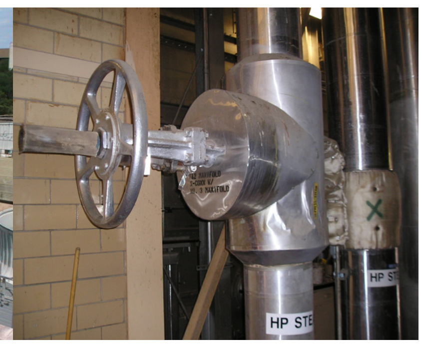
THE UNIVERSITY OF TEXAS AT AUSTIN

Carl J Eckhardt Heating and Power Complex

A Study in the Benefits of Efficiency Improvements to Emissions and Fuel Costs





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Executive Summary

The University of Texas campus has experienced rapid growth over the past thirteen years, expanding usable square footage at the main campus by 16% while bringing heating and cooling demands up with it. Meanwhile, ever increasing technology requirements have caused the electrical demands to increase by nearly 26%, resulting in an 18% total increase in campus energy demands. Over this period however, the natural gas burned yearly by the UT power plant to generate electricity, heat and cooling has remained constant. Through continual efficiency gains, the power plant has been able to offset the rising campus energy demands with no increase in fuel consumption. Likewise, operating a combined heat and power plant allows for higher efficiencies than could ever be accomplished through purchased grid energy. Savings have been realized by these efficiency gains, both in fuel and operating costs, as well as emissions and environmental impact.

The University power plant is a combined heating and power facility (CHP), supplying the campus and chill stations with electricity as well as steam salvaged from waste heat. In 1996, the power plant's overall energy distribution efficiency was 62%, compared to a typical combined-cycle power facility's energy efficiency of only 40%. Through 2008, the UT power plant efficiency had been increased to 73% due to plant modifications and process optimization.

Natural gas prices rose dramatically in this time, from \$2.07 per mmBTU to \$8.70, peaking during 2006 at \$12.08. This caused a rise in the power plant's annual gas costs from \$9.1 million in 1996, peaking at \$47 million in 2006, to \$39 million in 2008. Without the efficiency gains over the decade, the natural gas costs in 2006 would have totaled over \$55 million, a full \$8 million higher. The cumulative fuel savings due to efficiency gains over the past thirteen years have totaled over \$39 million.

Emissions have always been an area of concern with fossil fuel power plants, more recently with a growing awareness of a facility's "carbon footprint". Over the past thirteen years, the UT power plant has generated a total 3,200,000 tons of carbon dioxide, averaging about 250,000 tons per year. Figuratively, this is equivalent to the carbon output of 45.500 cars and light trucks on the road, or the amount of carbon that 320 square miles of deciduous forest would absorb each year; a forest roughly 1.5 times the size of the Austin metropolitan area. Meanwhile, the efficiency gains have avoided the cumulative release of 400,000 tons of carbon dioxide since 1996, the same as taking nearly 6,300 cars off the road, or planting 35 square miles of forest; a forest roughly 100 times the size of the main UT Austin campus. The efficiency gains have allowed the campus to continue growing in size and energy consumption without emitting any additional carbon dioxide, effectively classifying all campus growth as carbon-neutral. Additionally, boiler upgrades have reduced annual nitrous oxide (NOx) levels by 35%.

When compared to purchasing all electricity and running natural gas boilers for heating, the benefits are even more pronounced. By studying the components of the campus's energy needs, the costs and emissions of purchased energy can be directly compared to the UT power plant's generated energy. From 1996 through 2008, the University spent a total of \$272,000,000 on natural gas as power plant fuel. Had the campus been purchasing energy, it would have spent \$86,000,000 on natural gas for heating and steam production, and \$223,000,000 on electricity, reaching \$309,000,000 for total purchased energy over the decade. The University saved an average \$2,900,000 per year purchasing natural gas as fuel rather than purchasing grid electricity and natural gas. These savings carry over to carbon emissions, where purchased energy would have resulted in the 13 year cumulative release of 3,700,000 tons of CO2, compared to the power plant's release of 3,195,000 tons. By operating a CHP facility rather than purchasing energy, the University prevented the release of 511,000 tons of CO2, or nearly 40,000 tons per year, the same as taking 7,280 cars off the road, or planting 32,720 acres of forest.

