# Dispatch from the Gas War Front: Issues in Calculating Fuel-Switching Cost-Effectiveness

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Many cost-effectiveness evaluations of electric/gas fuel-switching oversimplify the analysis: by comparing only the direct cost of end-use equipment, by calculating supply cost impacts using simplified estimates of marginal costs, and by not considering the full range of investment options available to customers making fuel choice decisions. This paper uses a case study of the residential water heating market to illustrate the effect these issues can have on fuel-switching cost effectiveness.

## Introduction

This paper analyzes fuel-switching in the residential water heating market under a number of different scenarios. We first develop a “base case” scenario, using only very simple characterizations of equipment costs and utility marginal costs. We then address a number of additional issues that need to be considered in a thorough evaluation. These include:

- Appropriate characterization of utility marginal costs;
- Appropriate consideration of utility customer-related costs (e.g., meter charges);
- Full consideration of participant costs (e.g., auxiliary equipment); and
- Consideration of the full range of options available to customers making fuel choice decisions.

This paper is not presented to advocate the use of one fuel over another. Since fuel-switching cost-effectiveness depends on the equipment cost, equipment performance, and fuel costs specific to individual utilities, such a blanket classification is neither possible nor necessary. Instead, our goal is to identify the key issues that should be addressed in a thorough and fair evaluation. The data presented for the residential water heating market is provided merely to illustrate the effects of these key issues. While reasonable, the data does not represent exact conditions in any service territory.

## Scenario 1: Base Case

The most simple cost-effectiveness evaluation of fuel substitution compares only the direct cost of end-use equipment and calculates supply costs using simplified estimates of marginal costs.

Water heater useful energy requirements are assumed at 10.26 million Btu, which requires 3,341 kWh at an energy factor of 0.90 for a new electric water heater. Substitution with a new gas water heater at an energy factor of 0.54 would require 190 therms per year.

Water heater installed costs for both electric and gas systems are assumed at $460. This includes the costs of the water heaters themselves, but no auxiliary costs (these will be addressed in subsequent sections). Water heaters are assumed to have a useful life of 13 years.

Electric and gas marginal costs are both expressed in simple terms of cost per unit of energy consumption (i.e., $/kWh and $/therm) and exhibit no differentiation between energy and demand or across periods of the year. Electric marginal costs represent the energy and capacity costs that would be incurred to serve an incremental load that follows the utility system load shape. Gas marginal costs represent energy costs that would be incurred to serve an incremental load that follows the utility system load shape, but assume zero marginal capacity costs.

For the purpose of this paper, we assume electric marginal costs that begin at $0.07 per kWh for electricity and $0.30 per therm for gas. Table 1 presents the marginal costs used in Scenario 1.

**Table 1.** Marginal Costs Used in Scenario 1

| | Electric $/kWh | Gas $/therm |
|---|---|---|
| 1994 | $0.069 | $0.300 |
| 1995 | $0.075 | $0.323 |
| 1996 | $0.082 | $0.348 |
| 1997 | $0.090 | $0.374 |
| 1998 | $0.098 | $0.403 |
| 1999 | $0.106 | $0.434 |
| 2000 | $0.116 | $0.467 |
| 2001 | $0.127 | $0.502 |
| 2002 | $0.138 | $0.541 |
| 2003 | $0.150 | $0.582 |
| 2004 | $0.164 | $0.626 |
| 2005 | $0.179 | $0.674 |
| 2006 | $0.195 | $0.726 |
| 2007 | $0.212 | $0.781 |
| 2008 | $0.231 | $0.841 |

Table 2 presents the cost-effectiveness results for Scenario 1.

**Table 2.** Cost-Effectiveness Results Scenario 1: Simple Comparison

| | Electric Technology | Gas Technology |
|---|---|---|
| Installed Cost | $460 | $460 |
| Annual Cost | $0 | $0 |
| Load (kWh, therms) | 3,341 | 190 |
| Supply Cost (Marginal) | $2,974 | $688 |
| Participant Cost | $460 | $460 |
| Total Resource Cost | $3,434 | $1,148 |
| Benefit Cost Ratio (electric to gas) | | 2.99 |

## Scenario 2: Detailed Marginal Costs

A better characterization of utility marginal costs specifies costs separately for energy and demand components and differentiates among time periods within the year. With this approach, the additional costs associated with the load shape change caused by the water heaters (as opposed to an average load shape change across the system load) can be assessed.

### Electric Marginal Costs

For electric utilities, marginal costs for both energy and capacity can differ on an hourly basis. Variation in marginal energy costs reflect generation plants with different efficiency, fuel type, and fuel cost that can be used to serve marginal loads in different hours. Variation in marginal capacity costs reflect the relative reliability of the system in different hours. Since utilities add generation, transmission, and distribution capacity to maintain reliability across a number of hours (rather than to merely meet loads in an individual system peak hour) capacity costs should be allocated across a number of hours.

The most accurate approach to calculating the impacts of water heating load on system cost (for large changes) involves the use of generation expansion and production costing simulation models to identify the change in plant construction and operation that would be required to meet the load shape change. However, such an approach is beyond the scope of this paper.

