Operating Strategies for Campus Cogeneration System in a Turbulent Utility Market

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ABSTRACT

The future is unpredictable, natural gas prices are fluctuating wildly, and electricity rates are increasing sharply as a result of higher fuel prices. In unstable utility market environments like we are seeing today and that we expect in the near future, operating a large university cogeneration system presents opportunities as well as challenges. Will the existing "generate-as-much-as-we-can and buy-the-rest" operation scenario continue to be the best, or does the operation need to be optimized? If operational changes are recommended, what is the optimum scenario? How sensitive is the optimum scenario to natural gas prices and electricity purchase rates? The Texas A&M University combustion gas turbine is an old machine. The economics of an overhaul and upgrading costs also come into play.

Various operation scenarios are proposed, then evaluated and compared for different natural gas prices and purchased electric rates. The results show how to maintain flexibility in the uncertain electricity market, and to minimize the impact of electric utility deregulation. The analysis also investigates the cost impact of increased natural gas prices, and the economics of the major gas turbine upgrade. The various scenarios analyzed include: 100% purchase of electricity, i.e., shutting down the gas turbine; generate as much electricity as you can and buy the rest; operate in a pure Combined Heat and Power (CHP) mode and buy the rest; and operate the CHP units during summer months only and buy the rest. The above scenarios are also evaluated with an overhauled and more economical gas turbine/generator set.

The fact that Texas A&M's cogen system can produce up to 65% of its own electricity, has both electric-driven and steam-driven chillers, and can purchase its additional electricity on the wholesale market presents additional opportunities and operating strategies, which will be discussed in the paper.

Introduction

Texas A&M University (TAMU), College Station, generates approximately 65 % of on-campus power consumption with its own cogeneration power plant, and the rest is purchased from power suppliers. On a peak day, the University has to buy half of its power demand. The largest on-campus turbine is a combustion turbine, which generates almost 25 % of the campus peak demand, and is about 30 years old.

Before any crucial decision on operational scenarios could be made, it was essential to examine the economic and operational issues relevant to the overhaul of combustion turbine generator #6, CTG 6. This examination led to evaluating the composite cost of power under various combinations of self-generation and commercial power purchases. Because the price of natural gas has been both high and volatile in recent months, those effects were also evaluated. An independent assessment of the prudence of overhauling the gas turbine at a cost of $2.7 million, was considered necessary "due diligence" by the University Utilities Department.

In addition to the technical/economic operating analyses, there are a number of externalities which have to be considered, such as the age of the current combustion generator, the impact of electricity deregulation, the status of infrastructure improvements to the current campus utility grid, TAMU's status as a wholesale purchaser of electricity, and its current contract with its local power supplier. These factors will be discussed as well as the more quantifiable operating scenarios.

Cogeneration System Information

TAMU has one main central plant and four satellite central plants, which produce electricity, steam, chilled water, heating hot water, and domestic hot water. The maximum generation capacity is 36.5 MW including 15 MW from a gas turbine (CTG 6), 17.5 MW from two steam turbines, and 4 MW from a back pressure steam turbine.