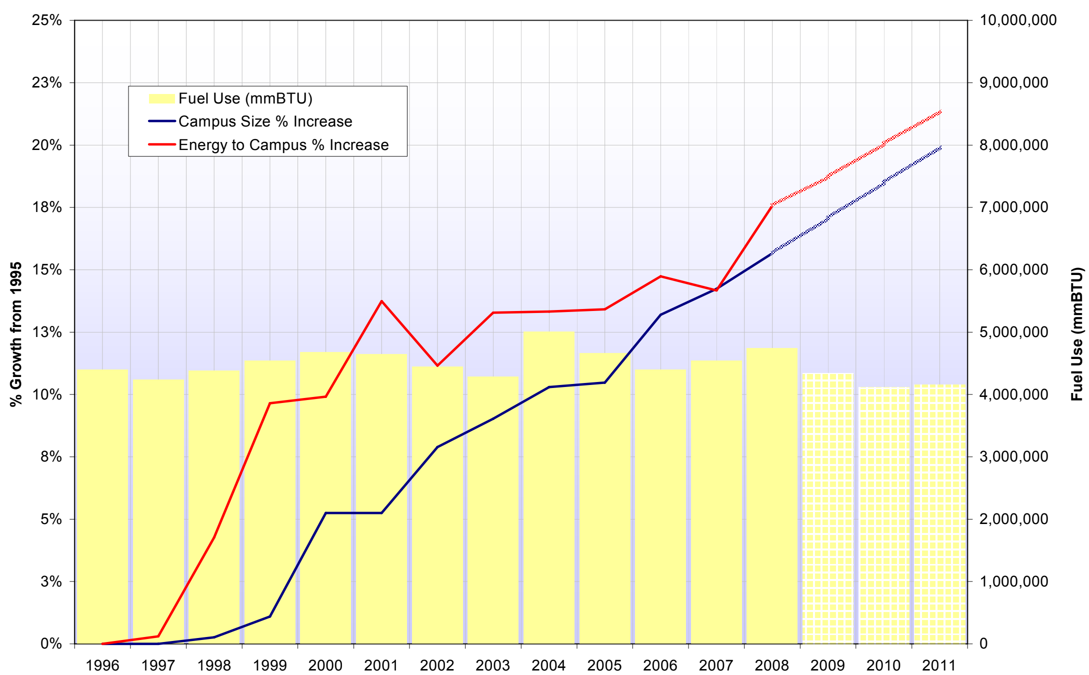
A new gas turbine, planned to come online in 2010, and a new chilling station to be completed in 2009, will further reduce the natural gas demands in spite of ever growing campus energy needs, continuing the University's commitment to clean growth and maintaining cost effective and reliable energy.

Efficiency Increases Result in Reduced Emissions and Fuel Costs

The University of Texas at Austin campus has experienced steady growth through the past decade, both in infrastructure and electrical demands. These needs are met through the on-campus power plant, providing electricity, chill water, and heating to the entire campus. Despite the growing energy demands, the power plant has maintained consistent yearly fuel usage due to persistent efficiency gains, as seen in Figure 1 below. These efficiency gains have saved the University millions of dollars in fuel costs and prevented the release of millions of tons of CO2.

Operating as a combined heating and power (CHP) plant, the University is able to function at a much greater efficiency and reliability than that afforded through purchased energy.

