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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

[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

irrational factors explain why consumer behavior can deviate from optimality:

1. Consumers have imperfect information.
2. Consumers' chief concern is the economic effect on themselves, not on society as a whole (e.g., the environment).
3. Consumers undervalue future benefits, resulting in required payback periods shorter than economically justified (i.e., myopic consumers).
4. Inertia (or status-quo bias) reflects the reluctance of rational risk-averse consumers to change energy sources because of uncertain outcomes that could make them worse off.
5. High transaction costs make it more costly or inconvenient for consumers to switch energy sources.
6. Even with a shift to electricity that will save money and improve the environment, a consumer might worry about electricity price volatility and view the environmental benefit as trivial.
7. Inefficient rate designs that deviate from the full costs of producing and delivering energy would likely induce consumers to make uneconomic energy choices.[13]
8. Heuristics or so-called rules of thumb over-simplify the decision-making process.
9. Energy consumers choosing appliances and other durable goods tend to focus on the initial installation cost, not the life cycle cost.

1.2.2. Digression on consumer-behavioral problems

Even in well-functioning markets, consumer-behavioral problems can hamper optimal consumer decision-making. Behavioral problems can justify governmental intervention beyond the standard market-failure reason. One line of action is out-of-market assistance in private decision-making – even in a well-functioning market – when people know what is in their interest, but are still unable to make "correct" choices.

Analysts have referred to this new age form of intervention as soft or libertarian paternalism.[14] The nomenclature refers to preserving people's freedom of choice while guiding them in a direction that improves their lives. For example, people need sin taxes and outright bans to protect themselves from their own self-destructive biases and lack of self-control. In the context of electrification, this might require prohibiting or discouraging people and businesses from consuming fossil fuels even though they know that such fuels could have a disastrous effect on climate. Such a policy would be draconian, but conceivable in practice if interest groups are successful in convincing policymakers that the stakes are that high. Specifically, if environmentalists are able to persuade policymakers that they should aggressively promote electrification to avoid climate catastrophe – and the sooner the better – tight constraints on fossil-fuel consumption might ensue. Such action could have a high social cost, but myriad examples exist where a public policy has incurred economic costs far beyond the realized benefits.

We know that when consumers make energy choices efficiently, they serve society well in the absence of any governmental involvement. The questions are then:

1. Do consumers make rational (or good) choices, or is out-of-market intervention necessary to ensure a more socially desirable outcome?
2. What factors should exist to justify out-of-market intervention in consumers' energy choices?
3. If intervention is necessary, what forms are more defensible than others?

The objective is to guide Policymakers, such as state utility regulators, in placing electrification in a context that would allow them to make decisions for the public good. In the absence of policies redressing environmental and national-security externalities, an evitable gap exists between the market rate of adoption of new technologies and the socially efficient rate of adoption.[15]

1.3. Is there an electrification gap?

There are several ways to view this gap. At its core, it refers to a nontrivial difference between observed levels of electrification and some notion of optimal electrification. Analysts often will calculate a discount rate for placing future benefits in present-value dollars to determine whether a "gap" exists. The problem with this approach is that typically the analyst will fail to account for the irreversibility of investments in new technologies as well as the uncertainty over future benefits. The implicit discount rate for consumers' decisions is therefore higher, with the "gap" narrowed or closed completely.[16]

A relevant question for policymakers is whether private economic decisions about the chosen level of electrification by energy consumers are economically efficient. The answer depends on both market conditions consumers face – for example, energy prices, information availability – and the economic behavior of individual consumers in response to those conditions. If policymakers find the existence of a "gap," the question then becomes how to redress it cost-effectively.[17]

2. Public policy options

In the absence of a national policy to cap or tax carbon emissions, the accelerated development of low- or zero-emitting energy technologies through a combination of standards and incentives has become the principal policy strategy for mitigating climate change. For electrification, similar policies would include restricting the consumption of fossil fuels for end uses and distributing subsidies to consumers who choose electricity for space and water heating. This section advises policymakers that before taking such actions they should articulate a

(*footnote continued*)
make decisions with less-than-perfect information because of limited time and mental capacity. People often exhibit what economists call "rational ignorance." The behavioral economics literature draws heavily upon cognitive psychology to inform experimental, observational, and theoretical analyses on understanding how consumers make decisions. See, for example, Richard H. Thaler and Cass R. Sunstein, Nudge: Improving Decisions about Health, Wealth, and Happiness (New Haven, CT: Yale University Press, 2008); and Robert H. Frank, The Economic Naturalist: In Search of Explanation for Everyday Enigmas (New York: Basic Books, 2007).

