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Electric-to-Gas Substitution: What Should Regulators Do?

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Executive Summary

With concerns over global warming and energy sustainability increasing, policy options in responding to these problems have broadened to include fuel switching, or, as it is more correctly termed, electric-to-gas substitution. Electric-to-gas substitution, as defined in this paper, refers to the decision of small, generally residential consumers to use natural gas rather than electricity for certain end-use applications. The decision can involve conversion from electricity to natural gas in an existing home or installation of gas-burning equipment in a new home. In each instance, the consumer must decide on the appliance or energy-using equipment she wants to purchase. End uses for which electric-to-gas substitution is common include space heating, water heating, cooking, and clothes drying.

This paper views electric-to-gas substitution as a consumer activity. A threshold issue is whether market barriers or imperfections, or regulatory obstacles, prevent utility customers from making rational and socially desirable decisions. Market barriers and imperfections, by definition, hamper consumer decisionmaking.

This inquiry starts with a question: Have market or regulatory barriers prevented or discouraged socially beneficial fuel switching? In almost all fuel and nonfuel markets in the U.S., even those heavily regulated on the supply side, the market is the primary institutional arrangement in which consumers to make decisions. Consumers' responses to the market determine what they buy and what benefits they receive from a purchase. An energy consumer's major concern is the capital equipment and energy costs she must incur to enjoy the heating comfort and other energy services she desires. This paper recommends that regulatory intervention in consumer markets should pass some cost-benefit test: There should be evidence of market problems (defined by consumers making poor choices for themselves) serious enough to justify the cost of such intervention.

The test applied in this paper is similar to the one regulators use to assess utility initiatives promoting energy efficiency. In fact, the regulator can compare both forms of regulatory intervention—intervention to encourage energy efficiency and intervention to encourage electricity-to-gas switching—to arrive at the most cost-effective solutions.[1]

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[1] Most state commissions mandating utility energy-efficiency initiatives require that these initiatives pass some cost-effectiveness test. Regulators generally ground these initiatives on the premise that market problems have hindered consumers from making energy-efficiency investments that are in their own self-interest and in society's interest.

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Electric-to-gas substitution or switching refers to the decision of small, generally residential consumers to use natural gas rather than electricity for certain end-use applications. Common end uses conducive to both electricity and gas include space heating, water heating, cooking, and clothes drying. Consumers normally make their choices when their existing appliances become either physically or economically depreciated, or when they purchase or build a new house. The choice is available in most parts of the country, except very rural areas.

Regulators have an interest in how well consumers make this choice. If consumers make this choice efficiently, they avoid waste and conserve resources for all. This paper asks these questions: Do consumers make choices that deploy utility service efficiently, or is regulatory intervention necessary to ensure greater efficiency? What factors should influence a regulator's decision to intervene in retail customers' energy choices? If regulatory intervention is necessary, what types are appropriate?

Part I of this paper describes the possible benefits and costs of switching. **Part II** explains the market defects that might cause inefficient customer decisions. **Part III** describes options for regulators who contemplate intervening. Two appendices provide a technical discussion of the economic analyses underlying the substitution decision, its costs, and its benefits.

I. What are the benefits and costs of switching?

This discussion looks at the benefits and costs of switching from the following perspectives: consumer, regulator, environmental, and utility cost recovery.

A. Consumer's perspective

Energy services at issue here include cooling, space heating, water heating, and clothes drying. How much service consumers desire depends upon such factors as climate, house size, fuel prices, and income. The consumer tries to choose fuels that will provide service at least cost and satisfy other objectives (e.g., high service reliability and moderate price risk). "Least cost" refers to the sum of the appliance or equipment purchase and installation cost plus annual operating costs. Other factors bearing on energy substitution decisions include comfort levels and convenience, and the cost of converting appliances from one energy source to another.

From the consumer's perspective, the cost-effectiveness of energy substitution depends on several factors. They include: (1) for existing customers, conversion costs (e.g., electrical and plumbing work); (2) the cost of new natural gas connections or extension lines required; (3) the avoided cost of electricity; and (4) the incremental cost of natural gas (e.g., purchased gas costs and any additional distribution costs).

The customer must consider initial costs (appliance and connection costs) and operating costs (mainly the cost of energy). Natural gas appliances usually are more expensive than electric appliances. Annual operating costs for gas appliances usually are lower, however, because the price of natural gas is lower than electricity (on a British thermal unit basis). But operating cost also is affected by how efficiently the appliance converts the energy purchased from the utility (therms of natural gas or kilowatt-hours of electricity) into usable energy (e.g., the heat of a flame on a gas stove). This measure of energy efficiency is referred to as the energy factor of appliances. Electric appliances generally have higher energy factors. Conventional electric and natural gas water heaters have energy factors of around 0.90 and 0.60, respectively.[2] In other words, for the same amount of energy consumed, the electric water heater produces 50 percent more energy in the form of hot water. The higher price of electricity (on a Btu basis) is somewhat offset, therefore, by the normally higher efficiency of electric appliances.

Appendix A presents a theoretical discussion of the parameters affecting a household's decision to switch fuels. It also provides some insight into what drives consumer energy substitution decisions, through the lens of a new branch of economics called behavioral economics.

Appendix B explains these factors in more detail. It shows that while gas-fueled appliances have lower energy efficiencies than electricity-based appliances, switching from electricity to natural gas would generally reduce a household's total energy cost, i.e., the expenses incurred by the household to pay for the production and delivery of energy services. The main reason is the lower price of natural gas (on a Btu basis). The outcome will vary, of course, with retail gas and electricity prices. In most parts of the country, gas appliances would have a lower energy cost than electric appliances; exceptions, however, can occur where electricity prices are far below the national average, or if a utility has low off-peak rates (e.g., 5-7 cents per kilowatt-hour), or natural gas prices increase to extremely high levels because of tight market conditions.

