

Assessing the Energy-Efficiency Gap[†]

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Energy-efficient technologies offer considerable promise for reducing the financial costs and environmental damages associated with energy use, but it has long been observed that these technologies may not be adopted by individuals and firms to the degree that might be justified, even on a purely financial basis. We survey the relevant literature on this “energy-efficiency gap” by presenting two complementary frameworks. First, we divide potential explanations for the energy-efficiency gap into three categories: market failures, behavioral explanations, and model and measurement errors. Second, we organize previous research in terms of the fundamental elements of cost-minimizing energy-efficiency decisions. This provides a decomposition that organizes thinking around four questions. First, are product offerings and pricing economically efficient?[‡] Second, are energy operating costs inefficiently priced and/or understood?[‡] Third, are product choices cost minimizing in present value terms?[‡] Fourth, do other costs inhibit more energy-efficient decisions?[‡] We synthesize academic research on these questions, with an emphasis on recent empirical findings, and offer suggestions for future research. (JEL D24, D82, L94, L98, O33, Q41, Q48)

1. Introduction

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Global energy consumption is on a path to grow 30–50 percent over the next twenty-five years, bringing with it, in many countries, increased local air pollution and greenhouse gas emissions. Adoption of energy-efficient technologies could potentially reap both private and social returns, in the form of economic, environmental, and other social benefits from reduced energy consumption. In response, governments and firms around the world have adopted policies and programs to increase energy efficiency and capture these benefits. Still, there is a broadly held view that various barriers to the adoption of energy-efficient technologies have prevented the realization of

TABLE 1
PRIVATE AND SOCIAL CONCEPTIONS OF THE ENERGY-EFFICIENCY GAP

Potential explanations	Private gap	Public gap	Social gap
Innovation/adoption spillovers, market power, imperfect information		X	X
Too-low energy prices due to unpriced externalities		X	X
Biased beliefs about energy prices and energy usage	X		X
Inattention to operating costs, myopia, and cognitive limitations	X		X

a substantial portion of these benefits. Our purpose is to survey, synthesize, and advance understanding of economics research on this “energy-efficiency gap.”

We distinguish between two closely related notions of the energy-efficiency gap based on whether they are defined relative to private or social optima. We designate the “private energy-efficiency gap” as the apparent reality that some energy-efficiency technologies that would pay off for adopters are, nevertheless, not adopted. This basic definition highlights potential deviations from private optimality, and has often been referred to as the “energy paradox” in prior work. More broadly, we use the term “social energy-efficiency gap” to encompass energy-efficiency decisions where technologies that would be socially efficient are not adopted.

The private energy-efficiency gap is nested within the scope of the social energy-efficiency gap (table 1). We view the broader social energy-efficiency gap as the appropriate lens through which to evaluate the potential net benefits of government policy, and therefore use the broader definition to define the scope of this review. Hence, we follow the convention from previous literature of using the phrase “energy-efficiency gap” to refer to deviations from either private or social optimality.

Over the last several decades, a number of scholars have observed that cost-effective energy-conservation technologies appear to

diffuse at suboptimal rates. Shama (1983) and the US Department of Energy (1991/1992) noted the paradoxically slow rate of penetration of various energy-conservation technologies, and Jaffe and Stavins (1994a) provided a conceptual framework for thinking about possible explanations. Noting this phenomenon, some analysts and advocates have argued that government intervention to promote energy efficiency could produce environmental benefits at little or even negative economic cost. At the same time, the US federal government, states, and other countries have implemented policies to promote energy efficiency. But the veracity of this argument and economically efficient public-policy responses depend crucially on the underlying causes of the energy-efficiency gap.

Why do decision makers underinvest—or at least appear to underinvest—in energy-efficient technologies, relative to the predictions of some engineering and economic models? Explanations fall into three broad categories: (1) market failures, (2) behavioral explanations, and (3) modeling flaws.

Potential market-failure explanations include: information problems (such as principal-agent issues affecting decisions about the adoption of energy-efficiency technologies in renter-occupied commercial and residential properties, and asymmetric information); energy market failures (including environmental and national-security

externalities, and average-cost electricity pricing); capital-market failures (such as liquidity constraints); and innovation market failures (such as information spillovers from research and development).

