Feature Story

Is Wind Energy Hot Air?

The University of Texas at Austin checks it out

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Combined heat and power is getting more attention than it used to. But it still just doesn't compare to that received by wind energy, which even has T. Boone Pickens rallying support. But what about combining these 'up-and-comers' – CHP and wind energy? What would that do for energy efficiency? The University of Texas asked this very question and conducted a detailed analysis of what purchasing wind energy might mean for its CHP-based Austin campus energy system. The results might surprise you.

Efficiency Always a Priority

The University of Texas (UT) at Austin campus has experienced rapid growth over the past decade, expanding usable square footage at the main campus by 13 percent, which has meant a simultaneous increase in heating and cooling demands. In addition, growing high-technology requirements have raised electrical demands nearly 25 percent. In spite of these mounting demands, the amount of natural gas burned annually by UT's CHP plant has remained constant.

That has been possible because continual efficiency gains at the plant have offset increased demand. Operating a CHP plant that generates electricity, heating and cooling allows for higher efficiencies than could ever be accomplished through purchased grid energy. Dramatic savings – in fuel and operating costs and environmental impact – have been realized by these efficiency gains.

> Continual efficiency gains at the plant have offset increased campus energy demand.

Emissions have always been an area of concern for fossil fuel power plants, most recently with a growing awareness of a facility's carbon footprint. Over the past 10 years, the UT power plant has generated a total 3 million tons of carbon dioxide, averaging about 266,000 tons per year. However, the efficiency gains have conversely prevented the cumulative release of 388,000 tons of carbon dioxide (CO_2) since 1996. The efficiency gains have allowed the campus to continue growing in size and energy consumption without emitting any additional CO_2, effectively classifying all campus growth as carbon-neutral.

As part of its ongoing commitment to higher efficiencies, cost-effective operations and environmental stewardship, UT plans to install a new gas turbine that is scheduled to come online in 2010. This will further reduce the natural gas demands despite campus growth.

Evaluating wind energy's potential to further reduce carbon emissions has also become a priority.

What Does Wind Mean?

Combined heat and power facilities are among the most efficient ways to generate usable energy from fossil fuels. Unfortunately, reliance on natural gas is subject to increasing prices and the continued release of emissions, the downfalls of using any nonrenewable resource. Austin Energy, the community-owned public electric utility, has a growing commitment to renewable resources, with the goal of obtaining 20 percent of electrical capacity from renewable sources by 2020. Through wind energy contracts in West Texas, Austin Energy has been recognized by the U.S. Department of Energy as the leading electric utility in renewable energy sales the past two years.

The University of Texas is in a position to utilize its tie-in with Austin Energy to directly purchase wind energy for use on campus through Austin Energy's GreenChoice® program. (See sidebar.) For example, the university could purchase 5 MW of wind energy, which would continuously offset the UT power plant's electrical generation. On average, this

Austin Energy's GreenChoice® Program

Austin Energy's GreenChoice is the nation's most successful utility-sponsored green energy program. Most of Austin Energy's green power comes from wind turbines in McCamey and Sweetwater, Texas, which have been operating since summer 2001 and December 2005, respectively. More turbines should be online soon. Austin Energy also receives electricity from several solar installations and three landfill gas projects in Austin and San Antonio.

With 753 million kWh in subscriptions, GreenChoice is currently fully subscribed, and Austin Energy is not taking new applications at this time. However, the company plans to make more GreenChoice energy available at long-term fixed rates in January 2009.

When customers subscribe to GreenChoice, Austin Energy contracts for green power to meet their needs. The green power reaches Austin over the statewide transmission system. Once it enters Austin Energy's system, it mixes with power from the generating plants. This means the electricity generated from 'green' sources is not being directed to a specific home or business. Rather, as more customers subscribe to GreenChoice, the proportion of green power in that mix grows larger and larger.

Source: Austin Energy

would mean that 6 percent of the campus's yearly electrical needs would be supplied by wind energy.