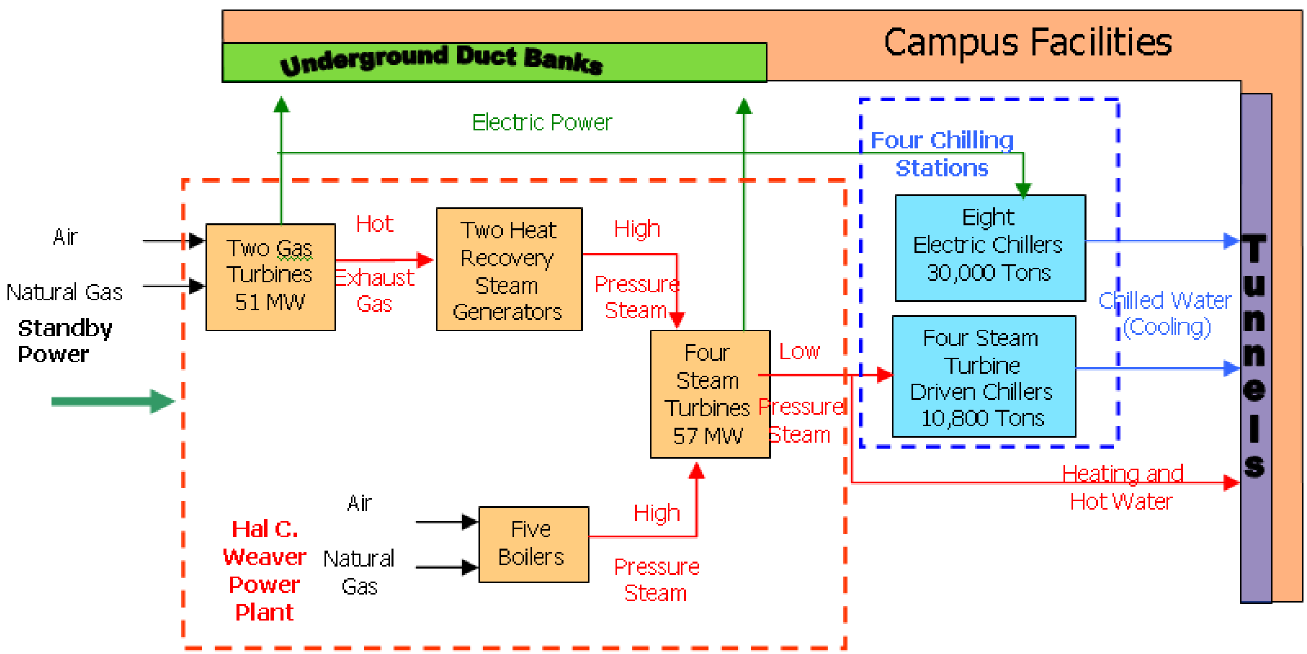
Fig. 1 - Growth in Campus Size, Electricity Demand, and Fuel Usage
Including three year forecast

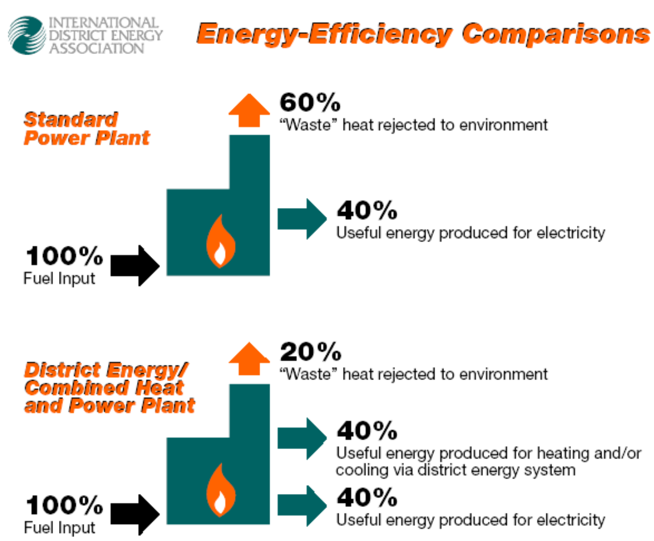


District Energy/CHP

Combined heating and power (CHP) describes power plants that produce both electricity and useable heat. All power plants generate excess heat which is not used for electricity production and is generally expelled, either into the atmosphere through cooling towers or into local reservoirs. A CHP facility is typically able to convert this heat into useful work, such as space heating and hot water, thereby converting around 80% of the energy into useful work. The diagrams below provide general and more specific outlines of how the University's district energy system operates.