The variation in electric costs across the hours of the year can be captured in a marginal costing framework by differentiating marginal costs. While few utilities characterize marginal costs with full 8,760 hour differentiation, many capture it with marginal costs specified on an hourly basis for a series of typical day types. Others capture it with marginal costs differentiated by season (e.g., winter, summer) and time of day (e.g., on peak, off peak).

### Gas Marginal Costs

Gas marginal costs include commodity (energy) and capacity components. Gas marginal costs show less variation within years. For example, gas utilities typically respond on a daily basis to changes in system loads as opposed to the hourly (or subhourly) responses of electric utilities.

While gas marginal costs can vary on a daily basis, most gas utilities can adequately characterize marginal costs using seasonal differentiation for commodity and capacity. Variations in commodity costs reflect access to different suppliers at the margin as system loads change. For example, summer marginal costs are usually lower than winter costs because gas utilities can serve increases in system loads using their lowest price supplier. Capacity costs can also show seasonal variation. For example, summer capacity costs may reflect the costs of entering gas into storage during the summer.

### Scenario 2 Results

Table 3 presents the gas and electric marginal costs used in Scenario 2. The costs for both fuels are differentiated by energy and capacity and for different time periods within each year. Table 4 presents the cost effectiveness results for Scenario 2.

## Customer-Related Costs

The addition of gas or electric end use devices can require the utility to make additional investments in customer-related costs. Customer-related costs include the costs of extending service from the local distribution system to the customer premise, the cost of installing a meter, and the costs associated with billing (e.g., meter reading, mailing).

If a fuel-substitution choice does not cause the need for service extension, no customer-related costs need to be considered in the cost-effectiveness analysis. For example, most residential customers will maintain electric service regardless of their water heating fuel choice. However, the decision to maintain gas service often depends on the water heating fuel choice (or more broadly, space and water heating fuel choices). Note that in some cases it would be appropriate to include electric customer-related costs. For example, some utilities service electric water heaters on a separate tariff requiring an additional meter and additional meter reading and billing.

Some utilities allocate line extension costs directly to individual customers, while others include line extension costs in base rates charged to all customers. From the total resource cost perspective used here, the allocation of costs does not matter as long as the total costs incurred to provide service are included.

In Scenario 3, we include reasonable estimates of customer-related costs. We include no costs for electric water heat, assuming that customers will maintain identical electric service regardless of their water heating fuel

**Table 3a.** Marginal Costs Used in Scenario 2: Electric

| | Energy | | | | Capacity | |
|---|---|---|---|---|---|---|
| | Winter | | Summer | | Summer | Winter |
| | On-peak $/kWh | Off-peak $/kWh | On-peak $/kWh | Off-peak $/kWh | $/kW-yr | $/kW-yr |
| 1994 | $0.025 | $0.020 | $0.027 | $0.023 | $120 | $120 |
| 1995 | $0.027 | $0.022 | $0.029 | $0.025 | $131 | $131 |
| 1996 | $0.030 | $0.024 | $0.032 | $0.027 | $143 | $143 |
| 1997 | $0.032 | $0.026 | $0.035 | $0.030 | $155 | $155 |
| 1998 | $0.035 | $0.028 | $0.038 | $0.032 | $169 | $169 |
| 1999 | $0.038 | $0.031 | $0.042 | $0.035 | $185 | $185 |
| 2000 | $0.042 | $0.034 | $0.045 | $0.039 | $201 | $201 |
| 2001 | $0.046 | $0.037 | $0.049 | $0.042 | $219 | $219 |
| 2002 | $0.050 | $0.040 | $0.054 | $0.046 | $239 | $239 |
| 2003 | $0.054 | $0.043 | $0.059 | $0.050 | $261 | $261 |
| 2004 | $0.059 | $0.047 | $0.064 | $0.054 | $284 | $284 |
| 2005 | $0.065 | $0.052 | $0.070 | $0.059 | $310 | $310 |
| 2006 | $0.070 | $0.056 | $0.076 | $0.065 | $338 | $338 |
| 2007 | $0.077 | $0.061 | $0.083 | $0.071 | $368 | $368 |
| 2008 | $0.084 | $0.067 | $0.090 | $0.077 | $401 | $401 |

**Table 3b.** Marginal Costs Used in Scenario 2: Gas

| | Gas Commodity Winter $/therm | Summer $/therm | Gas Demand Winter $/therm/day |
|---|---|---|---|
| 1994 | $.300 | $.220 | $29.2 |
| 1995 | $.322 | $.236 | $30.8 |
| 1996 | $.347 | $.254 | $32.5 |
| 1997 | $.374 | $.274 | $34.3 |
| 1998 | $.402 | $.295 | $36.3 |
| 1999 | $.433 | $.317 | $38.3 |
| 2000 | $.466 | $.342 | $40.4 |
| 2001 | $.502 | $.368 | $42.6 |
| 2002 | $.540 | $.396 | $45.0 |
| 2003 | $.581 | $.426 | $47.5 |
| 2004 | $.626 | $.459 | $50.2 |
| 2005 | $.674 | $.494 | $53.0 |
| 2006 | $.725 | $.532 | $55.9 |
| 2007 | $.781 | $.572 | $59.0 |
| 2008 | $.840 | $.616 | $62.4 |

choice. For gas water heat, we include $300 to cover the line extension from the local distribution system to the house, and $70 per year to cover the annual costs of meter reading, billing, and amortized meter capital costs (amortized, the $70 annual cost is equal to $680). Table 5 presents the cost-effectiveness results for Scenario 3.