[13] Economic regulation of retail electricity markets generally results in prices deviating from marginal costs, and this difference can distort incentives for energy choice. If regulated prices are above marginal cost, then regulation contributes to an "electrification gap," although the opposite can also be true; namely, an excessive amount of electrification from uneconomically low electricity prices.

[14] *See*, for example, Cass R. Sunstein and Richard H. Thaler, Libertarian Paternalism Is Not an Oxymoron, *The University of Chicago Law Review*, Vol. 70, No. 4 (Autumn 2003): 1159–1202.

[15] Frank J. Convery, Reflections: Energy Efficiency Literature for Those in the Policy Process, *Review of Environmental Economics and Policy*, Vol. 5, Issue 1 (January 2011): 172–91; and Adam B. Jaffe and Robert N. Stavins, The Energy Paradox and the Diffusion of Conservation Technology, *Resource and Energy Economics*, Vol. 16, Issue 2 (May 1994): 91–122.

[16] Another way of saying this is that one possible obstacle to investments in a new technology is the high uncertainty over future benefits. When consumers perceive high risk because of uncertainty over future electricity prices and the performance of the technology, they will demand a higher expected rate of return. High discount rates to account for uncertainty are a normal market feature that falls outside the definition of a market failure. The discount rate reflects the tradeoffs that consumers make between initial capital costs and future energy savings and the other benefits from electrification.

[17] For utility energy-efficiency programs, the presumption is that if these programs can reduce energy use at less than the cost of energy, they economically correct for a market failure. Most state regulators apply the cost-effectiveness test to evaluate utility energy-efficiency initiatives. Under the total resource cost (TRC) test, for instance, the utility compares the cost savings from producing, transporting, and distributing less electricity with both the utility and customer costs for energy efficiency. It implicitly presumes that suboptimal energy efficiency derives from unidentified market and consumer-behavioral problems unrelated to price distortions. Passing the TRC test therefore translates into cost-effective, energy-efficiency initiatives that supposedly counteract these problems.

Table 2
Multistep approach for policymakers.

Step	Comment
Review the end-use energy market	Need for better understanding of the market before taking any action
Evaluate its economic efficiency	Comparison of the actual market with a well-functioning market
Detect undue barriers ("electrification gap")	Obstacles to electrification, segmented by normal market forces and artificial barriers
Identify the preferred policy response	Alignment of the best policy response with a specific undue barrier
Conduct cost-benefit analysis	Measurement (to the extent possible) of the benefits of a policy response along with its costs
Execute policy action	Cost-beneficial action to improve market performance (i.e., economic efficiency)
Evaluate action ex post	Periodic review of action in light of changing market and other conditions

rationale and determine whether they are cost-beneficial.

2.1. A multi-step approach

2.1.1. The seven steps

Policymakers can take several steps for justifying a specific action on electrification (Table 2), with the goal of achieving a cost-beneficial outcome.[18] First, they can determine whether an electrification gap exists because of undue barriers. This requires understanding the market for electricity as well as for other energy sources. Part of this review would include how electrification has evolved over time for specific end uses.

Policymakers can then evaluate the overall end-use energy market. When the diffusion of certain electric technologies appears "slow," it becomes imperative for policymakers to know the reasons: Do they relate to market and consumer-behavioral failures, or are they just simply normal market forces (as discussed earlier)?[19] This leads to identifying any specific undue barriers, defined here as an obstacle to socially beneficial electrification.[20] One example of an undue barrier is policymakers giving unsupported favors to fossil fuels to increase their attractiveness to energy consumers. This imposes an "obstacle" for electricity, placing it at an uneconomic disadvantage, which jeopardizes both economic efficiency and equity.