The nature of the peak demand for each utility also affects cost. An example of a switch that reduces total cost for a given area is a switch from an electric utility with tight capacity (i.e., high long-run marginal cost) to a gas utility with surplus distribution capacity. By reducing its summer peak, the electric utility could avoid or defer new generation; by increasing its off-peak demand (summer being off-peak for most gas utilities), the gas utility would increase its capacity utilization rate and lower its average (per-unit) cost.

In short, the benefits from switching are case-specific, depending on such matters as differences in home size, building shell energy efficiency, the energy services desired, and the relative costs of gas and electric energy. A small home with an efficient shell might opt for electric resistance heating, while a large home that consumes large amounts of energy may prefer natural gas for space heating.

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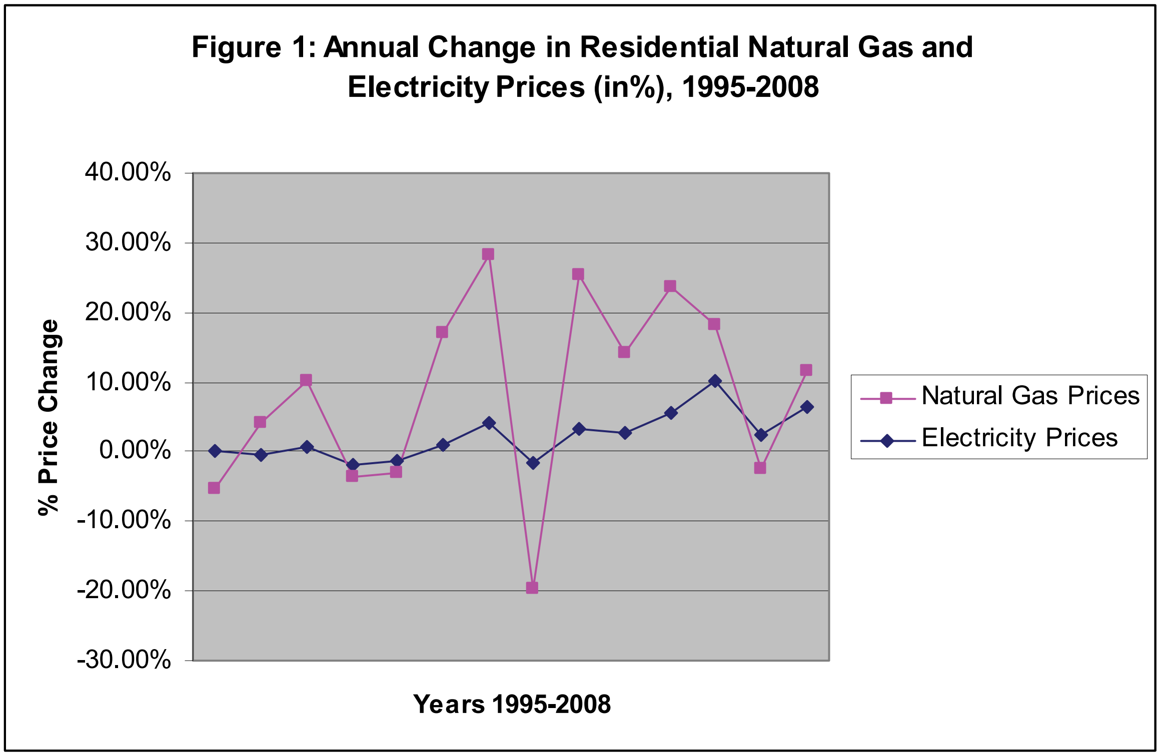
[2] If the energy factor is 0.9, for example, that means 90 percent of the energy input into a water heater converts to useable energy in the form of hot water.

A customer also cannot count on price stability. As Figure 1 shows, since the mid-1990s the residential price of natural gas has exhibited much more volatility than the price of electricity.[3] Consumers basing their switch-to-gas decision on current low gas prices may experience future high prices.



B. Regulator's perspective

The regulator's perspective is broader than the individual consumer's. If the regulator's goal is to reduce total cost, she must consider several aspects. Energy efficiency measures the ratio of energy output to energy input. Energy efficiency can be measured from two perspectives: (1) at the consumption site, looking at the appliance alone, i.e., the amount of energy needed to run the an appliance or equipment (e.g., cooling, space heat); and (2) the full fuel cycle, taking into account the production, transportation, and distribution of energy.

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[3] The figure uses national price data for the residential sector from the U.S. Energy Information Administration for the years 1995-2008. *See* http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html and http://www.eia.doe.gov/fuelelectric.html.

Looking at the second measure, natural gas tends to be more energy efficient.[4] The full-fuel-cycle measure would in most instances show higher total energy consumption in producing and delivering energy to an electric appliance than a gas appliance. Exceptions could occur with a state-of-the-art electric heat pump, or when renewable energy is used to generate electricity. At least half of the energy embedded in fossil fuels is lost during the generation, transmission, and distribution processes. An older, inefficient coal-fired plant may lose as much as two thirds of the energy input in electricity generation. Newer plants lose less energy; for renewable plants, energy losses mostly occur in transmission.

