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Electrification: The nexus between consumer behavior and public policy

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ABSTRACT

With deepening concerns over climate change, policymakers, electric utilities, environmentalists and others are increasingly championing the idea of 'electrification,' or the replacement of fossil fuels with electricity for direct end uses like transportation and space heating. The electric industry sees electrification as an opportunity for revitalizing sales and revenues. The focus of this paper is on consumer behavior and its nexus with public policy for advancing electrification.

Electrification is the choice of consumers to use electricity as the source of energy for satisfying their energy-service demands. It involves the decision of energy consumers to rely on electricity rather than natural gas and other fossil fuels for specific end-use applications. These decisions can include conversion from natural gas to electricity in an existing home or installation of electric technology in a new home. In each instance, the consumer must decide on what appliance or energy-using technology to purchase.

End uses (i.e., energy services) for which electrification is feasible include transportation, space heating and cooling, water heating, agricultural pumping, cooking, and clothes drying. A small number of end uses, for example, account for 85% of the direct fossil fuel use in New York and New England: space and water heat in residential and commercial buildings; industrial process heat and steam; and light and medium/heavy duty on-road vehicles.[1] All of these end uses to varying degrees are candidates for electrification.

For the U.S., a little less than 50% of households have electric water heating, meaning that potentially the other half can convert to electricity.[2] About 25% of residential floor space in the U.S. has electricity as the primary heat source, mostly in the Southern states and the Pacific Northwest.[3] In other locations, natural gas is the predominant source of energy for both space and water heating.

The major drivers for the choice of a specific energy source in the U.S.are relative prices, climate, environmental regulation (e.g., removing coal for home use), and energy-source availability. Rural areas use little natural gas because of the unavailability of gas-distribution lines. This situation stems from the cost-ineffectiveness of extending lines to these areas. Natural gas is the energy choice in most areas where households have access to a gas-distribution main.

Table 1 shows the breakdown of home energy consumption by end use. Water and space heating together account for almost 60% of total energy consumption. These end uses are prime candidates for conversion to electricity, especially from natural gas.

As noted by the Electric Power Research Institute (EPRI), electrification has potentially diverse benefits:

Electrification – customers' shift from direct combustion of fossil fuels to electricity – has emerged as a valuable strategy for not only boosting efficiency, but also for reducing emissions at minimum cost. While acknowledging those circumstances in which it remains more efficient or less expensive to burn fossil fuels directly, there is a growing array of energy uses for which electricity is the best option – especially where pollution must be cut nearly to zero, such as in densely populated cities.[4]

In early 2017, EPRI unveiled its Integrated Energy Network (IEN) as

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[1] Asa S. Hopkins et al., *Northeastern Regional Assessment of Strategic Electrification*, report prepared for the Northeast Energy Efficiency Partnerships, July 2017, 1.

[2] U.S. Energy Information Administration, *Residential Energy Consumption Survey*, Table HC8.6, 2015.

[3] Geoffrey J. Blanford, "Long-Term Decarbonization Scenarios," presented before the EPRI-IEA Workshop: Clean Energy for Industries, Nov. 29, 2016. Over 38% of homes use electricity for space heating, which means that the average square footage of homes with natural gas exceeds that of homes using electricity. [U.S. Census Bureau, *American Community Survey*, *2016 Data Release*, 2017.].

[4] Electric Power Research Institute, *The Integrated Energy Network: Connecting Customers to Reliable, Safe, Affordable, and Cleaner Energy*, February 2017, 8.

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Table 1
Composition of residential energy consumption by end use (2009).
Source: U.S. Energy Information Administration, *Residential Energy Consumption Survey,* Table CE3.1, 2015, at https://www.eia.gov/consumption/residential/data/2015.

End Use	Percentage of Total Energy Consumption
Refrigerators	4.8%
Air conditioning	6.2
Water heating	17.7
Space heating	41.5
Other appliances and lighting	29.8

a "pathway" to a more efficient, reliable and productive energy system. It identified requisite key actions, technology development, policy, regulation, and standards. One component is what it calls "efficient electrification." EPRI has made several presentations before different groups touting the IEN concept.

Climate advocates consider electrification as essential for transforming the energy sector to meet stringent climate goals (for example, curtailing carbon by 80% by 2050, or what analysts call the "80 by 50" scenario). According to some analyses, completely decarbonizing the electric sector would only reduce greenhouse gas (GHG) emissions by less than half of the 80% target.[5]

The electric industry sees electrification as an opportunity for revitalizing sales and revenues. A growing number of utilities now view electrification as an integral part of their future business plan. With smart dispatching, utilities can realize the added benefit of optimizing their load shape from electrification of transportation and water heating.

This paper starts with the premise that electrification is fundamentally an economic activity for which rational consumers aim to maximize their welfare from energy services subject to given market and other conditions. Departures from this premise have implications for public policy[6] in promoting electrification or allowing the market on its own to determine the level of electrification.