Policymakers should distinguish between artificial and natural market barriers, with the former category warranting consideration for out-of-market intervention. A *natural barrier* is a consumer's rational response to risk and uncertainty by hesitating to adopt new electric technologies. An *artificial barrier* includes regulatory rules that unduly discourage electric utilities from promoting electrification. Policymakers should always try to mitigate artificial barriers, which, by definition, derive from market imperfections, consumer-behavioral problems or flawed regulatory practices, as long as the benefits exceed the costs of mitigation.[21] Mitigating natural barriers, on the other hand, would likely lead to a negative outcome. Stakeholders often lobby regulators to eliminate barriers that supposedly disfavor their preferred energy technology or energy source. Frequently, these barriers are simply normal market conditions whose mitigation would create a cost (e.g., via subsidies) greater than the benefits.[22]

Each identified undue barrier has a preferred policy response. If the problem is lack of adequate consumer education on new electric technologies, then the proper response is dissemination of more information. Policymakers should align any actions with an identified undue barrier. Otherwise, what is likely is a policy, although perhaps well-intentioned, that achieves suboptimal effectiveness in costs and performance.

Policymakers should calculate the net benefits for each policy action. Of course, this is easier said than done. How do regulators, for example, quantify the benefits of an action that makes electrification more attractive?

After following these steps, policymakers can then decide whether to take action, or no action, and rationally defend it. As a final step, even after executing a policy, policymakers should conduct periodic reviews to determine whether the underlying undue barrier (the premise for the action) still holds.

Overall, this multistep approach is a process for taking rational actions with the goals of improving market performance and advancing the public interest. It is preferable to taking action that achieves some goal, like carbon reductions, in the absence of a cost-benefit analysis.

2.1.2. Discussion

Economists have advocated that the best public policies to improve market performance are those individually tailored to address specific market failures. In more recent times, economists have suggested policies to address consumer-behavioral failures could also improve market performance.[23]

Listing barriers, and showing how they might stifle electrification, is relatively simple. Recommending appropriate action is a more challenging task. Which of them, for example, require any action by state utility regulators has no easy answer. One alternative is for regulators to address barriers on a case-by-case basis. For example, some utilities have time-variant rates that encourage electric vehicles (EVs), while others do not. Some barriers would require no action, as they reflect normal market features that buyers and sellers of electric technologies can best overcome themselves in the marketplace.

Some electrification proponents have identified barriers to electrification that have stifled its advancement. One presumption is that the current level of electrification is below the socially desirable level, largely because of unpriced carbon. A complete analysis would include other factors that might unduly discourage (or even encourage) electrification.

One area of focus is identifying obstacles that unduly restrict electric technologies and position them at an economic disadvantage relative to alternative technologies. A disadvantage, as defined in this paper, occurs when a barrier imposed by government or a market failure unduly impedes the growth of electrification. Some advocates of subsidization for electrification implicitly apply a broader definition of barriers that

[18] There is surprisingly little research on energy efficiency and even less on electrification that have attempted to better understand (a) exactly what the relevant barriers are or (b) alternative approaches to assist consumers in making decisions that are more aligned with their self-interests.

[19] As an example of normal market forces, electric heat pumps are more cost-effective in regions of the country that have mild winters and relatively low electricity prices. Heat pumps also have higher capital or upfront costs than other heating alternatives. [https://asm-air.com/hvac/heat-pump-vs-furnace-pros-cons/, and *supra* note 1] There is the cost of heating upgrades along with building retrofits. For cooking, according to various surveys most consumers prefer natural gas over electricity. Low turnover of electric equipment means that any electrification would follow a gradual growth.

[20] One example is customer bias that causes an underuse of electricity for specific end uses.

[21] Policymakers should also determine whether mitigation achieves net benefits that are larger than if they spend the same money on alternative actions.

[22] The benefits of subsidies, for example, to the electric industry and recipients would fall short of the costs of the subsidy funded by utility consumers or taxpayers. A subsidy to

(*footnote continued*)
lower the price of an advanced electric technology may only have this temporary effect, as it may drive out the utility's competitors in the long run.

[23] The basic argument is that consumers face numerous barriers to making rational long-term, energy-related investment and "operating" decisions.

risks unwarranted out-of-market intervention. They tend to recommend any mitigation of barriers whether cost-beneficial or not. This acts against society's interest, and is contrary to good public policy and basic economics.