The second measure, which takes into account the full fuel cycle, is theoretically superior, but accurate measurement is difficult. The dilemma facing a commission is that it can choose the site definition of energy efficiency and not account for the energy losses involved in the production, transportation, and distribution of electricity and natural gas; alternatively, it can choose the source definition and risk having an inaccurate measure of energy efficiency. Calculating the energy reduction from switching would, moreover, require knowing which generating units would run less, a fact that changes hourly. If the effect of switching is to reduce reliance on wind turbines, nuclear plants, or hydro facilities, the energy savings are less than if the effect is to reduce reliance on older fossil fuel plants with high heat rates.[5]

Even if electric-to-gas substitution were to lead to greater energy efficiency, however it is defined, that fact alone would not justify regulatory intervention.[6] Most state commissions involved in promoting energy efficiency evaluate options using the Total Resource Cost (TRC) test.[7] This test accounts for all quantifiable costs and benefits (e.g., avoided supply and delivery costs) experienced by all those affected (e.g., program participants, other customers, and the utility) as a result of the action taken.

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[4] The federal government is currently trying to track greenhouse gas emissions by measuring energy use applying a full fuel cycle approach. The U.S. Environmental Protection Agency, through its national performance ratings, evaluates the energy use of buildings by accounting for source energy (e.g., the energy expended in producing and delivering electricity to a building). *See* EPA's Energy Star Performance Ratings, at http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf.

[5] From a short-term perspective, those instances are arguably rare: utilities are unlikely to back out on wind or hydro, whose costs are free, and incremental nuclear energy costs are a fraction of fossil fuel operating costs. In the long-run, however, energy substitution can result in less building of renewable and other non-fossil fuel power plants that would displace power produced from fossil plants.

[6] This criterion also could apply to utility initiatives that aim to increase consumer purchases of energy-efficient appliances. These initiatives usually receive regulatory approval only when they pass some cost-effectiveness test.

[7] *See*, for example, California Public Utilities Commission, *California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects*, October 2001.

Regulators should address whether to impute a value to the energy source with the higher energy efficiency from the perspective of a full fuel cycle. The price of electricity should reflect its higher consumption of energy in producing and delivering electricity compared with natural gas. Higher energy losses should therefore translate into a higher price, which in the above example would make electricity more economically unfavorable relative to natural gas. Assigning a separate value to natural gas because it has a higher energy efficiency from a full fuel cycle perspective would therefore be a "double accounting" of its benefits.

C. Environmental effects

A study by the American Gas Foundation[8] found that energy substitution reduces air pollutants. The study assumed that the electricity generation avoided from energy substitution would come from fossil fuel plants. It assumed that these plants use either coal or natural gas, or both, as fuels.

The AGF report's conclusion about emissions depends on the fuel mix used by the utility. If the power plants affected by energy substitution are to some degree non-emitting, such as wind, hydro, solar, or nuclear, the environmental benefits of switching to gas are less, and may well be negative. Electric end-use appliances also produce no carbon and other air pollutants, unlike natural gas appliances; this factor could be an issue in urban non-attainment areas.

D. Effects on the utilities

For electric utilities, a customer's switch to gas means less electricity consumption per household, not fewer customers. For natural gas utilities, the same switch means higher gas consumption per customer or an increase in customers, or both.[9] The financial effects for both electric and gas utilities depend on: (1) the end-use energy services affected; (2) the change in revenues for both utilities, which depends to a significant degree on rate design;[10] and (3) the

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[8] American Gas Foundation, *Direct Use of Natural Gas: Implications for Power Generation, Energy Efficiency, and Carbon Emissions*, April 2008. The Gas Technology Institute has reported similar findings. *See* Ron Edelstein, "A Lower-Cost Option for Substantial CO_2 Emission Reductions" (presentation at the NARUC Winter Committee Meetings, February 18, 2008). AGF is a 501(c)(3) organization providing information, research, and programs on energy and environmental issues that affect public policy, with a focus on natural gas. Gas distributors provide most of the financial support for AGF activities.

[9] Gas-to-electricity substitution could mean lost customers for the gas utility. Everyone needs electricity for at least some uses, even if just for the lighting and operation of small appliances. Not everyone, however, needs natural gas, as electricity can provide all the energy needs of a household.

[10] Rate design determines how a utility collects dollars from customers at varying levels of consumption.

change in avoided cost and incremental cost for both utilities, including any conversion inducements and other promotional costs. Consider two scenarios.

The first scenario is one in which the electric utility's peak demand falls and the gas utility's off-peak demand increases,[11] as would occur when electric customers convert to natural gas air conditioners. Lower peak electric demand would reduce the requirements for new electric generating capacity. For electric utilities with uniform average-cost pricing, it also would tend to avoid costs greater than the lost revenues. That is, since costs during peak periods generally are above average, rates based on average costs will be below actual marginal cost.[12] For a gas utility building its load during off-peak periods, the increased capacity utilization would tend to lower its average cost per unit. Increasing off-peak demand also would tend to increase its earnings, both because of average-cost pricing (which tends to set prices above marginal cost during off-peak periods) and the recovery of fixed costs in the volumetric charge.

The second scenario is cold winter mornings, when space heating and water heating would likely be used. Switching from electric space and water heating to natural gas would tend to increase peak demands on the natural gas system, while having little or no effect on electric annual peak demands (which are due primarily to summer air conditioning). The electric utility would likely experience lower earnings, assuming that revenue declines would exceed the avoided cost (because in off-peak periods, average-cost rates exceed below-average costs). The gas utility, on the other hand, would likely enjoy higher earnings, for the opposite reasons.[13]

Regulators should consider using the Rate Impact Measure (RIM) test as a secondary test (with the Total Resource Test, for example, as the primary test) to determine whether electric customers who do not switch to gas would be worse off. This test compares the changes in a utility's revenues and revenue requirements from a particular action. If one condition for energy substitution is to prevent the electric utility's rates from going higher, according to the RIM test the revenue losses could not exceed the avoided costs. This test imposes a "second-best" condition for fuel-switching incentives to be efficient—namely that electricity prices are below

[11] *See,* e.g., David M. Boonin, "Bridges between Electric and Gas IRP: Clean Air Act Compliance" (paper presented at NARUC's Fourth National Conference on Integrated Resource Planning, Sept. 1992). The presentation discussed the economic efficiency benefits of shifting air conditioning load from electricity to natural gas, arguing that it would help clip the summer peak of an electric utility and increase the off-peak load valley of a gas utility.