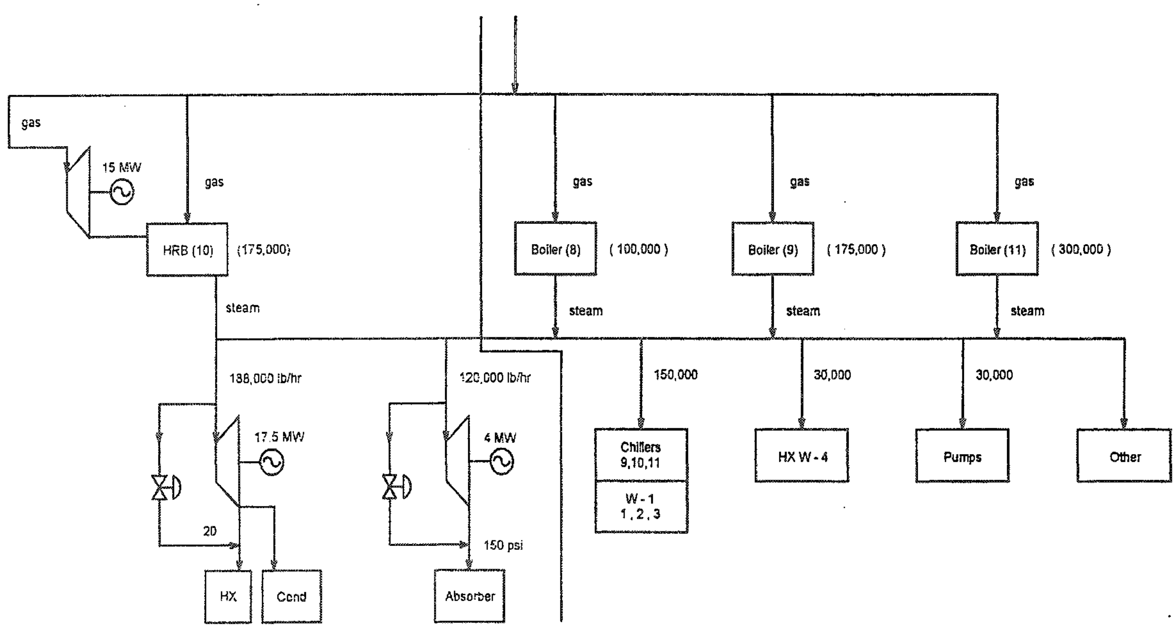

Figure 1. Simplified System Diagram of TAMU Cogeneration

Figure 1 presents the simplified system diagram of the TAMU cogeneration plant. The heat recovery boiler (Boiler 10) of CTG 6 has a capacity of 175,000 lb/hr. Condensing steam turbines 4 and 5 consume approximately 188,000 lb/hr of 600-psig steam under full load conditions. The 20-psig low-pressure steam extracted from these two steam turbines is sent to heat exchangers to produce campus heating hot water and domestic hot water. Backpressure steam turbine 3 receives 600-psig steam, too, and its 150-psig medium-pressure steam exhaust is used by the double effect chillers. If all equipment is in good condition, the operation has good energy efficiency.

Boilers 8, 9, and 11 also have to provide steam to the following equipment: steam-driven centrifugal chillers 9, 10, and 11 in the main plant, turbine driven pumps in the main plant, steam-driven centrifugal chiller and single-effect absorption chiller sets A, B, and C in West-I plant, and heating hot water heat exchangers in West-IV plant (not shown in Figure 1).

Examination of Non-Quantifiable Factors

There are several non-quantifiable/subjective factors that could impact the decision to overhaul the combustion turbine/generator. They include:

1. The age of the turbine. CTG 6 is nearly 30 years old, which is beyond the typical useful life of a combustion turbine without major overhaul. The Power Plant's 1970's vintage turbine/generator has a higher heat rate (lower efficiency in producing electrical power) than newer machines, and this overhaul will significantly improve the heat rate (approximately 20 %). Reliability is also an important issue. The longer this turbine is operated without refurbishment, the more likely a breakdown will occur. A failure of CTG 6 could precipitate blackouts on campus as well as set new, costly demand peaks for commercial power purchases. A major overhaul of the gas turbine/generator would improve both operating reliability and efficiency.
2. Electrical Infrastructure Improvements. The current TAMU Utilities Capital Plan has two major projects that address electric infrastructure: Electric Distribution Improvements and Looped 138 kV Electrical Feed. The former is currently under construction with an anticipated completion date of September - December 2001. The latter should be complete by December 2003. The Electric Distribution Improvements project improves system reliability by adding a transformer, additional conductors between the 138 kV substation and the main campus, new switchgear and relays, and additional feeders. Of particular importance for the main campus are the two additional sets of conductors from the substation. Currently, main campus peak loads require the generation from CTG 6 and supplemental commercial power delivered on the two existing conductors. A failure of CTG 6 during a peak load period could cause a secondary failure of one or both of the two ties to the substation. Parts of the main campus would be subject to a "brown out" for an extended period under this scenario. The University does not want to assume the risk of overstressing the two old conductors by not operating CTG 6, or by operating it in an unreliable condition. This condition will be partially relieved when the new conductors and accompanying switchgear are completed. Even then, however, the University should not assume the risk of total reliance on only one external 138 kV feed. Until the completion of the Looped 138 kV Electrical Feed project, the highest reliability state for the University is continued reliable operation of CTG 6.
3. Uncertainty over electricity deregulation. Currently, TAMU enjoys a highly favorable status as a wholesale purchaser of electricity. The purchased electricity contract with the local power supplier is based on TAMU generating base load electrical power. As long as the University continues to generate power and purchase electricity from the local power supplier, it can maintain its wholesale purchaser status. The fact that TAMU is served by a co-op limits its participation in a retail electric market under the current law deregulating the electric utility industry in Texas, and if the gas turbine generator failed

