Energy Equipment Choices: Fuel Costs and Other Determinants

By J. Alan Beamon and Steven H. Wade*

Fuel costs are only one of several criteria that shape energy equipment purchase decisions. In the residential sector, consumers may consider a wide range of factors in addition to purchase costs—including expected utilization rates, equipment purchase incentives or rebates, the rate at which future energy savings are discounted, and relative utility rates—when making space conditioning equipment choices.

Decision makers in the electricity generating sector must likewise weigh non-cost factors that influence generating technology choices. An analysis based on projected fuel prices and demand shows that the total levelized costs of coal-fired and natural gas-fired combined-cycle generating plants are affected differently by key assumptions. The coal-fired plants' costs are more heavily affected by factors influencing per-unit capital costs, while the natural gas-fired plants' costs are driven primarily by operating cost factors.

In both sectors, fuel prices are only one of a number of determinants of the capital equipment decisions. All factors must be carefully considered in order to make the optimal (lowest life-cycle) choice.

Current and expected fuel costs are important criteria in the selection of energy equipment, but other factors also play critical roles. These factors include interest rates, prices of alternate fuels, consumer preferences, and equipment capital costs, operating costs, and operational efficiency. This article uses sensitivity analysis of examples from the residential end-use and electricity generating sectors to show how non-cost factors can overrule fuel-cost advantages in technology selection.

Residential Equipment Choices

Cost is probably the most widely considered determinant in consumers' decisions about the purchase of durable goods, but others (such as features, convenience, and style) may be more important. For space conditioning (i.e., heating and air-conditioning) equipment purchases, the main non-cost factors are most likely fuel preference and natural gas availability. The following discussion compares the importance, over the life of the equipment, of purchase and installation costs with fuel and maintenance costs.

Some of the considerations involved in selecting a space conditioning system include:

- Fuel availability
- Selecting agent (resident owner, landlord, or builder)
- Preferences for higher temperatures of warmed air
- Relative installed costs of different options
- The discount rate or payback period
- Prices of alternate fuels, both present and projected
- Utility incentive programs
- Factors influencing usage intensity, such as home size, climate, temperature settings, and occupancy patterns
- Other preferences, such as for a single-fueled home or for certain safety features.

While all these considerations may figure in consumers' investment decisions, we employ only a subset with direct cost consequences to illustrate their relative importance in determining the ultimate costs to consumers.** Below we compare two popular options for providing heating and air conditioning services to a household: 1) a system employing a natural gas-fired furnace and an electric air conditioner (hereafter called the gas/electric, or G/E, system) and 2) an all-electric (AE) system using a conventional heat pump.

We estimate the costs for these two systems for the period from 1990 through 2010 for each of the nine U.S. Census

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**This is not meant as a practical guide to choosing space conditioning systems. Readers seeking such guidance are invited to consult the Energy Information Administration's *Reducing Home Heating and Cooling Costs*, SR/EMEU/94-01 (Washington, DC, July 1994).

divisions.* Future costs are discounted** and expressed in present dollars. Because different consumers may have widely varying implicit (observed) discount rates and because of the sensitivity of comparisons to variance in discount rates, we employ a range of discount rates in the examples for each option. When costs are discounted over the life of an investment, the discounted total is often referred to as the life-cycle cost of the investment. Because the 1990-through-2010 period approximates the average life of a gas heating system, we refer to the cost comparisons as life-cycle cost comparisons. Both the heat pump and the air conditioner component of the G/E system are assumed to require replacement before the end of the period.

Our sensitivity-case calculations begin with the equipment cost and performance data, including installation and maintenance costs, equipment lives, and energy efficiency ratings (Table 1). The calculations also incorporate life-cycle cost estimates (Table 2), derived from the following:

- Price data and projections for electricity and gas for each of the nine U.S. Census divisions from 1990 through 2010, taken from the *Annual Energy Outlook 1996* (*AEO96)* reference case

*This article presents the summary results of the life-cycle cost calculations. Detailed tables of the results for all Census divisions, the five sensitivity cases, and the four discount rates, as well as a map of the Census divisions, are available from the authors.