University of Texas at Austin Combined Heat and Power Plant





In a common setup, superheated steam is taken from the low pressure section of a steam turbine and piped to heat exchangers where needed. The superheated steam then returns to the plant as a condensate. The University of Texas campus is connected through an elaborate network of steam tunnels, allowing the power plant to fulfill the heating needs of most buildings on campus. Heat that would normally be supplied through individual gas-fired boilers is provided straight from the power plant, resulting in substantial savings in natural gas requirements.

Offsetting Growth through Efficiency Gains

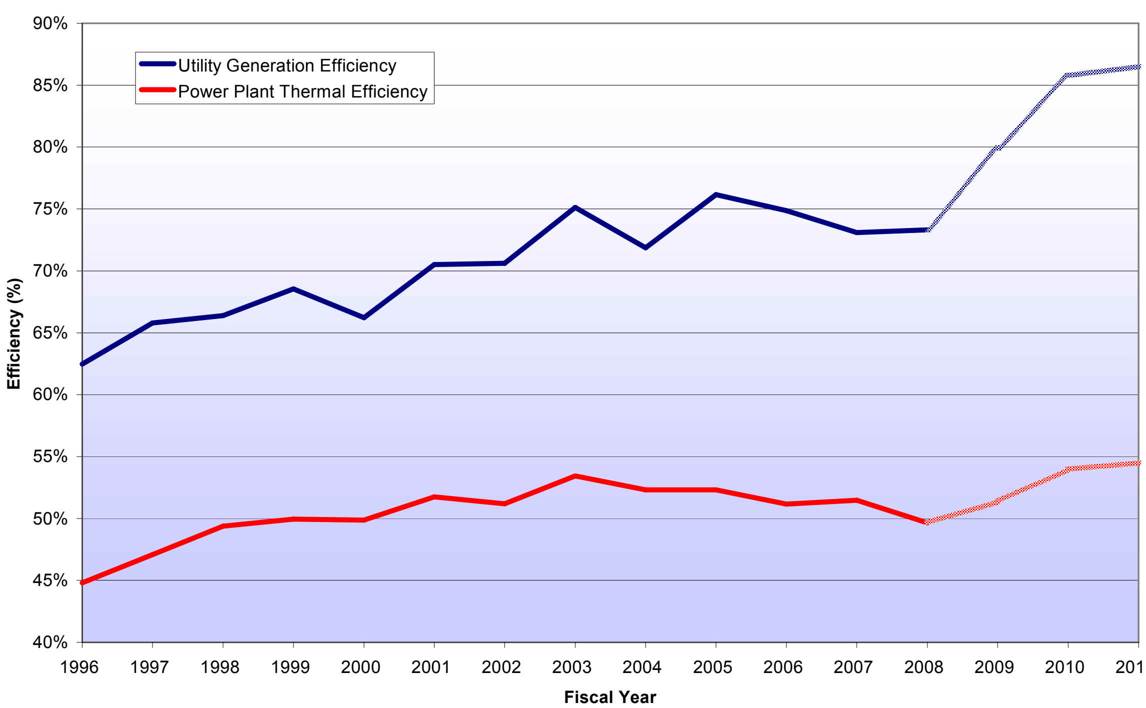
Even with the rising energy requirements over the past thirteen years, total power plant fuel use has remained fairly steady. Natural gas usage since 1996 has varied less than 5% from average, despite the nearly 18% increase in total campus energy demands for electricity, heating, and chilled water. Effectively, the power plant efficiency has grown fast enough to offset the increasing campus demand for energy, allowing the campus to grow with no increase in the rate of fuel consumption.

To better understand the relationship between fuel usage and growth in campus demands, an investigation into the power plant's historical energy generation and distribution was conducted, looking at measurements from September of 1995 (the beginning of fiscal year 1996), through August of 2008 (the end of fiscal year 2008). Future predictions were also included through fiscal year 2011 to illustrate the impact of future power plant expansions and efficiency improvements.

Measuring the efficiency of the campus utilities is most easily represented as the ratio of total energy produced, in this case as electricity, steam and chilled water combined, to the energy purchased in the form of natural gas. This encompasses not only the electrical and steam generation efficiency of the power plant, but also the increases in the efficiency of chill water production by the chilling stations. In 1996, the power plant and chilling stations had an overall efficiency of 62%. By 2008, this efficiency had grown to 73%.