[12] Energy utilities generally incur higher costs, both on the margin and on average, during periods of high demand. Most utilities, however, charge the same rate across different periods. The rates reflect a utility's average cost over the year or season.

[13] We assume here that the gas utility's additional revenues would exceed additional costs. This assumption is realistic in view of the rate structure of most gas utilities. One exception may be when the shift in consumption causes the gas utility to spend more and sooner on capacity additions, which in effect drives up its long-run marginal cost.

incremental or marginal cost. This condition can occur, for example, when average-cost prices are below peak electricity costs, and especially when prices do not account for external costs such as those relating to air pollutants emitted.

E. Comments on a recent gas-industry study

The AGF study cited the following benefits from small electricity consumers switching to natural gas for direct applications such as space and water heating.[14] These benefits included reductions in (1) energy consumption, mostly from eliminating the high energy losses in producing and transmitting electricity; (2) the need for new generating facilities; (3) energy costs incurred by end-use consumers; and (4) carbon dioxide (CO_2) emissions.[15]

The AGF study has some limitations. It makes no assumptions as to whether consumers make rational decisions or whether market and regulatory impediments to switching exist. It omits some real-world costs that consumers would incur when switching, such as transaction costs and the inconvenience of switching fuels in an existing house. The study is, therefore, unable to distinguish between reasonable and unreasonable consumer behavior. It also did not measure the cost of the regulatory intervention necessary to induce substitution, such as the cost of promotional activities or planning studies.

In assessing the AGF study, regulators should keep the following considerations in mind:

1. It uses national averages, but the appropriateness of switching depends on regional, utility-by-utility, and even household factors. Would more case-specific data show different results?

2. If the study makes clear the benefits of switching, why don't more customers switch? Are there institutional barriers, transaction costs, or forms of customer irrationality shaping consumer choice?

3. Does the study accurately account for the lower energy factor of most gas-fueled appliances and equipment relative to electric appliances and equipment?

4. Do the projected reductions in CO_2 in the study accurately reflect which generating units of electric utilities would operate less as a result of energy substitution?

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[14] The study assumes that seven percent of the total electric load of the residential and commercial sectors shifts to natural gas. The Gas Technology Institute has reported similar findings. *See* Ron Edelstein, "A Lower-Cost Option for Substantial CO_2 Emission Reductions" (presentation at the NARUC Winter Committee Meetings, February 18, 2008).

[15] Under one scenario, with the passage of greenhouse gas legislation, energy cost savings could reach $29 billion by 2030. Under a different scenario, investments by electric utilities could decline by $122 billion.

5. Does the study bias its results in favor of natural gas by assuming advanced gas-burning technologies but not advanced electricity-using technologies?

II. What market defects might affect the switching decision?

If all actors considered all cost factors rationally, and if price reflected all those factors, switching would occur to the extent that it is economically efficient—no more and no less. The field of behavior economics asserts that the real world does not work that way.[16] Here are examples of divergences from the ideal:

1. Consumers have imperfect information. With uncertainty over future gas prices, for example, a rational consumer would discount the potential benefits from electric-to-gas substitution and, therefore, might decide to do nothing. Consumers also could have conflicting information that could cause them to make a wrong decision.

2. Consumers' chief concern is the economic effect on themselves, not on others or on the environment. The environmental effects of energy consumption are not fully reflected in the prices.

3. Consumers overvalue present dollars and undervalue future benefits, resulting in insistence on payback periods[17] that are shorter than are economically justified. Highly energy-efficient gas equipment, for example, has a higher initial cost than corresponding electric equipment. This cost differential, assuming consumers

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[16] Behavioral economics combines economics and psychology to explain how people make decisions. It assumes "bounded rationality," where people make decisions with less-than-perfect information because of limited time and cognitive capacity. They exhibit what some analysts call "rational ignorance." People are susceptible to making predictable and avoidable mistakes. Ideas from behavioral economics include: (1) faulty discounting (consumers under-value future benefits relative to present costs), (2) status quo bias (even if consumers know or are told that the status quo is not in their self-interest), (3) overconfidence (believing that gas prices, for example, will stay low indefinitely), (4) complexity can delay choice, and (5) loss aversion (the possibility of losses or simply uncertainty over the benefits of fuel switching, for example, discourage action). *See*, e.g., Richard H. Thaler and Cass R. Sunstein, *Nudge: Improving Decisions about Health, Wealth, and Happiness* (New Haven, Yale Univ. Press, 2008); and Robert H. Frank, *The Economic Naturalist: In Search of Explanation for Everyday Enigmas* (New York, Basic Books, 2007).

[17] "Payback period" refers to the period of time required to recapture the original investment.

heavily discount the benefits of lower energy cost over the life of the equipment, favors electric utilities even when lower gas prices may make gas preferable on a life-cycle cost basis.[18]

4. Inertia is a powerful force. Decisionmaking is often costly. Doing nothing may be an appropriate response to a changing environment if potential benefits are small or uncertain relative to transaction and search costs. One often-used example of consumer inertia is the long-distance telephone market, where the penetration of non-AT&T carriers progressed slowly; several years passed before these carriers collectively increased their market share above AT&T's.