such that the University could not generate electric power, it could possibly lose its status as a wholesale purchaser of electricity. The net effect would be a loss of the current contract with the local power supplier and higher electric utility rates. Having its own generation capacity increases the University's options, and it is very important to have a reliable turbine generator.

4. Resale value of an overhauled CTG 6. The TAMU physical plant has been told that the resale value of an overhauled combustion turbine/generator would exceed the value of the \$2.7 million overhaul. If the university decided, for example, to purchase all electricity three or four years from now after the Looped 138 kV Electric Feed project is complete, the university could recover the cost of the overhaul from the CTG 6 sale. Further, since the operational savings from an overhauled CTG 6 would have already paid for the cost of the overhaul, the university would realize a significant positive cash gain. There is little financial risk to TAMU in authorizing the overhaul but considerable risk, because of reliability and higher operating costs, if the overhaul is not done.

In summary, these subjective factors all point to the necessity of overhauling CTG 6.

Examination of Quantifiable Operating Scenarios

This analysis covered seven different operating scenarios for three different natural gas and electricity prices. These scenarios are:

1. Current plant operation, base loading with the combustion turbine, CTG 6, and steam turbine generators, STG's 4 and 5, without the gas turbine overhaul. In the current operation, the plant produces essentially all the power it can by producing additional steam in the boilers for power production.
2. Base load with CTG 6 and STG 4, operating in a simple combined cycle, without the gas turbine overhaul. In this mode, the plant could cut back on the amount of auxiliary steam produced, generating electrical power only from the steam produced in the waste heat boiler. In this scenario, electrical production is reduced, and more electricity is purchased from the local power supplier.
3. Same as scenario 1 above, i.e., current operation but with the gas turbine overhaul.
4. Same as scenario 2 above, i.e., simple combined cycle, but with the gas turbine overhaul.
5. Same as scenario 1, i.e., current operation, but with a failure of the CTG 6 during the summer utility peak period, where a demand penalty will be incurred.
6. A buy-all electricity policy. There are three prices noted for this case. The low cost scenario assumes TAMU could remain as a wholesale purchaser of electricity. The other two pricing scenarios assume retail status, and the two prices are 15 % and 30 % above the current wholesale price.
7. Operation of the CTG 6 in the four-month peak utility season (June - September), operating in a simple combined cycle mode, with an overhaul of CTG 6. (This scenario will not be possible until after the Electric Distribution Improvements and Looped 138 kV Electrical Feed projects are complete; however, it is a long-term mode of operation that should be considered.)

All of the above scenarios are analyzed with \$3, \$4, and \$5 per million Btu gas and a corresponding price for purchased electricity, including the local power supplier charges for demand and transmission.

Discussion of Operating Scenarios

Figures 2, 3, and 4 show the differences in "make" vs. "buy" and the composite price for electricity for each scenario. Figure 5 and Table 1 give the expected savings from the base case (current operation with no overhaul.)

Detailed Technical Evaluation

Figure 2 is a plot of the seven scenarios based on $3.00 / MMBtu gas and the corresponding electricity purchasing price. The dots represent the TAMU "generate electricity" prices and the squares represent the buy prices. The diamonds are the composite rates.

Several observations can be made from this figure.