2.2. Policy directives

2.2.1. Incentives or mandates?

Two general policy options are promotional activities (e.g., incentives) to encourage electrification and mandates to require it. The question then turns to which of these approaches is more socially beneficial. Some regulators would consider, for example, issuing mandates that utilities invest in certain new technologies (e.g., infrastructure for EVs). They can justify a mandate (e.g., "command-and-control" regulation) with the belief that a technology is in the public interest but, for whatever reason, utilities fail to invest in it. Mandates can also increase the surety of a certain outcome regarded as socially desirable by policymakers.[24]

Mandates carry risks, however. Mandates requires policymakers to pick winners and losers, which is inherently a difficult task given the limited knowledge of policymakers.[25] The problem is particularly acute for new technologies with a high level of uncertainty over cost and performance. For example, a policy that mandates "electrification" technologies as a preferred resource can backfire if the price of natural gas falls sharply, or those technologies fail to develop economically and technically as anticipated. The problem is that utilities operate in a dynamic world where conditions can rapidly shift the relative economics of different technologies.

2.2.2. Regulatory corrections

Out-of-market interventions would attempt to mitigate or eliminate any market or consumer-behavioral distortion. Tailoring each intervention to a particular market or behavioral problem would reflect sound policy. Well-functioning markets require no outside intervention. In fact, intervention in such markets risks inefficiencies that diminish social welfare (i.e., constitute regulatory or governmental failure).

A micro perspective in rationalizing out-of-market intervention is superior to using macro data. Macro studies are unable to accurately calculate the benefits and costs for individual customers in a particular environment.[26] Their design also precludes them from detecting market and consumer-behavioral problems. Instead, policymakers should rely on market characteristics and performance rather than on simplistic economic analysis at a 50,000-foot level, as the basis for action.

Policymakers have available five general categories of options to stimulate more electrification: Mitigation of market and consumer-behavioral problems, lowering of technology costs (e.g., via research and development, or R&D), mandates, additional incentives, and education and marketing. For utility regulators, these options can involve the following specific actions:

1. Improve the quality of information offered to utility customers;
2. Review rate structures of both electric and gas utilities to eliminate any regulatory favoritism toward either energy source;
3. Identify any artificial obstacles to increased electricity usage[27];
4. Review any existing restrictions on utility promotional practices to determine if they deny utility customers critical information to make rational choices;
5. Conduct pilot programs to assess the feasibility and economics of electrification of buildings (e.g., with electric heat pumps); these programs can overcome regulators' skepticism of new "electrification" technologies; and
6. Recognize that if regulatory policy encourages customer to switch from natural gas to electricity, natural gas utilities will experience under-recovery of fixed charges, requiring regulator's to consider alternatives means of compensation for this stranded cost.

One "hot" issue today involves social benefits from EVs extending beyond those received directly by direct beneficiaries (i.e., social benefits exceed private benefits): Is it appropriate to spread the additional costs from accommodating EVs to all customers? Assume that the benefits from EVs include a cleaner environment and less dependency on foreign oil. Regulators might approve the recovery from all utility customers of costs associated with promoting EVs and investing in additional infrastructure. On the other hand, if the utility and EV owners primarily benefit from EVs, the risks of utility actions should exclude the general ratepayer. In this instance, a policy of balancing the risks and benefits would have utility shareholders and EV owners shouldering the entirety of the risks.

2.2.3. Potential costs

Governmental intervention can produce benefits by eliminating economic-efficiency and other social losses from market defects and customer "error." Policies can also lead to net costs when intervention is unwarranted, either because of: (1) markets performing adequately[28] (if not perfectly), or (2) intervention that fails to mitigate a market or consumer-behavioral problem cost-effectively (creating waste or excess costs).

The potential costs of regulatory intervention can come from several sources:

1. Inadvertent subsidies (e.g., improper price signals leading to resource misallocation; favoritism toward one energy source)[29];
2. Procedural delays and costs, especially with multi-utility integrated resource planning (IRP)[30];
3. Welfare losses from stakeholders expending dollars and resources in the regulatory process to advance their positions – namely, "fighting costs" from natural gas utilities and other stakeholders opposing electrification, counteracted by electric utilities and other advocates supporting electrification;
4. Administrative costs (e.g., enforcement cost of regulatory mandates

[24] If energy consumers are unresponsive to incentives like carbon taxes, then mandates become more tenable, especially if it is critical to attain some GHG emissions target to avoid climate catastrophe.

[25] The classic problem for regulators is that they observe only a utility's performance, not the effect of management effort on cost, service quality and other outcomes affecting consumer welfare. Information asymmetry has two major implications. The first is that utilities can misrepresent their performance to regulators. The second, which is more relevant here, is that regulators need to exercise caution in requiring utilities to take specific actions. Regulators could wrongly prescribe an action because of limited knowledge. *See*, for example, Paul L. Joskow, Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks, prepared for the National Bureau of Economic Research Conference, Jan. 21, 2006.

