two double effect absorbers be installed to replace the two existing machines. These newer and tried models can successfully be used to their potential to effectively use turbine waste heat and decrease daytime electrical consumption.

Excessive Waste Heat

It was noted that there is a significant amount of unused waste heat vented from the turbine rather than going into steam production. This is partially due to the inefficiencies of the absorbers and partially due to the fact that there is no other heat sink on the system. In the theoretical operation model of the cogeneration system, replacement of these absorbers with newer ones should cause the utilization of nearly all of the turbine waste heat, as desired.

New Mexico State University
Utility Development Plan
Stage 2 - 06-16-09
Simple Payback for Data Center Backup Generator

Assumptions - These numbers are reflective of 2008 performance data only. The savings shown herein are dependent the spiking costs of natural gas for the mentioned year.

2008 Cogen Overall Savings	2008 Cogen Overall Savings w/ Backup Generator (cost of generator not included)	Difference in Savings
-$78,822	$405,355	$484,177

Cost of 2.5 MW Generator, Skid Mounted:	$685,000
Additional Fees:	$137,000
Simple Payback Period (years):	**1.7**
Cost of 2.5 MW Generator w/ Enclosure and Sub Base Fuel Tank:	$850,000
Additional Fees:	$170,000
Simple Payback Period (years):	**2.1**

New Mexico State University

Utility Development Plan

Stage 2 - 06-16-09

Simple Payback for Peak Shaving 2055 kW Nat Gas Generator

Assumptions:	These figures reflect the EPE proposed rate 26 and are currently independent of other peak shaving techniques.
	The generator will only be used during on-peak electrical times

Cost of Equipment	$975,000	
Installation/Additional Fees	$438,750	
Heat Rate	10,712	btu/kWh (hhv)
Actual Output	1,800	kW
Maintenance	$0.01	/kWh
Cost of Elec. Consumption	$0.20115	/kWh
Cost of Elec. Demand	$10.02	/kW
Cost of Nat Gas	$5	dTh
Annual Runtime	500	hrs
Annual Demand Savings	$72,144	
Annual Cons Savings	$181,035	
Annual Cost of Operation	$57,204	
Annual Net Savings	**$195,975**	
Simple Payback	**7.2**	**years**