**Discounting embodies the assumption of conventional economic theory that a cost or benefit is worth less in the future than in the present. The application of discount rates reflects both the fact that current assets can be invested to yield potentially greater future assets as well as the fact that the unpredictability of the future makes the value of future assets uncertain to the consumer. The present value of a cost C in year t with discount rate I is $PV = C/(1 + I)^t$. The sum of the present values for all costs incurred over the life of an investment is the total present value cost or life-cycle cost.

Table 1. Residential Space Conditioning Technology Characteristics

Characteristic	G/E System: Gas Furnace	G/E System: Central A/C	G/E System: Total	AE System
Installed Costs	$1,428	$2,222	$3,650	$3,015
Annual Maintenance Costs	—	—	$102	$102
Average Equipment Life (years)	20	13	—	12
Equipment Efficiencies:				
AFUE	80%	—	—	—
SEER	—	10.50	—	10.50
HSPF	—	—	—	6.80

— = Not applicable

Notes: • Costs are in 1994 dollars. • The G/E system consists of a natural gas-fired furnace and an electric central air conditioner. The AE system (all-electric) is a heat pump. • AFUE is the annual fuel utilization efficiency for gas furnaces. SEER is the seasonal energy efficiency ratio for the cooling efficiency of air conditioners and heat pumps. HSPF is the heating season performance factor for the heating efficiency of heat pumps.

Source: Calculated from data in Arthur D. Little, *EIA Technology Forecast Updates*, Reference Number 41615, June 1995, pp. 16, 20, and 22.

Table 2. Projected Electricity and Gas Prices to Residential Consumers, 1995-2015
(1994 dollars per million Btu)

	1995	2000	2005	2010	2015
Electricity	24.74	24.49	24.62	24.63	24.72
Natural Gas	5.95	6.08	5.96	5.89	6.39

Source: Energy Information Administration, *Annual Energy Outlook 1996*, DOE/EIA-0383(96), p. 78.

- A discount rate ranging from 5 to 50 percent***
- Data on average energy consumption for both systems by Census division[1]
- Weather and climate data[2] expressed as heating degree-days (HDD) and cooling degree-days (CDD).

We developed the average requirements for heating and cooling energy output by Census division from estimates of energy consumption for single-family homes derived from the Energy Information Administration's 1993 Residential Energy Consumption Survey. We used data about actual weather conditions to adjust the 1993 average consumption estimates for 1990, 1991, 1992, and 1994. For 1996 through 2010, we used 30-year-average weather data. Finally, for 1995, we combined a partial year of actual weather data with long-term average data for estimated 1995 HDD and CDD.

Sensitivity Cases. The installed cost of the G/E system is more than $600 higher than that of the A/E system (Table 1). However, the G/E system saves $100 to $400 in fuel costs annually, depending upon Census division. The calculation of life-cycle costs gives weight to both the initial installation savings of the AE system and the future energy cost savings for the G/E system. The importance of the lower energy costs to the equipment decision varies with the discount rate; lower rates place a relatively higher weight on the future energy costs. In our examples, the life-cycle costs for the G/E system are lower than those of the AE system at the lowest discount rates. However, even at very low discount rates, for households with below average heating loads (for example, loads in very small dwelling units) the resulting reduced stream of energy cost savings for natural gas systems is sometimes insufficient to offset the higher installed costs.

We calculated life-cycle costs at discount rates of 5, 20, 35, and 50 percent for each Census division and for the following five sensitivity cases:

- *AEO96 price case*—serves as a baseline; uses the *AEO96* price forecasts for the residential sector for electricity and natural gas.