Potential behavioral explanations include: inattentiveness and salience issues; myopia or short sightedness; bounded rationality and heuristic decision making; prospect theory and reference-point phenomena; and systematically biased beliefs.

Finally, modeling-flaw explanations refer to reasons why the observed rate of diffusion of energy-saving technology may not be as paradoxical as it may at first appear. Evidence for the gap typically involves assumptions about the economic costs and energy use of alternative product choices, the usage profile and characteristics of consumers, and interactions among these factors. Predictions founded on incorrect assumptions could misstate the size of the energy-efficiency gap. These are model and measurement explanations and include: unobserved or understated costs of adoption; ignored product attributes; heterogeneity in benefits and costs of adoption across potential adopters; use of incorrect discount rates; and uncertainty, irreversibility, and option value.¹ In the context of Joseph Schumpeter's classic trio of invention, innovation, and diffusion, our investigation focuses primarily—but not exclusively—on diffusion (adoption).²

¹For additional discussion of the energy-efficiency gap using this taxonomy of market failures, behavioral effects, and measurement flaws, see Gillingham, Newell, and Palmer (2009) and Gillingham and Palmer (2014). Allcott and Greenstone (2012) suggest the energy-efficiency gap is substantially smaller than it appears to be, emphasizing the role of model and measurement errors.

²On innovation, see Newell, Jaffe, and Stavins (1999) and Hall and Rosenberg (2010). For a review of technological change and the environment more generally, of which energy-efficiency technological change is one component, see Jaffe, Newell, and Stavins (2002); Jaffe, Newell, and Stavins (2005); and Popp, Newell, and Jaffe (2010).

To provide structure to the many economic elements that enter into adoption decisions related to energy efficiency, we find it useful to think in terms of the fundamental elements of cost-minimizing energy-efficiency decisions. This decomposition is deliberately simple in order to highlight the main features of the issue, and does not explicitly account for all of the factors we consider in our analysis, such as uncertainty, the dynamic nature of decisions (and resulting option value), and heterogeneity:

$$\underbrace{\text{min Total Cost}}_{\text{objective}} = \underbrace{K(E)}_{\text{equipment purchase cost}} + \underbrace{O(E, P_E) \times D(r, T)}_{\text{discounted operating costs}} + \text{other costs}$$

Where $K(E)$ = equipment purchase cost;
 E = annual energy use;
 $O(E, P_E)$ = annual operating cost;
 P_E = price of energy;
 $D(r, T)$ = present-value factor;
 r = discount rate; and
 T = time horizon.

Based on this decomposition of cost-minimizing energy-efficiency adoption decisions, we organize our synthesis of existing literature around four fundamental questions and a total of twenty-three sub-questions. Referring to the first term of the above equation, we ask whether product offerings and pricing are economically efficient. This question is examined in section 2 of the paper.

Then, in section 3 of the paper, we ask whether energy operating costs are inefficiently priced and/or understood. In section 4, referring to the entire equation, we ask whether product choices are cost minimizing in present-value terms. Finally, in section 5,

we focus on the final term in the above equation and ask whether other costs inhibit more energy-efficient decisions. Alternative explanations of the energy-efficiency gap become parts of sub-questions in these four sections of the paper. In section 6, we offer some conclusions and suggestions for future research priorities.³

2. *Do Spillovers, Market Power, or Informational Market Failures Prevent the Energy Efficiency and Associated Pricing of Products on the Market from Being Economically Efficient?*

One set of possible explanations for the energy-efficiency gap is related to the potential economic inefficiencies associated with the first element of the cost-minimization framework—namely, the variety of energy-efficient products on the market, their energy-efficiency levels, and their pricing. Although the theory is clear, empirical evidence is limited. Going forward, more data are becoming available that can facilitate empirical research, although firm-level data are less available than data on consumer decision making.

Given the range of existing public policies in this realm (such as energy-efficiency standards, labeling, utility demand-side management programs, and public funding of research), it is unclear whether there are specific issues related to the variety, availability, and pricing of energy-efficient products, as distinct from other products. Partly because of this, we do not see this area as meriting a high priority for future research specifically in the domain of energy efficiency. Two exceptions are empirical work on whether consumers have adequate

information regarding energy-efficient products, and research evaluating and improving the efficacy and efficiency of current information policies.