The thermal efficiency of the power plant alone, operating strictly to produce electricity and steam for distribution, grew from 45% in 1996 to 50% in 2008. The savings afforded by this increase, both in fuel costs and environmental impact, have been immense.

Fig. 2 - Power Plant and Utility Efficiencies
Including three-year forecasted



Fuel Costs

Natural gas prices have risen 300% in the past 13 years, from $2.07 per mmBTU in 1996 to $8.20 in 2008, peaking at $10.44 in 2006. Correspondingly, the power plant's yearly expenditure for fuel has increased from $9.1 million to $39 million. While rising fuel prices have been unavoidable, the efficiency gains over the past decade have helped curb the rising fuel expenditures. If the power plant were still operating at its 1996 efficiency, the total fuel usage would have risen along with the electricity demand and campus size. By 2008, the natural gas bill would have totaled over $45 million, a full $6 million higher than the actual fuel cost for that fiscal year. In the thirteen year span from 1996 through 2008, the efficiency improvements have saved a total of nearly $40 million in fuel costs.

CO2 Emissions

The environmental impact of fossil fuels has always been an issue of concern. While natural gas is considered one of the "cleanest" fossil fuels available, it is still a significant source of greenhouse gas emissions, notably carbon dioxide. Carbon dioxide emissions are currently unregulated; however methods exist to calculate the gross CO2 output based on fuel consumption. The Environmental Protection Agency (EPA) released the AP-42, a set of emissions factors relating to a variety of combustion sources. For a natural gas fired turbine, it provides the factor of 110 pounds of CO2 emitted per mmBTU of fuel burned.

Applying this factor against the measured fuel usage over the thirteen years from 1996 through 2008, the University power plant has released an average of 452,000 tons per year, totaling almost 3,250,000 tons. Similarly to fuel usage, the consistent yearly average of CO2 emissions is in spite of rising energy demands and campus size. Without the overall gains in plant efficiency, the fuel use would have risen each year, causing a likewise larger emission of CO2. Comparing the actual CO2 emissions of the power plant to the supposed case with no efficiency gains results in the following chart:

Fig. 3 - Power Plant Annual CO2 Emissions
Including three-year forecast

Over the thirteen year period, efficiency gains have offset the cumulative release of nearly 400,000 tons of CO_2. While the efficiency gains have not caused a physical reduction in CO_2 emissions, they have allowed the campus to continue growing in size and energy consumption without emitting any additional carbon dioxide. Effectively all campus growth from 1996 to 2008 has been carbon neutral.

NOx Emissions

The emissions of nitrous oxides (NOx) are enforced by state and federal regulations, with the University power plant operating in full compliance to these standards. Nevertheless, improvements have been made to greatly reduce the NOx outputs of the less efficient boilers. Flue gas recirculation reduced the boilers' emissions rates from 0.22 pounds NOx per mmBTU fuel, to 0.03 lbs/mmBTU. While this represents an 88% reduction in Nox emissions form the boilers, the primary firing unit is gas turbine-eight which has experienced increased use. Still, total plant NOx emissions were reduced 35% annually by the boiler upgrades.

Benefits of Producing versus Purchasing

Operating a campus based CHP facility provides the University with a reliable, cost effective, and environmentally conscious method for energy generation. The advantages as compared to purchased energy, such as on-grid electricity and natural gas heating, are even more pronounced. Assuming there was no power plant on campus, the electricity required for all buildings and chilling stations would be purchased off the grid, and natural gas would be purchased to operate steam boilers for space and water heating and running the steam driven chillers.

Converting Fuel Purchases into Energy Purchases

Monthly utility records have been recorded since fiscal year 1996, which began in September of 1995, and have continued through today. In 2005 the Historian system was installed, allowing even greater accuracy and resolution in recording energy distribution and measuring the demand requirements of the campus.