[26] A macro review could include an economic analysis that applies the right framework but takes average data. Since consumers are heterogeneous, outcomes which on average are cost-effective may fail to hold true for most homes or businesses. Macro studies also often omit certain obstacles and local conditions faced by consumers, causing them to make a rational decision that conflicts with what the studies predict.

[27] Such an approach would entail a regulator reviewing whether its policies and other actions have unduly favored one energy source over another. What actions, for example, would cause consumers to prefer natural gas over electricity when it would be in society's interest for them to switch to electricity?

[28] Placing a price on carbon would penalize most those energy sources that emit the highest levels of carbon. If, for example, natural gas has higher carbon emissions than electricity, the price of natural gas would increase more, which would make electricity increasingly attractive to consumers. One of the major arguments for regulatory-induced electrification would become moot.

[29] Subsidies, especially when poorly structured, can be (a) unfair to funding parties (e.g., ratepayers or taxpayers), (b) economically inefficient, and (c) unfair to competing energy sources. Overall, subsidies are likely to fail a cost-benefit test from an aggregate economic-welfare perspective.

[30] Some proponents of multi-utility planning view it as a way to encourage energy consumers to switch to electricity. One alternative is to create an IRP process that includes electrification as an option along with supply resources and energy-efficiency initiatives.

or targets);

5. Disruption of robust competition between electricity and natural gas in certain regions and for specific end uses; subsidizing electricity, for example, would lessen the competition between the two energy sources and harm energy consumers in the long run; and
6. Incorrect actions because of imperfect information (e.g., uncertainty over future electricity prices).

2.3. Recap of policy principles

From the previous discussion, certain principles should dictate out-of-market actions to promote electrification. First, policymakers should aim for the mix of market and governmental influences that would maximize social benefits, or more narrowly economic efficiency. Policymakers should re-examine periodically the need for any outside intervention, as facts and conditions change.

Second, intervention becomes justified only when market defects or consumer-behavioral problems produce unsatisfactory results of a severity that justify the cost of intervention. Government policies frequently cause counterproductive results or mitigate a problem at a higher-than-necessary cost.[31] Policymakers should therefore evaluate the benefits of any proposed action against their costs. Justification for governmental intervention anytime a market operates non-optimally is extreme, since few markets are purely optimal.

Third, any outside intervention should address market or consumer-behavioral problems directly. This requires policymakers to (1) identify the sources of any market barriers or consumer-behavioral problems over which they have some influence and (2) evaluate the magnitude of their distortive effect on consumers' energy choices. If consumers, for example, fail to electrify their appliances because of inefficiently high electricity prices, utility regulators should consider lowering those prices.

Fourth, the default should be private markets determining the energy choices of consumers. In almost all U.S. sectors, whether energy or nonenergy, the market is the primary institutional arrangement for consumer decision-making.

Fifth, market players are most often the best source for suppressing barriers. An argument against intervention is that some barriers reflect normal market features best addressed, over time, by buyers and sellers of electric technologies.[32] Lowering capital costs from advancements in electric technologies exemplifies an expected market response to improving the economics of those technologies. The presumption is that the market would have sufficient motivation to innovate when expected returns adjusted for risk are sufficiently high. Other barriers to electrification can, however, justify governmental/regulatory interventions with the condition that they produce net benefits.

3. Closing comments

This paper poses the following question: Do end-use markets for energy operate well and in the interest of customers and society at large? In most instances, consumers express their choices and make the best decisions from their perspective, given the market within which they participate. With minimal market and consumer-behavioral problems, little justification exists for out-of-market intervention. For various reasons, however, markets sometimes fail to operate the way they should and consumers err in maximizing their well-being, justifying at least consideration of outside intervention. Policymakers should exhibit prudence as intervention can fail a societal cost-benefit test when misdirected.

Probably the two biggest barriers to electrification today are high upfront costs and low fossil fuel prices. They extend the payback period for electrification so as to diminish its economic appeal. The future holds more promise for electrification if technical improvements lower the cost of heat pumps, EVs and other advanced electric technologies, and the surplus of natural gas and oil diminishes.[33] A high penetration of unsubsidized EVs will demand not only continued innovation but also success in outpacing fossil fuels whose supplies and prices portend their economic viability for the foreseeable future.