***Although implicit discount rates of 35 and 50 percent may seem unrealistically high, studies of consumer behavior have reported even higher rates. A study reporting discount rates for residential air conditioning system purchases as high as 77 percent is Train, Kenneth E. and Atherton, T., "Rebates, loans and customer's choice of appliance efficiency level: combining stated and revealed preference data," *The Energy Journal*, 16(1), 1995, pp. 55-69.

- *National average price case*—replaces Census division average prices with national average prices to isolate the effects of regional price differences on the cost calculations.

- *Declining electricity price case*—combines the *AEO96* natural gas price forecast with electricity prices declining at 2 percent per year to illustrate the sensitivity to an alternate price path.

- *Low utilization case*—assumes heating and cooling requirements one-third lower than average.

- *AE rebate case*—uses *AEO96* prices and assumes a one-time rebate for the AE system of $500.

Results. Among the salient observations that can be made are the following:

- At the 5 percent discount rate, the G/E system has lower life-cycle costs in all Census divisions for all five of the sensitivity cases (Figure 1).

- The G/E system also has lower life-cycle costs at the 20 percent discount rate for both the *AEO96* case and declining electricity price case.

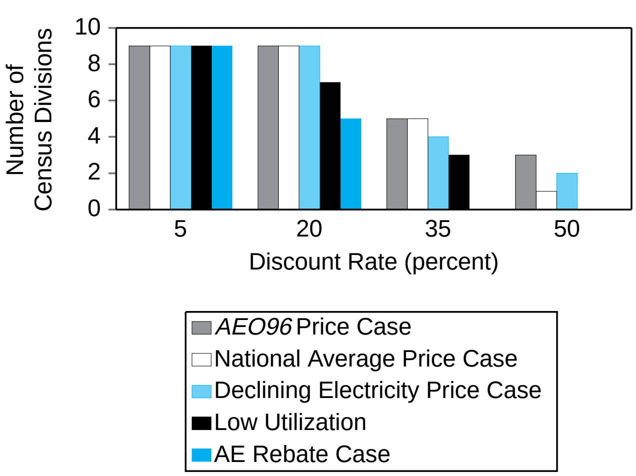
- In the AE rebate case, the number of Census divisions with lower G/E system costs drops to five.

- For the low utilization case, the AE system's life-cycle costs are lower in two Census divisions.

- At higher discount rates, AE system costs are lower for as few as four to as many as nine Census divisions.

At higher discount rates, then, installed costs become relatively more important than fuel costs, thus favoring the AE system in more cases. At lower discount rates, the annual fuel savings of the G/E system are relatively important and tend to offset the higher installed costs.

Figure 1. Life-Cycle Cost Advantage of a Gas/Electric Space-Conditioning System (Number of Census Divisions)



Source: Projection by Energy Information Administration, Office of Integrated Analysis and Forecasting.

It is noteworthy that life-cycle costs are relatively insensitive to declining electricity prices. Regardless of the discount rate, in only one Census division did the AE system yield lower projected life-cycle costs compared with the *AEO96* price case. This result occurred with both the 35-percent and 50-percent discount rates. We conclude that the initial difference in natural gas and electricity prices (electricity prices are four times higher per Btu than natural gas prices) outweighs, in most cases, an electricity price decline of 2 percent per year.

A second result is that the effects of electric utility incentives can be critical to the life-cycle cost calculation because a rebate occurs early in the cycle, when the present-value impact is the greatest. With a $500 rebate, at the two highest discount rates used, the life-cycle costs of the AE system are lower than the G/E system in all Census divisions. At the 5 percent discount rate, there is no change; the G/E system's life-cycle costs are still lower. At the 20 percent discount rate, AE system costs drop below G/E system costs in four Census divisions.