The basic assumption is that this 6 percent is clean, renewable, green energy and that, once established, is energy generated without emissions. Disregarding life-cycle costs of the wind turbines, and when fully integrated into a large-enough power grid, this assumption holds true. When evaluated over smaller grids such as the Austin Energy grid, and especially the university grid, there are two drawbacks to this assumption:

- Variations in wind energy generation require the use of low-efficiency 'peaking units' to offset sudden fluctuations.
- The purchased energy would cause the UT CHP plant to operate at times below the designed baseload generation, causing overall plant efficiency to suffer.

These drops in efficiency in no way fully counteract the environmental benefits of wind energy. However, when paying the higher premium for renewable energy, it is important for the university to fully consider the environmental impact of wind energy and not to simply assume it is 100 percent clean energy.

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Offsetting Wind Variations

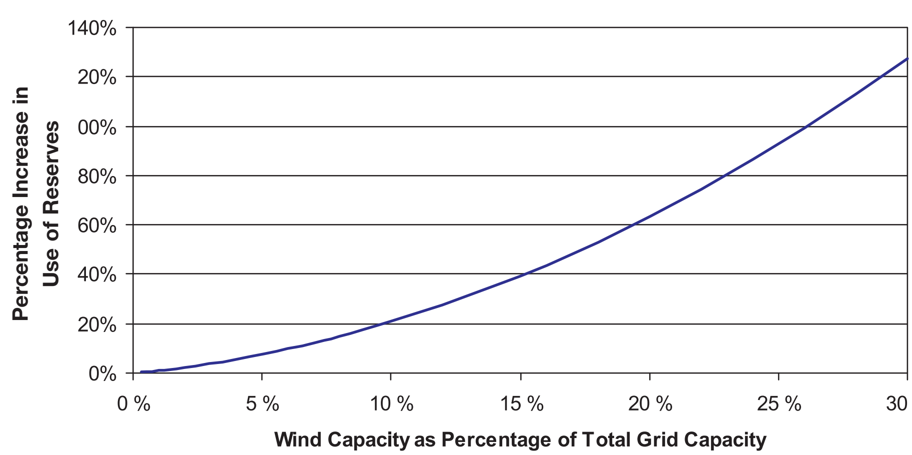
The inherent instability of wind results in rapid fluctuations of power output. Large-scale wind farms are able to predict wind levels a day in advance with up to 94 percent accuracy. The remaining 6 percent represents 'noise' in the energy capability of the wind farm and must be offset by some other energy source in the grid. On a large-enough grid, the distribution of large-scale combined-cycle power plants can handle a majority of these variations. However, in a smaller grid such as that maintained by Austin Energy, these abrupt swings require faster, near-immediate offsets.

If there are sudden drops in wind-generated power, Austin Energy fills in the gap with a variety of reserve sources – ramping up coal and natural gas plants, purchasing electricity off the Texas grid as regulated by the Electric Reliability Council of Texas (ERCOT) and bringing natural-gas peaking units online. Short-term purchases of ERCOT electricity are typically sold at a high premium and avoided if possible. During the summer, the coal and natural gas plants are base-loaded and unable to account for large variations in wind power, leaving peaking units as the most cost-effective option. During the winter, coal plants account for part of the variations in wind.

Each of these options is referred to as electricity 'reserves': power sources that can handle unexpected fluctuations on the grid. As the total capacity of wind energy increases on a grid, so does the utilization of these reserves, both in frequency and duration. Figure 1, derived from a National Renewable Energy Laboratory case study on the grid impact of wind power, demonstrates the increase in reserves usage relative to the increase in total wind capacity on the grid.

Austin Energy utilizes single-cycle aero-derivative gas turbines for peaking units, which can come fully online in 15 minutes. Compared to a combined-cycle unit, these units have a much lower effi-

Figure 1. Grid Capacity Impact on Reserves.