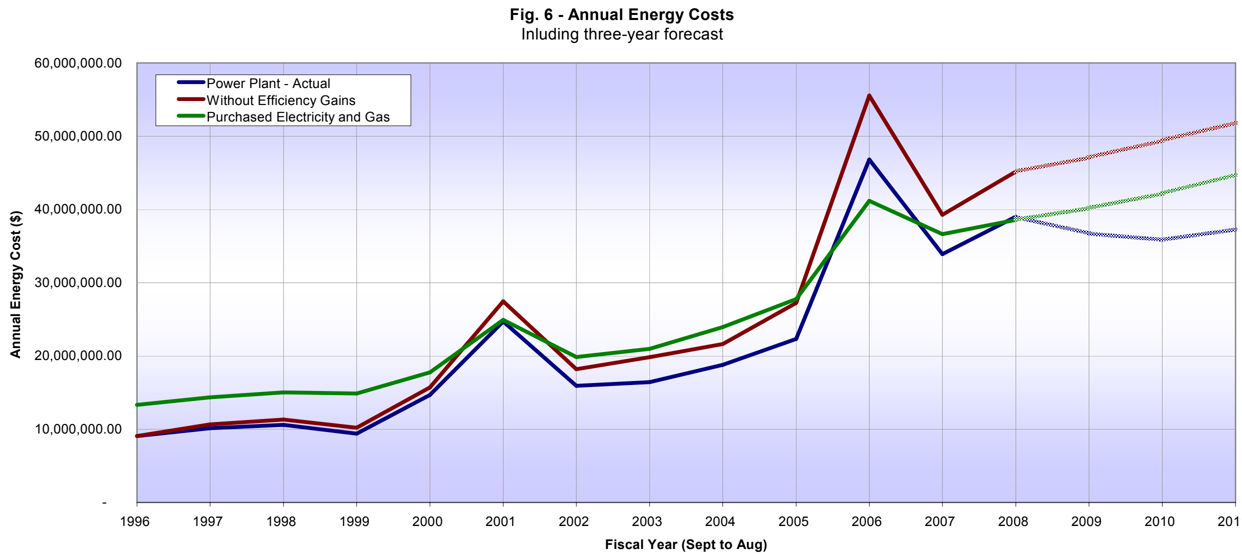
Currently only natural gas is purchased, with the power plant producing electricity that supplies the campus, chilling stations, and the power plant itself. Extraction steam is also distributed to campus for heating needs, and to chilling stations to operate the steam driven chillers. If all energy was purchased, demand for each component would remain the same while the source changed; all electricity would be purchased off of the grid, the chilling stations would still operate to distribute chilled water, and the boilers of the power plant would still use natural gas to generate low-pressure steam.

Total Costs

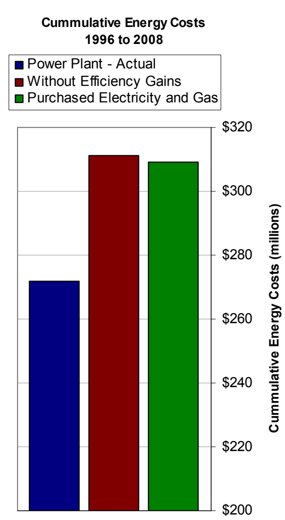
Electricity prices were based off of Department of Energy historic measures[1] of monthly average

[1] http://www.eia.doe.gov/cneaf/electricity/page/at_a_glance/sales_tabs.html

electricity prices in Texas for industrial facilities. Industrial prices reflect "bulk" purchases and match most closely Austin Energy's pricing structure for large state primary services[2]. Figure 6 compares the fuel purchased by the power plant to the total cost of purchased electricity and natural gas.



While both the power plant fuel costs and the price of purchased energy increased over the decade, purchased energy would have cost $2.9 million more on an average year. Bringing in the scenario of operating the power plant without the efficiency gains, the chart below illustrates the total cumulative energy costs over the thirteen year span. When compared to purchasing the energy, the power plant has saved over $37 million.