5. Even with information that a shift to natural gas will save money and help the environment, a customer might be more influenced by concerns about gas price volality, while also viewing the environmental benefit as trivial. The implication of volatile natural gas prices is that consumers may convert to natural gas based on low current prices, while natural gas prices can rise quickly and stay at a high level for extended periods. In the present environment of a deep economic recession, consumers may make decisions based on the low price of natural gas, but when the U.S. enters a period of economic recovery, it is likely that natural gas prices will rise again—conceivably at a sharply higher level. The problem for regulators is discerning when electric-to-gas substitution makes economic sense to customers. Regulators may encourage electric-to-gas substitution, but risk harming customers when natural gas prices rise.

6. Inefficient rate designs—where utility customers pay average cost rates that do not reflect the actual operating costs in a particular hour—induce customers to make fuel choices that do not reflect the full economic costs of producing and delivering energy. One possible outcome is what is called "uneconomic bypass," where a customer turns to a particular energy source (e.g., electricity) when an alternate source (e.g., natural gas) is less costly to society but more costly to the customer. Such a choice is uneconomic because society incurs a higher cost in meeting the customer's energy-service demands.

7. Home builders choosing appliances tend to focus on the initial installation cost, not the life-cycle cost. Many builders want to minimize installation costs for space-

[18] Studies have measured the social discount rate to be much lower than the discount rate most residential consumers apply to purchases of high energy-efficient appliances. They generally have shown that residential consumers reveal high "implicit discount rates" in their evaluation of the costs and benefits of energy efficiency. This evidence is applicable to energy-substitution decisions by households as well. *See*, for example, Jerry Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *Bell J. of Economics* 10,1 (Spring 1979): 33-54; and Jeffrey A. Dubin and Daniel L. McFadden, "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption," *Econometrica* 52,2 (March 1984): 345-62.

and water-heating equipment in new homes, which may conflict with new-home-buyers' interest. ("Green" certification of homes and appliances has served to correct some of this problem.)

Although this list is long, it is a mistake to consider all of these factors as impediments to better market performance. Inertia may reflect a rational customer's reluctance to change suppliers or products because of uncertain outcomes that could make them worse off.

Still, the possibility of market defects raises the question of whether regulatory intervention is desirable, and if so, what types. That is the subject of the next section.

III. What are the regulatory options?

Regulators have three categories of options. One is to take no action. That option would be based on an assumption or finding that customer choices are rational, efficient, and consistent with the public interest; that there are no serious market distortions warranting regulatory intervention; or that correcting for those distortions would not pass a cost-benefit test. In other words, regulatory intervention should only occur if the distortions are serious and the cost of intervention is less than the benefits.[19]

If instead the regulator finds that one or more of these assumptions is incorrect, there are two other approaches to consider: regulatory directives to the utilities, and regulatory corrections to the market. These two categories are not mutually exclusive. A regulator can mix directives to the utilities with efforts to correct market distortions.

A. Regulatory directives to the utilities

The regulator could mandate particular actions, or establish mandatory targets. This type of action would need the support of one or more assumptions or findings, such as:

1. Because of market imperfections, there are unexploited opportunities for cost-effective energy substitution.

2. The utility's obligation to serve customers at the lowest feasible cost includes an obligation to help guide them toward actions that minimize the cost of energy services (e.g., the life-cycle cost of producing hot water in a home).

[19] An analogous situation exists when the federal government tries to intervene in markets with alleged problems. Government policies frequently cause counterproductive results or mitigate a problem at a higher cost than necessary. *See*, *e.g.,* Clifford Winston, *Government Failure versus Market Failure: Microeconomics Policy Research and Government Performance* (Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies, 2006); and Charles Wolf, Jr., *A Theory of Nonmarket Failure: Framework for Implementation Analysis*, J. LAW & ECON., April 1979, at 107-39.

3. Absent regulatory intervention, the electric utility will not encourage, or will discourage, efficient switching.

The main option here is to create an integrated resource plan (IRP) process that includes electric-to-gas substitution as an option along with supply resources and energy efficiency initiatives. The standard IRP process is utility-centric: Each utility, focusing on its customers and its market, evaluates its resources and proposes the resource mix most likely to serve its customers at the lowest feasible cost. This approach, in separating gas planning from electricity planning, risks ignoring switching as an option. A shift from single-utility planning to all-energy utility planning would avoid this omission by including electric-to-gas switching as one of the ways to achieve least-cost energy service.

Multi-utility planning faces formidable challenges, however. Each of the gas and electric utilities would have a profit-maximizing stake that could vary from the public interest result. As direct competitors for customers, gas and electric utilities would not readily cooperate in the formulation of a joint plan. If they did cooperate, there would be a risk of anticompetitive results (such as conspiring to divide up customer groups between them rather than allowing competition to determine outcomes).[20] The commission or another state agency would need to develop such a plan, based on a broad public-interest perspective.

As with traditional integrated resource planning, each utility then would be responsible for carrying out actions consistent with the joint plan. If the plan, for example, showed that ten percent of the electric utility's existing space-heating customers should convert to natural gas, both utilities would be responsible for achieving this target.

Aided by such a plan, the regulator could consider requiring electric utilities to encourage their customers to switch when such an action would pass a specified cost-benefit test, such as the Total Resource Cost test.[21] This approach compares the incremental cost of providing more natural gas directly to customers with the avoided costs of providing less electricity.