**Table 4.** Cost-Effective Results Scenario 2: Detailed Marginal Cost

| | Electric Technology | Gas Technology |
|---|---|---|
| Installed Cost | $460 | $460 |
| Annual Cost | $0 | $0 |
| Load (kWh, therms) | 3,341 | 190 |
| Supply Cost (Marginal) | $3,459 | $788 |
| Participant Cost | $460 | $460 |
| Total Resource Cost | $3,919 | $1,248 |
| Benefit Cost Ratio (electric to gas) | | 3.14 |

**Table 5.** Cost-Effectiveness Results Scenario 3: Customer-Related Costs

| | Electric Technology | Gas Technology |
|---|---|---|
| Installed Cost | $460 | $760 |
| Annual Cost | $0 | $70 |
| Load (kWh, therms) | 3,341 | 190 |
| Supply Cost (Marginal) | $3,459 | $788 |
| Participant Cost | $460 | $1,440 |
| Total Resource Cost | $3,919 | $2,228 |
| Benefit Cost Ratio (electric to gas) | | 1.76 |

## Scenario 4: Participant Costs

Participant costs need to address all the costs incurred when installing the electric or gas water heater. While the participant costs in Scenarios 1 through 3 address the direct costs of material and labor associated with the water heaters themselves, a thorough analysis needs to also include any necessary auxiliary equipment.

Like customer-related costs, auxiliary participant costs are primarily associated with gas equipment. These include piping necessary to link the gas device to the utility service connection as well as a flue to remove exhaust gases. These costs vary widely; primarily due to variations in the length of piping and flue necessary for individual applications.

Electric auxiliary costs could include the costs of wiring or circuit panels. However, since most houses contain adequate electric service to accommodate electric water heaters, electric auxiliary costs are typically small or zero.

In Scenario 4 we add $110 to cover gas auxiliary equipment, including $60 for piping and $40 for a through-the-wall flue. We assume no auxiliary costs for the electric water heat. Table 6 presents the cost-effectiveness results for Scenario 4.

## Scenario 5: Economic Comparisons

Customer fuel choice decisions are not limited to single gas and electric options. Instead a range of equipment and energy service options are available to customers. Water heater manufacturers offer electric and gas water heaters in a range of efficiencies. They also offer integrated space/water heating systems for both fuels. Customers can also improve the efficiency of their water heating systems by adding insulation wraps, heat traps, or pipe insulation. They can improve the efficiency of their overall water energy service by installing low-flow showerheads, faucet aerators, or water conserving dishwashers and clothes washers.

**Table 6.** Cost-Effectiveness Results Scenario 4: Participant Costs

| | Electric Technology | Gas Technology |
|---|---|---|
| Installed Cost | $460 | $870 |
| Annual Cost | $0 | $70 |
| Load (kWh, therms) | 3,341 | 190 |
| Supply Cost (Marginal) | $3,459 | $788 |
| Participant Cost | $460 | $1,550 |
| Total Resource Cost | $3,919 | $2,338 |
| Benefit Cost Ratio (electric to gas) | | 1.68 |

Customers can invest in these different water heating technologies on their own or by taking advantage of electric and gas utility demand-side management programs. In addition to providing efficient technologies, utilities programs also offer other energy service options, including innovative rates, and, for electric utilities, load management options.

In Scenario 5 we illustrate this effect by assuming that the electric water heater is enrolled in utility direct load control program. To reflect this we add $220 in installation costs to reflect the installed cost of a load control receiver and we adjust the load impacts of the electric water heater to include no peak demand impacts. Table 7 presents the cost-effectiveness results for Scenario 5.

**Table 7.** Cost-Effectiveness Results Scenario 5: Economic Comparisons

| | Electric Technology | Gas Technology |
|---|---|---|
| Installed Cost | $680 | $870 |
| Annual Cost | $0 | $70 |
| Load (kWh, therms) | 3,500 | 190 |
| Supply Cost (Marginal) | $1,094 | $788 |
| Participant Cost | $680 | $1,550 |
| Total Resource Cost | $1,774 | $2,338 |
| Benefit Cost Ratio (electric to gas) | | .74 |

## Conclusion

This paper illustrates how simplified analyses of fuel switching can significantly distort cost-effectiveness analyses. In the simple case study presented here, the benefit-cost ratio for switching from electric to gas water heat changes from 2.99 for the simple base case to a value of 0.74 when all input values are adequately specified. This data is presented not to advocate one fuel versus another, but to illustrate the importance of the issues identified.