1. The cheapest operating scenario is operating under the conditions of scenario 7, i.e., operating the overhauled cogeneration system in the four-month summer peak period and buying power the rest of the year. Operating in this fashion is not practical in the short term, however, because the current electrical distribution system can not handle the Main Campus loads without some generation from the plant. However, beyond 2003, this scenario should be carefully considered.
2. The most expensive option occurs when the CTG 6 goes down during a peak period in the summer. TAMU would have to pay a severe demand penalty, which increases the electricity rate cost by nearly 50 % over the least cost condition. The result of the loss of CTG 6 for the short term, i.e., before the current electrical distribution system is upgraded in 2003, is that power cannot be supplied to the main campus, and a brown-out is likely.
3. The next cheapest operating option is a simple combined cycle mode, scenario 4, with an overhaul of CTG 6.
4. The "buy-all" option compares favorably in cost if the wholesale price is used, but it becomes one of the most costly options if the retail price of electricity is 30 % above wholesale prices. Again, the "buy-all" scenario could not even be considered until 2003.

Figure 3 shows all seven scenarios with $4.00 / MMBtu gas and a purchased electricity price comparable to the higher gas rate. Similar observations can be made for this figure. The least cost scenario is summer peaking operation (scenario 7). The operating costs with the CTG 6 overhaul are significantly less than without the overhaul, and the highest cost scenario is number 5, i.e., any outage of the CTG 6 during a peak summer month. The "buy-all" scenario is very attractive for wholesale rates, but becomes an expensive scenario if higher retail rates are used.

Figure 4 shows the impact of high gas and electricity prices, i.e., $5.00 / MMBtu gas and the purchased electricity price. The same general conclusions can be made from this figure as for Figures 2 and 3, except the scenarios are much more costly. Losing the combustion turbine during a peak summer period raises the electricity price to about 6.8 ¢/kWh, and scenario 7, i.e., operating in a simple combined cycle mode with overhaul for the summer months, represents the lowest cost operating scenario. The most practical operating mode, scenario 4, has a combined electricity price of about 4.7 ¢/kWh, with an overhaul of CTG 6.

Figure 5 is a plot of the savings resulting from the various scenarios, using the current base load operation as the starting cost. Significant savings can be achieved both by changing the operation strategies and by overhauling the combustion turbine. While the "buy-all" strategy appears one of the best for most of the gas prices, the savings shown on this figure are for wholesale electricity purchases and do not reflect the possible change from a wholesale purchaser to a retail purchaser of electricity. If the University tries to purchase all electricity, it may no longer be able to retain wholesale purchaser status.

The results presented herein represent a broad range of operating scenarios for the TAMU power plant. Some of the scenarios presented, i.e., scenario 7, summer peaking operation only, is not practical in the short term, because both electrical projects must be completed before total purchase of electrical power can be considered. It is a scenario, however, which could be followed, long term, after the electrical upgrades are made.

The "buy-all" scenario presents three different electrical rates, i.e., wholesale, 15 % above wholesale, and 30 % above wholesale. The "buy-all" scenario is presented for the sake of comparison, but may not be a realistic scenario. If TAMU does not generate any power, it may not be able to retain wholesale status and may have to be considered a retail purchaser of electricity. This represents a problem because TAMU power is delivered by a co-op through a municipal utility, neither of which will likely be participating in the Texas deregulated market, at least not at the beginning of deregulation (January 1, 2002). If the University were to purchase all its electricity, it would likely be as a retail purchaser, not as a wholesale purchaser, and that could only occur at some time in the future.

The worst-case scenario, for all gas prices, is the loss of the combustion turbine during a peak period. The most favorable practical scenarios represent the cases where the gas turbine is overhauled and is operating with a lower heat rate and thus greater efficiency.

Summary and Conclusions

The results are summarized below:

1. For all gas prices, the most efficient mode of operation is to operate an overhauled CTG 6 as a summer peaking machine. In this scenario, TAMU would purchase all electricity during the eight off-peak months. This scenario will be possible only after both electrical projects are complete. This scenario could result in additional savings due to the potential to negotiate better rates with the local power supplier or the subsequent wholesale power provider, because the university would be helping reduce the utility summer peaks, while buying 100 % of its power off peak. In this operating mode, TAMU would purchase more electricity during the utility's non-peak generating months and then help offset the utility's peak supply period by generating electricity. Annual savings from this scenario range from over $4 million to over $9 million dollars.
2. The most expensive scenario is not overhauling the CTG 6 and having a turbine failure during the peak summer months. This scenario presents the greatest risk to TAMU from a financial standpoint.