The sensitivity cases illustrate two ways in which utilization rates can also be important influences on life-cycle costs. First, heating and cooling energy requirements vary considerably across climate zones. In the *AEO96* price case, for example, at higher discount rates the AE system tended to gain a cost advantage in the more moderate climates, where utilization for space heating is lower. Second, factors other than climate may also lead to below-average utilization, including less conditioned floor space per housing unit, occupant preferences for more conservative thermostat settings, and seasonal occupation of units. Relative to the *AEO96* case (which assumed average utilization), the low utilization case significantly increased the likelihood that the AE system would yield lower life-cycle costs than the G/E system at all discount rates except 5 percent. Utilization rates can thus influence equipment choices even when climate and equipment availability are similar.

Finally, as mentioned above, at the 5 percent discount rate the G/E system was least costly in all sensitivity cases. This demonstrates the strong effect of the stream of future cost savings when discount rates are low.

Electricity Sector Equipment Choices

As in the residential sector, decision makers in the electric power generation sector consider many factors when reviewing generating technology options. Because the industry has been heavily regulated and prices are based on all of the expenses incurred to serve customers, all costs are reviewed very carefully. Among the key factors shaping capacity planning decisions are:

- Generating technology characteristics, including engineering efficiency, capital costs, operations and maintenance (O&M) costs, and emissions

- Fuel prices

- Interest rates (cost of capital)

- The demand for electricity

- The existing mix of capacity.

Utilities assess these factors and then attempt to build (or purchase) the mix of generating capacity that minimizes the total system costs of meeting the demand for electricity throughout the life of the generating technology assets.

As in the residential sector, the technology with the lowest fuel costs is not necessarily the most economical over the long run. For example, a typical pulverized coal-fired plant is much more expensive to build and less efficient in operation than a natural gas-fired combined-cycle plant (Table 3). However, the coal-fired plant has much lower fuel costs. When comparing these two technologies, an electricity producer weighs the lower initial costs and higher engineering efficiency of the natural gas-fired combined-cycle plant against the lower fuel costs of the coal-fired plant to determine which technology is most economical for its system. Both current and future costs are considered.

Sensitivity Cases. Such comparisons are very sensitive to the input assumptions, especially those concerning utilization, fuel prices, and construction costs. We ran the following cases to illustrate these sensitivities:

- *AEO96 price case*—uses the *AEO96* electricity-sector price forecasts for coal and natural gas in each of 13 electricity supply regions and subregions defined by the North American Electric Reliability Council.*

- *2000(60/100) price case*—compares coal- and natural gas-fired plants coming on line in 2000 and operating at 60- and 100-percent capacity factors** in Florida (Region 8***).

*For a regional map, see Energy Information Administration, *Supplement to the Annual Energy Outlook 1995*, DOE/EIA-0554(95) (Washington, DC, February 1995), p. 270.

**A 100-percent capacity factor is used purely for illustration. Because of required maintenance, no plant can operate at a 100-percent capacity factor for very long.

***Region 8 (Florida) is used for illustration because it represents a single State. The results of the comparisons would change only slightly if a different region were used.

Table 3. Electricity Generating Technology Characteristics

	Generating Technology	
Characteristic	Pulverized Coal	Natural Gas-Fired Combined Cycle
Construction Costs (1994 $/kW)	1,501	419
Fixed O&M[a] (1994 $/kW)	52	26
Variable O&M (1994 Mills/kWh)	2.4	0.5
Heat Rate, 1996 (Btu/Wh)	9,961	7,300
Heat Rate, 2005[b] (Btu/Wh)	8,142	5,687
Efficiency, 1996 (percent)	34	47
Efficiency, 2005[b] (percent)	42	60

[a]O&M = operations and maintenance.
[b]Projection.
Note: Characteristics are based on a 500-megawatt coal-fired plant and a 225-megawatt natural gas-fired plant, both single-unit facilities.
Source: Energy Information Administration, based on reports from the Electric Power Research Institute, the Gas Research Institute, and trade journals, adjusted for current market conditions.