Source: National Renewable Energy Laboratory case study (www.nrel.gov/docs/fy03osti/34318.pdf).

ciency. While the electrical efficiency of the UT power plant is 56 percent, each of these units has an efficiency of 37 percent. This decreased efficiency results in a corresponding increase in CO_2 emissions per megawatt-hour when the single-cycle turbines are in operation.

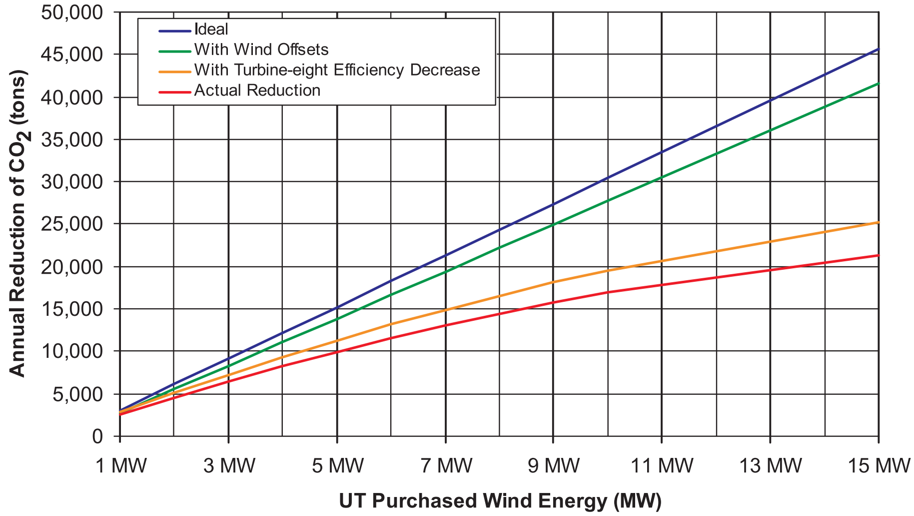
Increasing the capacity of wind energy on the Austin Energy grid causes increased usage of these less-efficient peaking units. In other words, as more wind energy is generated, there is a drop in the overall efficiency of fossil fuel-based energy on the grid, resulting in greater carbon emissions per unit of energy from the nonrenewable sources. Based on the studies performed by the National Renewable Energy Laboratory and combined with Austin Energy's current usage of peaking units, the increase in carbon emissions can be estimated.

For purchased wind energy from Austin Energy, with a 20 percent capacity of wind energy, each megawatt-hour of electricity would increase the emission from the fossil fuel sources by 60 lb of CO_2 . While this CO_2 emissions rate is lower than the current UT plant emissions of 694 lb/MWh, it is also not zero. Instead of the purchased wind energy being 100 percent carbon-free, the reserve offsets result in 91 percent carbon-free energy.

Impact on University Plant Load and Efficiency

The UT power plant is currently set up to operate primarily with gas turbine No. Eight, the plant's largest and most efficient unit, in combined cycle with extraction-type steam turbines operating at levels that accommodate necessary campus steam needs. The plant arrangement is so well-paired with typical campus load that any purchased electricity would reduce the load on this gas turbine. For example, purchasing a constant 5 MW of wind energy would typically reduce the load on the gas turbine by up to 5 MW. Gas turbines are most efficient at baseload conditions, and this offset would result in reduced efficiency of turbine No. Eight. The relation between load and efficiency is documented as a curve of correction factors; for this gas turbine, operating at 5 MW below baseload reduces efficiency by 3 percent. In effect, any wind energy purchased by the university will increase the turbine's rate of CO_2 emission per unit energy by 3 percent. This is in addition to the increase in carbon emissions due to Austin Energy's peaking units.

Figure 2. Carbon Dioxide Reduction Through University of Texas Wind Purchases.



Source: "Study in the Benefits of Efficiency Improvements to Emissions and Fuel Costs," Ryan Reid, et al.

Figure 2 illustrates this principle, pairing the reduction of gas turbine No. Eight efficiency with the wind offsets, described previously, to show the actual reduction in CO_2 emissions given a constant purchased supply of wind energy.