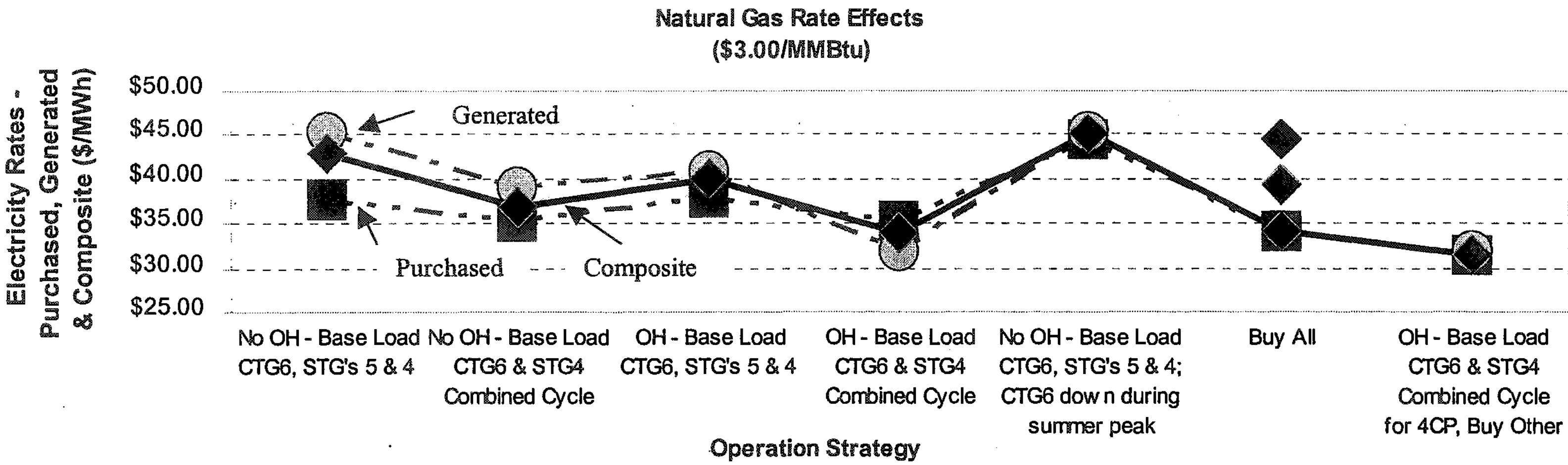

Figure 2. Buy, Make and Composite Electric Rates of Various Operation Scenarios at $ 3.00 / MMBtu Gas Price