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[2] http://www.austinenergy.com/About%20Us/Rates/State/stateLargePrimaryService.htm

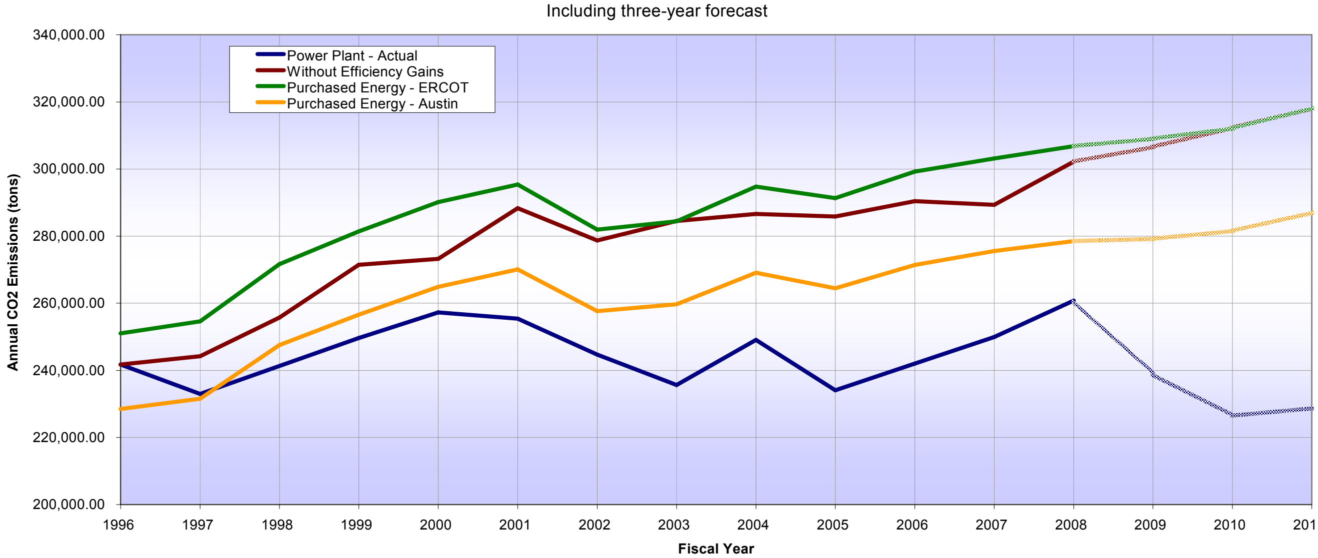
CO2 Emissions

For the University power plant, 100% of the energy generated comes from natural gas. Purchased grid electricity is generated from a mix of coal, natural gas, nuclear, and renewable sources. To evaluate the carbon emissions for grid electricity, a breakup of how much energy was generated by each source is required. For the state wide ERCOT grid and for Austin Energy, the following generated fuel mixes were used as reference.

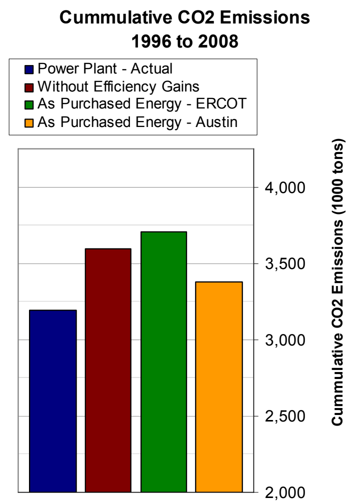
	ERCOT		Austin Energy
	2004	2006	2004
Coal	42.0%	37.4%	39.9%
Natural Gas	38.0%	46.6%	24.7%
Nuclear	18.0%	13.6%	32.3%
Renewable	2.0%	2.4%	3.1%

The fuel mix, combined with the rate of CO2 generated per megawatt-hour for each fuel source, can be used to determine the carbon emissions produced through purchased electricity. The CO2 emitted by natural gas boilers for space and water heating is added in to determine the total CO2 emissions associated with purchased energy. As illustrated below in Figure 7, the annual CO2 emissions due to purchased energy are greater than the actual power plant emissions, and further demonstrate the advantages of plant efficiency gains over the past thirteen years.