This figure shows the ideal situation, in which the wind energy is considered 100 percent carbon-free, and purchased energy has no negative effect on plant efficiency. This is the best possible scenario, in which purchased wind energy results in the maximum reduction in carbon emissions. Moving down the chart, losses are included such as the CO_2 emitted through wind offsets and the decrease in UT plant efficiency. The lowest line represents an estimation of the actual carbon reductions, where all losses are included.

For purchasing a constant 5 MW of wind energy, the ideal annual reduction would be 15,204 tons, or a roughly 6 percent reduction in total carbon emissions. Considering all losses, the reduction would be 9,971 tons, or about a 4 percent reduction. This puts the CO_2 generation rate caused by wind at 243 lb/MWh, equating to wind energy for the UT campus being only 65 percent carbon-free, rather than 100 percent.

Wind Energy Costs

For bulk commercial subscription to Austin Energy's GreenChoice program, cost is a combination of energy usage, peak demand requirements and a 'green power charge' that replaces the usual fuel charge. The most recent allotment, or 'batch,' of wind energy made available to customers began selling in January 2008 and would have added a $0.055/kWh green power charge to their average $0.020/kWh electricity rate, for a total $0.075/kWh plus the monthly demand charge of $12.61/kW at peak usage. (Wind energy has gotten more expensive over time. Austin Energy's GreenChoice green power charge has risen steadily in price from $0.0170/kWh in October of 2000 for large commercial customers in Batch 1 to the most recent Batch 5 charge of $0.055/kWh mentioned above.)

Under this pricing structure, it is most cost-effective to purchase a constant block of energy, such as the 5 MW mentioned above. However, to minimize taking the turbine off of baseload and to maximize the UT plant efficiency, a scenario is required in which energy is only purchased when demand exceeds the baseload of turbine No. Eight. This would reduce the inefficiencies associated with bringing wind energy onto the UT grid and make maximum use of the carbon reductions associated with wind energy. For this, a real-time model of the utility system developed in-house with LightRidge Resources was utilized.

Both the constant and variable scenarios were run through the model for a five-month summer period of heaviest load. For purchasing the constant 5 MW, the model predicted purchasing 13,654,000 kWh of wind energy at a cost of $1,340,000 ($0.098/kWh). This reduced the natural gas bill by $937,600 for the 117,200 MMBtu saved through the reduced load on the plant. The added cost for wind energy is the difference: $402,400 for a five-month period of purchased wind energy, ultimately offsetting the release of 6,857 tons of CO_2, a price of $59/ton. In this scenario, the purchase of nearly 2,000 kWh of wind is required to reduce carbon emissions by 1 ton.

When purchasing varying amounts of energy in a way that maximizes efficiency, the model predicts 2,390,000 kWh of wind energy purchased at a cost of $495,000 ($0.207/kWh). The natural gas bill was reduced by $202,320 for the 25,290 MMBtu reduction, putting the added cost of utilizing wind energy at $292,000 to reduce carbon emissions by 1,463 tons – a cost of $200 per ton. The greater efficiency achieved in this scenario results in 1,600 kWh of wind energy required to offset 1 ton of carbon.

A tradeoff exists between these two scenarios: The constant 5 MW results in a lower price for 1 ton of carbon reduction, but requires purchasing more wind energy to achieve that reduction. The variable energy purchasing has a higher cost per ton, but sees greater carbon reductions for the wind energy purchased (1,600 kWh/ton versus 2,000 kWh/ton).

With the goal of reducing carbon emissions, the constant 5 MW is more economically viable. However, as a comparison, current post-combustion CO_2-capturing methods have an operating cost of $57/ton of CO_2 removed, as determined through the International Energy Agency Greenhouse Gas R&D Programme (www.ieagreen.org.uk/glossies/co2capture.pdf). The Chicago Climate Exchange currently trades at $3.65/ton of CO_2. When compared to the efficiency gains and CO_2 reductions of installing an updated gas turbine, purchasing wind power is a much less cost-effective alternative.