- *AEO96(+20) price case*—compares coal- and natural gas-fired plants coming on line in 2000 in Florida with 20-percent higher fuel prices than in *AEO96*.

- AEO96(-20) price case—compares coal- and natural gas-fired plants coming on line in 2000 in Florida with 20-percent lower fuel prices than in *AEO96*.

- *2010(60/100) price case*—compares coal- and natural gas-fired plants coming on line in 2010 and operating at 60- and 100-percent capacity factors in Florida.

Key results. Using *AEO96* fuel prices (Table 4) and electricity demand, we compared the levelized cost projections for 2000 of a pulverized coal-fired plant with those of a natural gas-fired combined-cycle plant, both operating at a 60 percent capacity factor (Figure 2).**** In this scenario, natural gas-fired combined-cycle plants are the clear choice in all 13 regions of the model. Although the fuel costs of the combined-cycle plants are higher than those of the coal-fired plants, the much lower capital costs for the combined-cycle plants result in lower total levelized

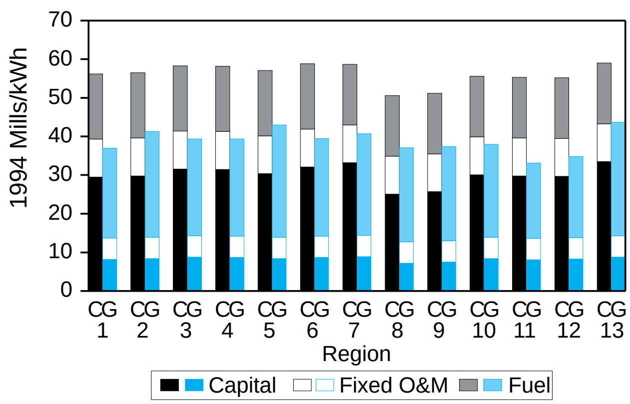
****Much like the life-cycle costs for residential space conditioning equipment described earlier, levelized costs represent the average per-unit (kilowatthour) costs of producing power from a plant over its entire lifetime. The levelized-cost calculations assume a 30-year economic life for each plant.

Table 4. Projected Steam-Coal and Natural-Gas Prices to Electric Utilities, 1995-2015
(1994 Dollars per Million Btu)

	1995	2000	2005	2010	2015
Steam Coal	1.32	1.26	1.28	1.26	1.28
Natural Gas	2.04	2.19	2.26	2.44	2.95

Source: Energy Information Administration, *Annual Energy Outlook 1996*, DOE/EIA-0383(96), Table A3, pp. 78 and 79.

Figure 2. Year 2000 Levelized Costs for Coal-Fired and Natural Gas-Fired Combined-Cycle Plants at 60 Percent Capacity Factor
(1994 Mills per Kilowatthour)



Note: C = coal-fired; G = natural gas combined-cycle.
Source: Projection by Energy Information Administration, Office of Integrated Analysis and Forecasting, using the National Energy Modeling System, run AEO96B.D101995c.

costs. In fact, in every region the difference is more than 12 mills (1.2 cents) per kilowatthour, or 21 to 43 percent. The results of this analysis were borne out in the *AEO96* electricity capacity expansion projections. In general, natural gas-fired technologies (both combined-cycle and simple combustion turbines) proved to be the most economical plants to add, especially in the near term, because of their high efficiencies and low relative initial costs and emissions.