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[20] Joint planning for the electricity and natural gas sectors would probably face less resistance when a combination utility is involved. A 1993 report mentioned that both Oregon and Wisconsin had encouraged utilities to consider fuel switching and adopted principles to guide the activity. Wisconsin utilities proposed fuel switching programs, while Oregon utilities did not. The report speculated that one reason for the different response was that Wisconsin utilities are combination utilities and Oregon utilities are not. *See* Charles Goldman et al., *Primer on Gas Integrated Resource Planning*, prepared for the National Association of Regulatory Utility Commissioners, December 1993.

[21] *See* footnote 7.

B. Regulatory corrections to the market

These interventions should be aimed at mitigating or eliminating any market distortions or defects. In this context, it is best to tailor each regulatory intervention to the particular market defect. Here are seven options:

1. Improve the quality of information offered to utility customers. The regulator could direct the gas utility to disseminate information on the economic benefits of gas water heaters over electric water heaters; alternatively, the commission or another government agency could carry out the informational effort. This information should alert customers to the fact that the relationship between electricity and natural gas prices changes over time, resulting in one source of energy becoming more or less attractive relative to the other.

2. Review rate structures of both electric and gas utilities to eliminate any regulatory favoritism toward either energy source. A review might reveal that the price for one of the energy sources is much closer to marginal cost than for the other energy source. Such price-marginal cost divergence could cause an uneconomic outcome where, from a societal perspective, customers are consuming too much electricity relative to natural gas, or vice versa.

3. Review any existing restrictions on promotional practices to see if they deny customers the information necessary to make effective choices. Such restrictions may be uneven across the two kinds of utilities, inducing consumers to switch to the fuel with the less restrictive promotional practices.

4. Grant rebates to residential customers who convert from electricity to natural gas for space heating and water heating, as long as energy substitution passes a given cost-benefit test (such as the Total Resource Cost test). Where consumers are reluctant to purchase a gas water heater because it is more expensive than an electric water heater, some regulators have considered allowing the gas utility to offer a rebate, say $200, to any residential consumer who purchases a new gas water heater. The cost of the rebate is borne by other customers. The rationale is that the long-term cost savings to all customers justifies the initial cost, which a single customer is unlikely to bear. There are two risks. If the rebate exceeds the real benefit to all customers, it becomes a subsidy that benefits one customer at the expense of others and results in excessive appliance purchases. Further, the rebate is wasted if the customer would have bought the appliance anyway—a fact that is difficult to discern.

5. Require or authorize the gas utility to offer ratepayer-funded incentives to home builders to install gas appliances.

6. Determine whether existing energy-efficiency initiatives cause choice distortions. If an electric utility offers more energy efficiency initiatives than the gas utility, customers might perceive electric service as more attractive than gas, even if the long-term efficiencies favor the latter.

7. Recognize that if regulatory policy encourages customer departure from electric to gas utilities, electric utilities will experience under-recovery of fixed charges, requiring commission consideration of alternative means of compensation.

One corrective approach would be for regulators to direct the gas utility to disseminate information on the economic benefits of gas water heaters over electric water heaters. Behavioral economics[22] would support the gas utility giving consumers a "nudge," for example, by informing them that if they do not purchase a gas water heater they would pay much more in energy costs over time.

C. Regulatory caution: principles, risks, and questions

Before taking any action, regulators should clarify their principles, measure the risks, and ask good questions.

Principles: Regulators should aim for the combination of market and regulatory influences most likely to produce economic efficiency. Regulatory intervention is justified when market defects or customer behavior produces inefficient results that exceed the cost of intervention. Regulators should re-examine that combination periodically, as facts change. For any given regulatory action, a commission must have sufficient commission staff resources and expertise to ensure effective design and implementation. Absent such resources and expertise, there is the risk of error.

Risks of regulatory intervention: Regulation has benefits and costs. The benefits are the removal of the economic efficiency losses associated with market defects and customer error. Regulatory failure occurs when there is intervention that is unwarranted, either because markets are performing adequately, because the intervention did not correct a market failure efficiently, or because the cost of regulatory intervention exceeds the benefits. The potential costs of regulatory intervention include: (1) inadvertent subsidies (e.g., improper price signals leading to a resource misallocation); (2) procedural delays and costs, especially those associated with multi-utility integrated resource planning; (3) welfare losses from stakeholders expending dollars and resources in the regulatory process to advance their positions (e.g., "fighting costs" from gas utilities pushing hard for electric-to-gas substitution, counteracted by electric utilities' resistance); and (4) administrative costs (e.g., the enforcement cost of regulatory mandates or targets).

Questions for regulators to ask: An informed decision by regulators on what action to take, if any, hinges on many pieces of information. Examples include:

1. Does preliminary information suggest that energy substitution has the potential to benefit consumers, improve the environment, and produce other social dividends?

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22 *See* footnote 16.

2. Have market or regulatory barriers prevented or discouraged socially beneficial economically efficient energy substitution? What information is necessary to answer the question?

3. Are consumers making the right choices from their own and society's perspective? If not, why not?

4. Is regulatory intervention necessary to encourage households to use natural gas in place of electricity for those end uses where both energy forms compete?

5. Do regulatory practices and policies distort energy substitution decisions?

6. What benefit-cost test should apply?

7. What are the direct and indirect costs associated with executing the actions? Who would bear those costs?

8. How and to what degree should regulators consider the non-monetized effects (e.g., energy efficiency and environmental) of consumer energy-choice decisions?

9. Are the uncertainties in calculating the costs and benefits of energy substitution too large to produce credible results?

10. Are the relevant facts so location-specific as to rule out categorical policies?

11. What regulatory actions would best address each of the problems identified?

12. Will the benefit of regulatory intervention exceed its costs? What are the risks associated with the proposed actions? What parties bear those costs? Will the regulatory action distort competition?