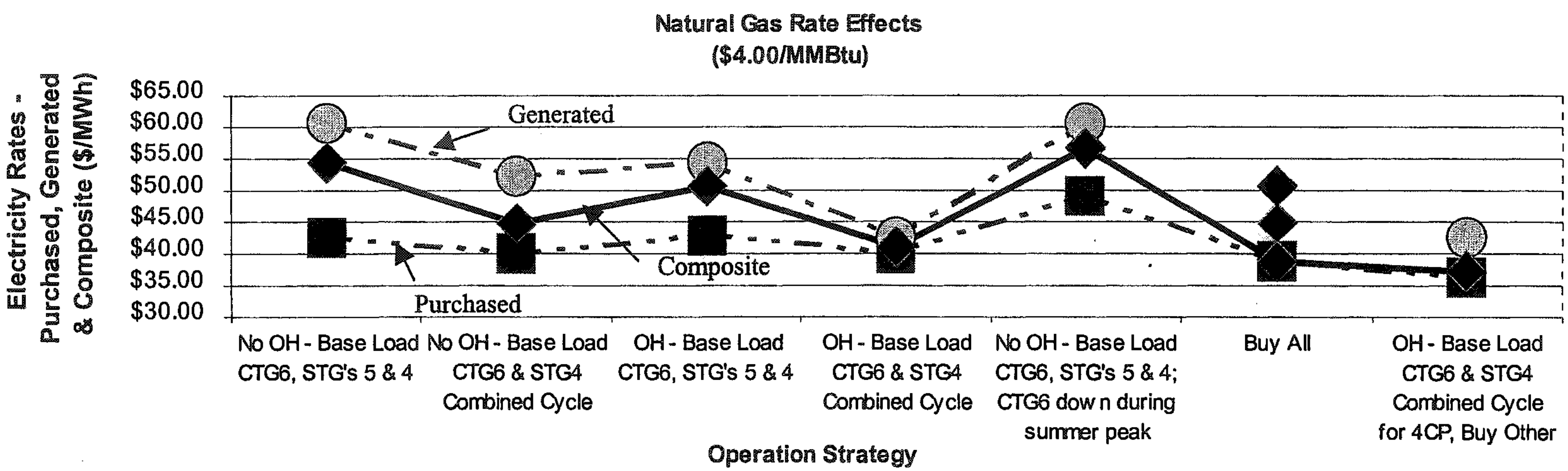

Figure 3. Buy, Make and Composite Electric Rates of Various Operation Scenarios at $ 4.00 / MMBtu Gas Price

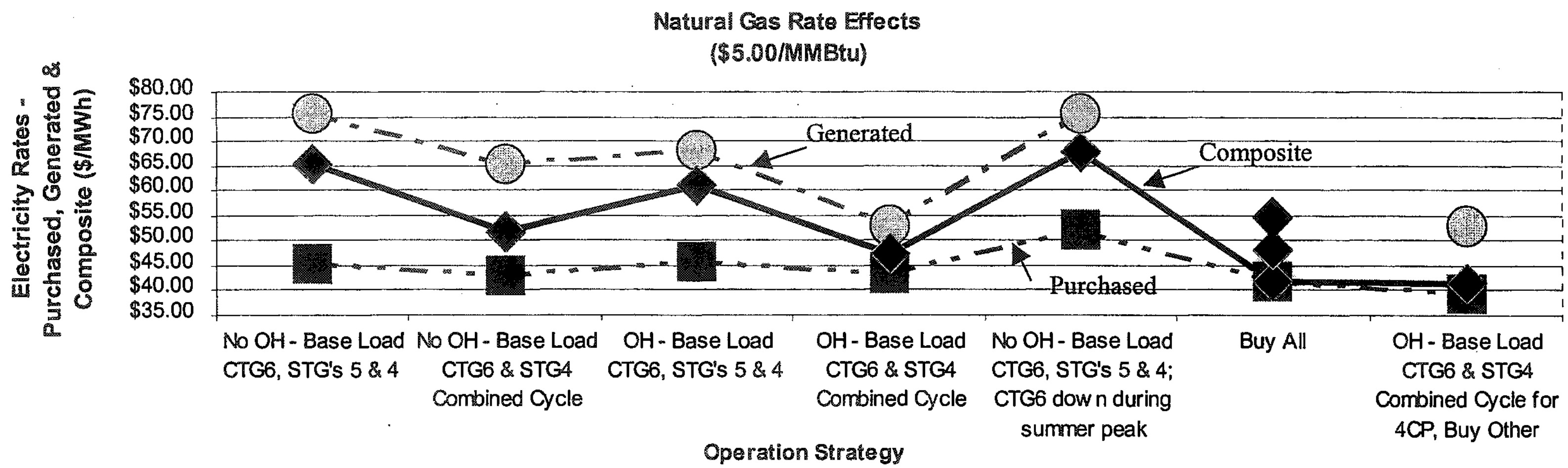

Figure 4. Buy, Make and Composite Electric Rates of Various Operation Scenarios at $ 5.00 / MMBtu Gas Price