Fig. 7 - Annual CO2 Emissions
Including three-year forecast



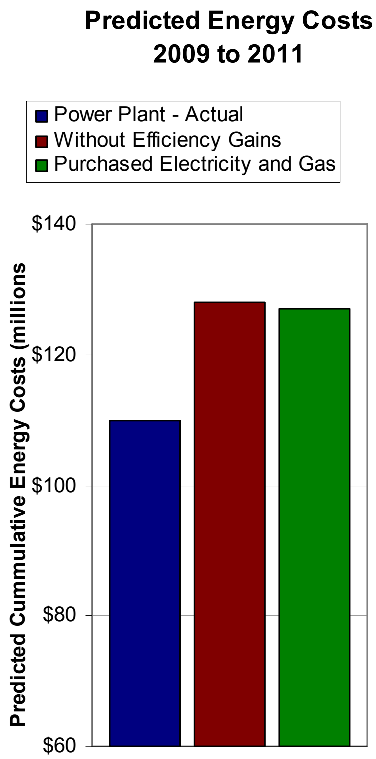
As mentioned before, actual carbon emissions from the University power plant have remained steady over the past thirteen years. In 1996 the carbon emissions that would have been generated by purchasing power were 4% greater than the actual power plant emissions. As campus energy demands grew, so too did the amount of purchased energy required, and by 2008 purchased energy would have released 19% more CO2 than the power plant. Cumulatively, purchasing energy through the ERCOT grid would have produced an additional 511,000 tons of CO2 over the thirteen year span, the same amount absorbed by over 32,000 acres of forest. Even purchasing through Austin Energy, an additional 181,000 tons of CO2 would have been released, or about 11,400 acres of forest.

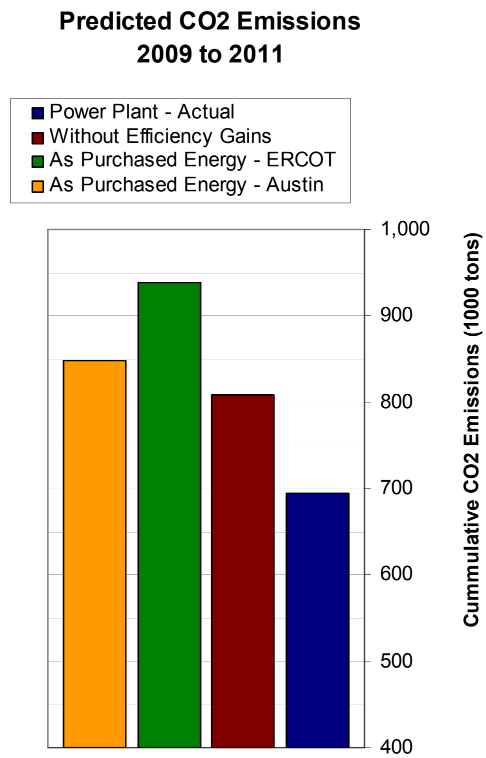


Future Efficiency Gains

Gas turbine-eight came online in 1986 and has been the primary unit ever since. Various improvements and optimizations have been made, many of which are reflected in the efficiency gains documented here, yet there reaches a point where a 20 year old turbine can not compare to newer turbine technology. The older and highly inefficient turbine-six has been removed and underway is the installation of a new primary gas turbine, using turbine-eight as backup when necessary. This new turbine could come online as soon as 2010.

The increased operating efficiency of this new unit will greatly reduce the power plant's fuel requirements. Combined with the completion of Chilling Station Six in 2009, which will increase the efficiency of chilled water production, the natural gas needs of the power plant will decrease even as the campus continues to grow. The yearly fuel costs through 2011 were represented in Figure 6, with the total savings expected over from 2009 to 2011 shown below. In three years, these efficiency improvements will have saved over $18,000,000. Similar savings are present with carbon emissions as projected in Figure 7 and summarized below, where two projects will have reduced carbon emissions over the next three years by 116,000 tons.





The University of Texas power plant has enabled the campus to continue growing while actively reducing the environmental impact due to fuel consumption. As the campus grows, so too will the efficiency of the CHP facility, continuing a trend of low cost, reliable energy generation.