13. Does the regulator have legal authority to execute those actions?

14. How should regulators evaluate the effectiveness of these interventions?

Appendix A: A Theoretical Discussion of Electric-to-Gas Substitution

A utility consumer who is contemplating a switch from electricity to natural gas for an energy service would consider the net benefits (NB):

$$NB^{i}_{j} = va_j + (ec_e - ec_g,) - s_j - ac_{g,}$$

where the net benefits of consumer j from switching to natural gas for energy service i (e.g., space heating) relates to: (1) any value added benefits va_j (e.g., more control of cooking temperature with gas); (2) the difference between the energy cost of operating an electric appliance, ec_e, and a gas appliance, ec_g, (discounted value over the life of the appliance); (3) the switching and search costs incurred by the consumer, s_j (e.g., the time of searching and receiving information, as well as other transaction costs);[23] and (4) the net cost of a gas appliance, ac_g.[24] If the consumer requires service-connection and main-extension lines, then their expense needs to be added to the cost as well.

The gross benefits of switching to natural gas derive from the presumed lower energy cost of operating a gas appliance and any additional value placed on natural gas relative to electricity. Lower energy cost depends upon consumption levels and future price expectations. Offsetting these benefits are the costs of purchasing and installing a gas appliance,[25] as well as any additional costs, such as searching and other transactions costs, plus any plumbing or electrical work required for converting from one energy source to another.

The above relationship shows that search and other transaction costs can act to deter electric-to-gas substitution. Facilitating information flow and transactions in general would cause consumers to find electric-to-gas substitution more attractive.

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[23] *See* Tore Nilssen, *Two Kinds of Consumer Switching Costs*, RAND J. ECON. 23, 4 (Winter 1992): 579-89; Paul Klemperer, *The Competitiveness of Markets with Switching Costs*, RAND J. ECON. 18, 1 (Spring 1987): 138-50; Paul Klemperer, *Competition When Consumers Have Switching Costs: An Overview with Applications to Industrial Organization, Macroeconomics, and International Trade*, REV. ECON. STUDIES 62 (1995): 515-39; and Paul Klemperer, *Entry Deterrence in Markets with Consumer Switching Costs*, ECON. J. 97 (1987): 99-117. For empirical evidence on the importance of transaction costs in a regulated industry (i.e., interstate long distance), *see* Christopher R. Knittel, *Interstate Long Distance Rates: Search Costs, Switching Costs, and Market Power*, REVIEW IND. ORG. 12 (1997): 519-36.

[24] The net cost accounts for new construction and the replacement of an old, highly depreciated appliance by including the avoided cost of buying and installing a new electric appliance.

[25] If the consumer switched after her electric appliance quit working, the relevant cost would then be the difference between the purchase and installation prices of a new gas appliance and a new electric appliance.

Some consumers also would find electric-to-gas substitution more appealing if they perceived noneconomic benefits from natural gas, such as more heating comfort and better cooking-temperature controls. These benefits presumably are consumer-specific and secondary compared with the energy cost savings realized over the life of a gas appliance.

Finally, consumers would find energy substitution more economical when their existing appliances become either physically or economically depreciated. Economic depreciation occurs, for example, when a household has an old gas furnace that is still functional but only has a few years of life left and is costly to operate relative to a more efficient gas furnace or electric heat pump.

The following expression calculates energy cost as:

$$\text{Energy cost} = \text{Price of energy} \cdot (1/\text{Energy factor}) \cdot (\text{Usable energy}),$$

where the price of energy is expressed in Btus and the energy factor is the ratio of useable energy to energy consumed by energy-using equipment. With conventional energy efficiency initiatives, regulators readily recognize that replacing an old gas furnace with a new one will require less natural gas for producing a fixed amount of space heating. By comparing the efficiency ratings for the old and new furnace, one can readily compute the energy savings as well as the reduced energy costs.

Even though the energy efficiency of an electric appliance is generally higher, in most cases the higher price of electricity when compared with natural gas (dollars per Btu) yields a higher cost to operate the electric appliance. The ratio of energy costs from a gas appliance to an electric appliance is expressed as:

$$ec_g/ec_e = (p_g/p_e)\cdot(ef_e/ef_g)$$

where ec_g and ec_e are the energy costs associated with operating a gas and an electric appliance; p_g and p_e are the retail prices of gas and electricity; and ef_e and ef_g are the energy efficiency of converting energy into an energy service (e.g., hot water).[26] Assume that the price of natural gas is \$12 per MMBtu and the price of electricity is \$35 per MMBtu,[27] and the energy factor for an electric water heater is 0.9 and 0.6 for a gas water heater. Based on this information, the gas water heater would have an energy cost about half of that for the electric water heater. In this example, even though the electric water heater is 50 percent more energy-efficient, its energy costs are much higher because the present price of electricity is almost triple the price of gas in this assumption.[28]

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[26] These terms are sometimes called energy factors.

[27] This corresponds to a price of 12 cents per kilowatt-hour.

[28] Because electric heat pumps are highly energy efficient, their energy cost would generally be lower than the energy cost for a conventional gas water heater.

The appliance energy factor is most transparent and clear to consumers when comparing appliances using the same fuel. The appliance with the higher energy factor always operates at a lower cost, although it almost always has a higher purchase price. The relationship between total energy efficiency (i.e., energy efficiency for a full fuel cycle) and consumer energy costs may not always be negative, however. Electricity produced from renewable energy (in dollars/Btu) would have higher total energy efficiency than electricity produced from a coal plant. The electricity from the coal plant would likely have a lower price. Most consumers would pay much more attention to the price of electricity than to total energy efficiency.