Future Efficiency Gains

Gas turbine No. Eight came online in 1986 and has been the primary unit ever since. Current plans are to install a new primary gas turbine, using gas turbine No. Eight for peak loads as necessary. This new turbine could come online as soon as 2010.

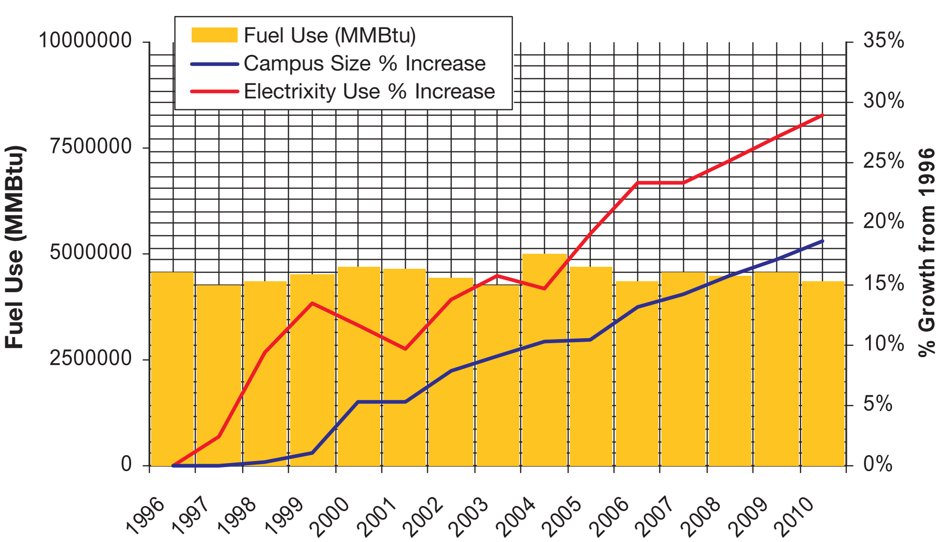
The increased operating efficiency of this new unit will greatly reduce the power plant's fuel requirements. Model predictions show that for fiscal year 2006, during which 4,401,000 MMBtu of fuel was purchased, operating the new turbine could have reduced total fuel consumption to 4,155,000 MMBtu – a $2 million savings in fuel costs and a 5.6 percent reduction in carbon emissions. Modeling the effects of bringing in the constant 5 MW of wind power, the carbon emissions would have been reduced by 11.6 percent; however the sum of the fuel and imported electricity costs would have actually risen by $331,000.

While purchased wind power may reduce carbon emissions by a greater amount, the new turbine allows for both a reduction in CO_2 and significant reductions in operating costs. These savings result in money that will be available for continued improvements in CHP efficiency and to allow UT to fund academics and research instead of the fuel bill. The new turbine will also provide capacity to handle future campus growth (fig. 3).

Although UT remains interested in the promising wind energy industry, detailed analyses of the costs and impacts of integrating wind energy purchases with current plant operations show that adopting the technology would have a negative effect on UT plant efficiencies and an increase in operating costs.

Because the department provides 100 percent of the campus energy with an optimized baseloaded system, importing wind power would cost the plant more than just the premium rate of wind energy overall. Through the new gas turbine and other planned projects, plant efficiency will continue to increase as the campus continues to grow – maintaining UT's tradition of low-cost, reliable energy generation. Meanwhile, the University of Texas will continue to look for ways to integrate renewable energy resources for the main campus in ways that take the greatest advantage of what they offer, while doing what is best for future campus growth. Renewable resources will also be considered for noncontiguous portions of the campus not served by the university CHP system.

Figure 3. University of Texas at Austin: Campus Size, Electricity Demand and Fuel Usage, 1996-2010.



Source: "Study in the Benefits of Efficiency Improvements to Emissions and Fuel Costs," Ryan Reid, et al.

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