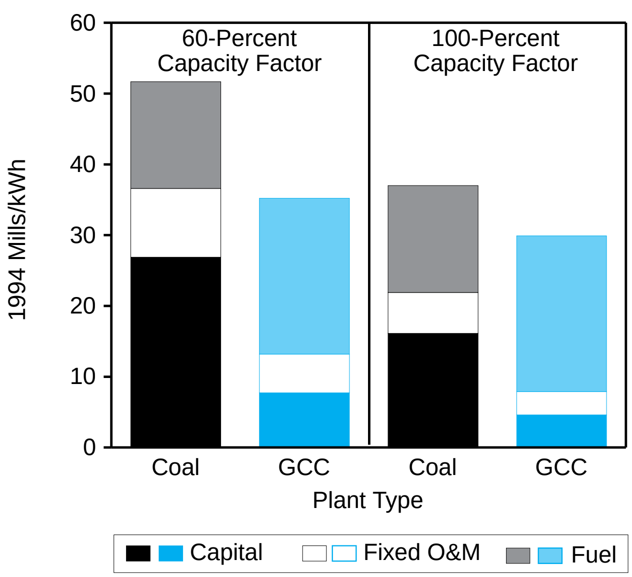
However, coal- and natural gas-fired plants are not equally affected by the fuel-price and utilization assumptions. The levelized costs of coal-fired plants are dominated by the capital component (Figure 2), while the levelized costs of natural gas-fired combined-cycle plants are dominated by the fuel component. This fuel component includes variable operations and maintenance (O&M) costs, which typically amount to less than 10 percent of fuel costs. In Region 8 (Florida), the coal-fired plant's levelized costs break down as follows: 52 percent capital, 29 percent fuel, and 19 percent fixed O&M costs. In contrast, the natural gas-fired combined-cycle plant's cost components are 22 percent capital, 63 percent fuel, and 16 percent fixed O&M. Factors affecting capital costs are thus central to the economics of coal-fired plants, while assumptions about fuel costs and engineering efficiency are critical in assessing the viability of natural gas-fired plants.

Utilization rates strongly affect the per-kilowatthour capital costs of generating power. In general, as a plant is used more intensively (i.e., as its capacity factor rises), its per-kilowatthour capital costs decline. A comparison (Figure 3) of the levelized costs at 60- and 100-percent capacity factors of coal-fired and natural gas-fired combined-cycle plants coming on line in 2000 in Florida reveals that levelized costs for both types of plants decline at the higher utilization rate. However, the coal plant's costs are affected much more dramatically, declining 28 percent when the utilization rate rises to 100 percent. The natural-gas plant's average levelized costs fall only 15 percent.

Like utilization rates, fuel-price variability affects the two technologies differently. We calculated the levelized costs for Florida coal-fired and natural gas-fired combined-cycle plants coming on line in 2000 and operating at a 60 percent capacity for three fuel-price cases (Figure 4). The first case assumes *AEO96* fuel prices, the second assumes fuel prices 20 percent lower than those projected in *AEO96*, and the third case assumes prices 20 percent higher. (Similar results would obtain if 20 percent higher and lower operating efficiencies, respectively, were assumed.) The coal plant's total levelized costs vary by only 6 percent in response to the 20 percent swings in fuel prices, while the natural gas plant's costs vary by 13 percent. The gap between the coal-fired and natural gas-fired plants' levelized costs narrows with higher fuel prices, but the coal-fired plant remains 38 percent more expensive.

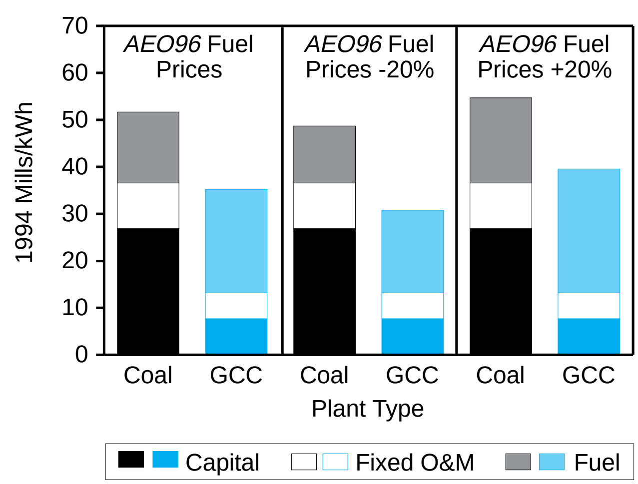
The cases discussed thus far show natural gas-fired combined-cycle plants as the more economical choice. However, the *AEO96* projects increases in natural gas prices of 11 percent between 2000 and 2010, while coal prices increase only 1 percent.[3] The disparity in the fuel-price increases narrows the gap between the total levelized costs in 2010 of a coal-fired plant and a natural gas-fired combined-cycle plant. In fact, the gap disappears entirely in Florida (Region 8) at the 100-percent capacity factor (Figure 5). Nationwide, the coal-fired plant coming on line in 2010 and operated at a 100-percent capacity factor is slightly more economical in three of the 13 regions.