Before proceeding with any action, policymakers should ask themselves what benefits electrification offers relative to the costs. It is unlikely that any jurisdiction would realize net benefits if the intent of accelerated electrification is solely to mitigate carbon emissions. It is somewhat puzzling, for example, why a state on its own, without cooperation from other states or the federal government or other countries, would revamp its energy sector (which massive electrification would do) at a high transition cost for something that would largely benefit the rest of the world, namely the mitigation of climate change from lower-carbon emissions.[34]

In the absence of a carbon tax or a cap-and-trade plan, policymakers face a tougher challenge of knowing how much electrification is cost-effective relative to other carbon-mitigation options and the continued use of fossil fuels as a dominat energy source. A carbon tax would likely give electrification a big boost. For example, heat pumps would become more economical in a larger number of regions in the country.[35]

Policymakers must account for electrification demanding substantial capital and stranding the assets of the fossil-fuel industry. Electrification would require significant capital costs to make electricity generation less carbon-intensive,[36] and for replacement of the existing infrastructure that supports fossil fuels in vehicles and buildings. The question of who pays for these capital additions and replacements should capture the attention of policymakers.

One often overlooked topic is the crucial role of R&D in the long-term economic viability of new technologies.[37] The private sector tends to underinvest in innovation and basic research.[38] The reason stems from the public good problem caused by a company's less-than-full appropriation of the benefits from innovation.[39] This is a form of market failure (i.e., a positive externality) that rationalizes government spending on R&D, especially for basic research. The long-term success

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[31] *See*, for example, 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," *Journal of Law and Economics*, Vol. 22, No.1 (April 1979): 107-39. As an illustration, a regulator might want to bolster heat pumps by allowing a utility to offer rebates. The aggregate cost of this subsidization to customers as a whole might exceed any benefits derived from the rebates. On the other hand, doing nothing might produce inferior market performance when serious market problems prevail. If, for example, there is little information on the benefits of heat pumps, consumers could forgo a technology that would benefit them.

[32] Recent advances have brought into the marketplace grid interactive water heaters controllable over very short time intervals and with near instantaneous response. These features allow them to provide frequency regulation and other grid balancing services that are particularly valuable on electric systems with rapid and unpredictable fluctuations in supply. [Ryan Hledik et al., "The Hidden Battery: Opportunities in Electric Water Heating," White Paper prepared by The Brattle Group, January 2016.].

[33] As a counter effect, the falling demand for fossil fuels would lower their prices, making them more attractive relative to electricity.

[34] With climate change reflecting a many-nations "commons" problem, any policy to combat it should require worldwide cooperation to negate the free-rider problem.

[35] *Supra* note 3.

[36] *See*, for example, Christopher T.M. Clack et al. Evaluation of a Proposal for Reliable Low-Cost Grid Power with 100% Wind, Water, and Solar, *Proceedings of National Academy of Sciences of the United States of America*, Vol. 114, No. 26 (June 2017): 6722–27.

[37] There is the issue (as previously discussed) of whether current constraints on electrification are primarily technological in nature or the result of under-adoption of existing cost-effective technologies.

[38] Some observers have pointed out that efficient electrification will require not only innovation in technology but also in public policy, regulation, the utility business model, and market design. "Efficient" here refers to cost-effectiveness in achieving a cleaner energy future.

[39] Innovation involves new knowledge, which embodies a public good: If someone produces knowledge, others can benefit from it without paying for it (i.e., others are "free riders"). Thus, the person producing it will be unable to collect the full value of the knowledge she created.

of electrification will depend critically on new technological developments that will improve its economics and acceptability to a larger segment of society.

"Artificial" electrification induced by subsidies and other monetary incentives can be a win–win for electric utilities and the environmentalists, but questionable for the rest of society. The problem of new electric technologies funded by utility customers and taxpayers with only a distinct minority benefitting is hard to avoid. It would likely have a regressive effect by disproportionately benefiting higher-income households, while being funded by all income groups. "Artificial" electrification can also have a negative effect on economic efficiency, especially when it misaligns public policies with actual market or consumer-behavioral problems.

In closing, policymakers need to do more homework before they extol the wonders of electrification. In the meantime, they can capture the low-hanging fruit by identifying any undue obstacles to socially beneficial electrification. This would achieve the objective of placing different energy sources on a level playing field.

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