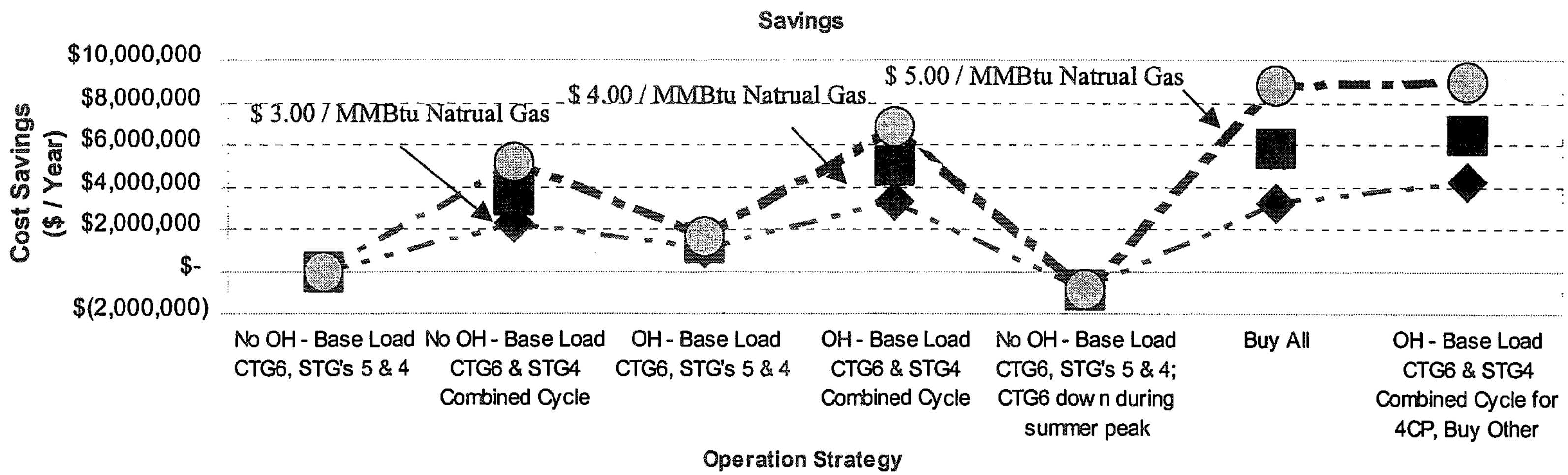

Figure 5. Annual Savings of Various Operation Scenarios Compared with Current Operation Scenario at Various Gas Prices

Table 1. Annual Savings of Various Operation Scenarios Compared with Current Operation Scenario at Various Gas Prices

No.	Operation Scenarios	Natural Gas Price		
		$3.00/MMBtu	$4.00/MMBtu	$5.00/MMBtu
1	No OH - Base Load CTG6, STG's 5 & 4	-	-	-
2	No OH - Base Load CTG6 & STG4 Combined Cycle	$ 2,200,000	$ 3,600,000	$ 5,200,000
3	OH - Base Load CTG6, STG's 5 & 4	$ 1,100,000	$ 1,400,000	$ 1,700,000
4	OH - Base Load CTG6 & STG4 Combined Cycle	$ 3,300,000	$ 5,000,000	$ 6,800,000
5	No OH – Base Load CTG6, STG's 5 & 4; CTG6 down during summer peak	$ (856,000)	$ (854,000)	$ (850,000)
6	Buy All*	$ 3,200,000	$ 5,800,000	$ 8,800,000
7	OH - Base Load CTG6 & STG4 Combined Cycle for 4CP, Buy Other*	$ 4,200,000	$ 6,500,000	$ 9,000,000

* Savings for this scenario are estimated at the wholesale purchasing price.

3. Over the next three years, until the second 138 kV electrical feed is added, TAMU will have to operate in a base load mode. Annual savings from the overhauled (more efficient) turbine range from $1 million for $3 gas to over $1.6 million for $5 gas. The payback for the gas turbine overhaul, therefore, ranges from 2.5 years down to 1.7 years. Our analysis also recommends reducing generation at night and weekends while the gas prices remain high. (Note: the Utilities Division is currently in the mode of backing off on generation to buy more commercial power.)
4. The "buy-all" electricity scenario is the second cheapest operating option, based on current local power supplier prices and expensive gas. While this is not a viable option until after completion of both electrical projects, it is an option TAMU will want to consider in the future. Certainly, after 2003, optimum scenarios will have to consider purchasing more electricity and producing less, provided the wholesale electricity prices remain less than self-generated power.

In summary, the technical/economic scenarios analyzed indicate that overhaul of the CTG 6 is warranted, with simple paybacks ranging from 1.7 to 2.5 years (The price of the overhaul will be paid for by the time the looped 138 kV Electrical Feed Project is completed in late 2003).