1. Core economic issues

1.1. New technology diffusion

Oftentimes, a technology that appears to surpass competing technologies in performance and cost will still have a low market share compared with existing technologies. A key policy question is whether this slow diffusion reflects rational actors responding to dissimilar incentives or a consequence of market inefficiencies and undue barriers.

The fact that those who adopt the new technology are enjoying net benefits should not infer that non-adopters are depriving themselves of similar benefits. The latter group can face dissimilar conditions (e.g., low energy use) and have unlike preferences that would make it rational for them to delay adopting the new technology. An often overlooked factor is a consumer expecting the future cost of the technology to decline over time, which means waiting to purchase the technology may be rational even though the consumer is forgoing benefits today.

One explanation for the S-shaped path is, therefore, potential technology adopters facing different conditions so that the economics of a new technology varies across potential users. The benefits of a new technology are both customer- and site-specific. Consumers are heterogeneous, assigning different benefits to a new technology. Some have a low risk tolerance, which translates into a higher discount rate in valuating future benefits. Empirical studies have shown that high individual discount rates, for example, can have a large effect on the adoption and diffusion of new energy-efficiency technologies.[7]

Another explanation S-shaped path is the intrinsic risk from investing in a new technology. This risk requires a potential user to acquire much information on both the generic features of the new technology and its use in the particular application under consideration.[8] These transaction costs can be significant relative to the magnitude of the net benefits of technology adoption.

1.2. Market and consumer-behavioral problems

A first-order area of inquiry for policymakers should be to evaluate whether market imperfections, consumer-behavioral problems, or regulatory obstacles are preventing energy consumers from rational and socially desirable decisions. Market barriers and imperfections, by definition, hamper consumers to make optimal decisions. These problems have rationalized utility energy-efficiency initiatives.[9] For example, the presumption is that utility customers underestimate the benefits of cutting back on their electricity usage or fail to invest in energy efficiency because of high upfront costs.

There is the legitimate question of whether policymakers should have an interest in how well consumers make energy choices. After all, since consumption is basically an individual or private-business matter, out-of-market intervention would seem ill-advised.[10] Yet, policymakers and regulators involve themselves with energy efficiency, which is just the obverse of consumption; namely, they try to induce consumers to use less electricity under the premise that the marketplace provides inadequate incentives or erect excessive barriers.[11] Either market problems (e.g., too-low electricity prices) are causing this or consumers are irrational ("behavioral problems") when it comes to curtailing their energy usage. The latter problem would cause consumers' actual behavior to deviate from what is optimal from their perspective. Consumers, in other words, err in their decisions to do what is in their best interest.

1.2.1. Sources of 'non-optimal' consumer behavior

The field of behavioral economics asserts that the real world fails to work according to neoclassical economics.[12] Both rational and

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[5] *See*, for example, Jurgen Weiss, "Electrification: Opportunities for Multiple Win Wins?!" presented before the Repowering the Western Economy, June 1, 2017.

[6] Public policy could derive from either the local, state or federal level. This paper assumes that state utility regulators can originate policy, although states vary as to the authority given to regulators versus the legislature and the executive branches of government to create policy. Some states restrict regulators to only enforce the policy developed by the other branches of government.

[7] *See*, for example, Jerry A. Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *The Bell Journal of Economics*, Vol. 10, No. 1 (Spring 1979): 33–54.

[8] *See*, for example, Adam B. Jaffe et al. *Technological Change and the Environment*, RPP-2001-13 (Cambridge, MA: John F. Kennedy School of Government, October 2001), 41.

[9] For a list of barriers to electrification, *see* supra note 1. A later section of this paper discusses some of these barriers. The policy challenge is to determine which of these barriers justify out-of-market intervention and which ones are normal for markets with new technologies.

[10] Consumers are free to make their consumption decisions subject to their preferences and budget constraints (i.e., income and net wealth). Consumers try to choose energy choices that will provide service at least cost and fulfill other sources of satisfaction like high service reliability, low carbon footprint, and tolerable price risk. From the consumer's perspective, the cost-effectiveness of electrification depends on several factors with price being a primary one. Consumers' behavior includes three separate decisions. The first is whether to purchase the energy-using technology (e.g., an air conditioner) as an input to an energy service like cooking, heating, lighting, and cooling. The second involves the characteristics of the technology to be purchased (e.g., the energy efficiency rating and cooling capability). The third involves the intensity and frequency of the technology's use (e.g., hours of operation of an air conditioner).

[11] The economics of switching energy sources to electricity have similarities with energy efficiency: (a) presumably large environmental benefits, (b) large upfront costs for consumers, (c) long-term net payoffs (in some instances quick payback), and (d) similar barriers, namely, market, regulatory and consumer-behavioral bias preventing socially optimal decisions. A technology like electric heat pumps can also promote energy efficiency by requiring less primary energy, since they move heat rather than create it from combustion in (say) a gas furnace.

[12] Behavioral economics combines economics and psychology to explain why people sometimes make "wrong decisions." It assumes "bounded rationality," where people