Studies have shown that the most cost-effective fuel choice is closely related to the specific conditions of a home. The most significant characteristic that affects the choice is the amount of energy used in a home. Home energy use depends directly on a number of factors including house size, the thermal efficiency of the house, climate, and preferences for indoor ambient temperature. The attractiveness of specific fuels also depends on energy prices and their expected escalation rates. The decision to convert electric space and water heating to natural gas depends on the costs of conversion and getting gas service to the house. Although the effect of these conditions on cost-effectiveness is well understood, studies of electric-to-gas substitution's potential and cost have relied on average assumptions to make their estimates.

It is conceivable that a consumer could be worse off after switching to natural gas. He could mistakenly underestimate the future price of natural gas, for example, by assuming that the future price will be the present price.

Behavioral economics[29] would have the following to say about electric-to-gas substitution:

1. Real-world decisionmaking is often inconsistent with the consumer decisions that neoclassical theoretical models would suggest to be optimal or rational. Consumers make decisions in a complex environment where uncertainty, unclear transaction costs, and conflicting information prevail. An apparently rational reason for consumers to substitute one form of energy for another may be offset by these factors that make taking no action seem more sensible.

2. Policymakers can "nudge" consumers into actions that are most beneficial to the consumer. By informing consumers of their financial losses from not substituting one form of energy for another (if, in fact, losses exist), policymakers can assist consumers in making better choices.

3. The human tendency is toward "inertia," which some people would call laziness. Since deliberating over whether to substitute one form of energy for another requires effort and time, the opportunity cost for many consumers may exceed their expected benefits. Unless natural gas or some other energy source offers clear advantages

[29] *See* footnote 7.

(e.g., large cost differences), why, in view of time constraints and other matters of higher priority, should anyone spend time deliberating over energy choices?

4. Making information clearer to consumers may facilitate consideration of their choices. Making price and life-cycle comparisons between fuels easier, in addition to providing factual information on the pluses and minuses of electric-to-gas substitution, may make consumers more active.

5. In economic activities like electric-to-gas substitution, where an investment involves short-run costs that are much greater than short-run benefits, consumers may forgo change even though its returns can be high in the long run. Behavioral economists call this myopic behavior "faulty discounting." This phenomenon prevails in most markets and is difficult to thwart, especially at a low cost.

Appendix B: Measuring Energy Efficiency from Different Perspectives

Table B1 presents three different definitions of energy efficiency. It also illustrates their measurements with a numerical example for water heaters using realistic assumptions. The table highlights a number of points relevant to electric-to-gas substitution. First, electricity loses much more energy than natural gas when it is produced and transported. While the energy loss for natural gas is pretty much constant across different situations, it can vary substantially for electricity. The illustration in the table assumes a 70-percent energy loss for electricity, which corresponds closely to the national average. The relevant energy loss depends on what power plants would run less with electric-to-gas substitution.

While electric appliances generally have higher energy efficiency than gas appliances, natural gas may be more energy-efficient from source to point of energy service. Appendix A and Table B1 show this outcome even though the electric water heater is 50 percent more efficient than the gas water heater.[30] This result may not always hold, given price variations in the energy sources from one market to another and different assumptions about energy losses in electricity generation and delivery.

Within the confines of a single source of energy, energy efficiency increases anytime a consumer purchases an appliance with a higher energy factor. The result occurs, for example, when a consumer purchases an energy-efficient air conditioner that can cool the air using less electricity than the existing air conditioner. This definition of energy efficiency also corresponds to the "site" energy-usage effect of customers switching from electricity to natural gas. If, for example, electric-to-gas substitution results in ten million fewer Btus of electricity being consumed in the home (i.e., at the "site") but 15 million more Btus of natural gas consumption overall, one could argue that energy efficiency has diminished. From a full-fuel-cycle perspective, the opposite effect could occur, namely that energy efficiency increased mainly because of the energy losses avoided from the generation of electricity.

Measuring energy efficiency from source to point of use (the first definition in Table B1), which some studies have done, overstates the real energy efficiency advantage of natural gas. It does so by ignoring the typically higher energy efficiency of electric appliances.

Measuring total energy efficiency (i.e., energy efficiency for a full fuel cycle, the third definition in Table B1) is prone to potentially high measurement error for the energy losses in electricity generation.[31] In contrast, measuring the energy efficiency of appliances and fuel-using equipment is more precise.

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[30] State-of-the art electric heat pumps are an exception.

[31] Energy losses would depend on such factors as the heat rates and the location of the power plants affected, which in turn hinges on the time of day and the month of year.

Table B1: Measures of Energy Efficiency

Source (production, delivery, processing) → Point of use (energy consumed in the home for appliances or fuel-using equipment) → Point of energy service (e.g., hot water, space heating)

Definitions

1. Point of use/source (POU/S): the ratio of the Btus of energy consumed by a household (e.g., the electricity delivered to a home) to the Btus used in producing, delivering, and processing the energy

2. Point of energy service/source (POES/S): the ratio of the Btus of energy service (e.g., hot water) to the Btus used in producing, delivering, and processing the energy

3. Point of energy service/point of use (POES/POU): the ratio of the Btus of energy service (e.g., hot water) to the Btus of energy consumed by a household

Illustration

Water Heaters

	Gas	Electric	Electric Heat Pump
POES (Btu)	5000	5000	5000
POU (Btu)	8333	5556	2500
S (Btu)	9259	18520	8333
Total Energy Efficiency (POES/S)	**0.54**	**0.27**	**0.60**

Assumptions: 10% and 70% energy loss from source to home use for natural gas and electricity, respectively; 60%, 90%, and 200% efficiencies for gas, electric, and electric heat pump water heaters, respectively.