Figure 3. Year 2000 Levelized Costs for Electric Power Plants in Florida at 60-Percent and 100-Percent Capacity Factors
(1994 Mills per Kilowatthour)



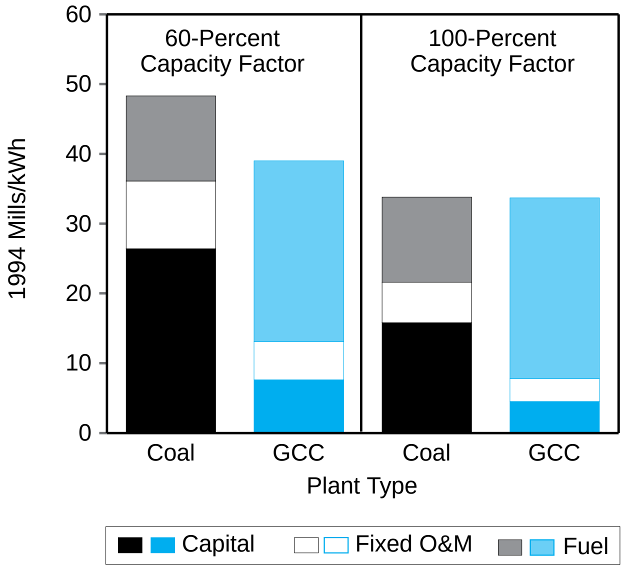
Note: GCC = natural-gas combined-cycle.
Source: Projection by Energy Information Administration, Office of Integrated Analysis and Forecasting.

Figure 4. Year 2000 Levelized Costs for Electric Power Plants In Florida Under Three Price Scenarios
(1984 Mills per Kilowatthour)



Note: GCC = natural-gas combined-cycle.
Source: Projection by Energy Information Administration, Office of Integrated Analysis and Forecasting.

Figure 5. Year 2010 Levelized Costs for Electric Power Plants in Florida at 60-Percent and 100-Percent Capacity Factors
(1994 Mills per Kilowatthour)



Note: GCC = natural-gas combined-cycle.
Source: Projection by Energy Information Administration, Office of Integrated Analysis and Forecasting.

Conclusion

Consumers of energy equipment, whether in the residential sector or the electricity generation sector, need information to make their purchase decisions. Unfortunately, much of the available information is conflicting. While some analysts say that natural gas is less expensive than electricity on a Btu basis, others say that electricity prices are less volatile, and still others argue that coal is less expensive than natural gas or oil; and so on, *ad infinitum*.

As confusing as that situation may be, however, reality is even more complex. Equipment buyers, as well as policy makers, need to consider a wide range of factors in addition to prices in making purchase decisions. Consideration of multiple factors necessarily adds to the complexity of decision-making, but—as this article has tried to illustrate—a careful study of the inevitable tradeoffs involved can improve the quality of the final decision.

Source Notes

1. Energy Information Administration, *Household Energy Consumption and Expenditures 1993*, DOE/EIA-0321(93) (Washington, DC, October 1995.)
2. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Historical Climatology Series 5-2,* September 1995.
3. Energy Information Administration, *Annual Energy Outlook 1996*, DOE/EIA-0383(96) (Washington, DC, January 1996), pp. 78 and 79.