2.1 *Do Product Developers Invest Too Little in Energy Efficiency Due to Technology Spillovers via Research and Development and Learning-by-Doing?*

Spillovers in the energy-efficiency invention and innovation processes can contribute to the energy-efficiency gap if they lead to underinvestment in the development of new energy-efficient innovations. These spillovers are possible both in basic research and development (R&D) and in subsequent commercialization.

R&D Spillovers.—In theory, firms will invest too little effort in research when the resulting knowledge benefits not only them, but other firms as well. A firm does not reap the full rewards of its investment when knowledge is non-appropriable. This effect is probably most pronounced for early stages of research, because firms cannot capture the knowledge generated in the process perfectly, whereas firms can reduce spillovers in later stages of research through intellectual-property protections (Nordhaus 2011).

While there is little direct empirical evidence of R&D spillovers associated with energy efficiency (Popp, Newell, and Jaffe 2010; Howell 2017), there is substantial evidence of these spillovers in other industries, with empirical estimates of such spillovers ranging from close to zero to 100 percent, with most estimates between 20 and 50 percent (Griliches 1992; Hall, Mairesse, and Mohnen 2010).

Many countries have policies to address generic R&D spillovers. Research grants are widely used to encourage basic research, and tax incentives are used to encourage applied R&D. In addition, intellectual-property protections ameliorate the problem of

³The vast majority of the literature is focused on consumer decision making, although where applicable and available we also discuss energy efficiency decision making by firms.

non-appropriability for innovations at the stage of commercialization.

Learning-by-Doing Spillovers.—Learning-by-doing (LBD) refers to productivity improvements that come with experience. The learning effect can be so strong that firms may be willing to operate at a loss when manufacturing a new product to improve productivity and become more competitive (Benkard 2004). But knowledge from such learning can spill over to other firms, creating a free-rider problem. Firms may then underinvest or delay investment to capture knowledge from other firms, rather than incur the cost of generating the knowledge themselves (Arrow 1962; Spence 1981).

Empirical evidence suggests LBD spillovers are present in many industries, with learning spilling over even to firms that are separated by national borders (Lieberman 1984; Irwin and Klenow 1994), although other research suggests that while learning spillovers within a firm can be significant, learning spillovers across firms can be small (Thornton and Thompson 2001).

We are not aware of any direct empirical evidence of LBD in energy efficiency, and none about the extent of any learning *spillovers*. One possible route for research would be to study the engineering pathways by which LBD spillovers occur, building on recent efforts to understand LBD mechanisms (Levitt, List, and Syverson 2013) and utilizing plant-level production data and dynamic structural models of firm production functions.

2.2 *Does Market Power Generate Distortions in the Number of Product Alternatives, Their Level of Energy Efficiency, or Their Prices?*²

It is conceivable that the socially optimal diversity of products may not be offered on the market. This could occur, for example, under monopolistic competition. Two forces

contribute to this outcome. First, not all welfare-improving products are offered if firms are unable to capture the consumer surplus associated with a given product, due to the difficulty of perfect price discrimination. Second, firms introducing a new product may not internalize the impact of their product's entry on other firms' profits, which can lead to too many products on the market.⁴ Despite the soundness of this theory, there is no empirical evidence on the effect of these factors in the energy-efficiency domain.

Economists generally consider energy-efficient products to be of higher quality than less efficient, but otherwise comparable, products. The theory of vertical differentiation suggests that for a single product offering, firms will under supply product quality (including energy efficiency) relative to the social optimum if the marginal consumer values efficiency less than the average consumer. Firms respond to marginal quality valuation, while the social optimum is achieved by setting quality according to average quality valuation (Spence 1975).⁵ However, in the case of multiproduct firms, theory does not provide clear guidance on quality distortion. Indeed, for any given product, the anticipated effect is ambiguous: a firm could supply too much or too little energy efficiency relative to the social optimum, due to demand interactions with the firm's other products.

Calibrations of a theoretical model of the automobile market suggest that multiproduct manufacturers would consider these

⁴In the case of complementary products, these two forces push in the same direction, leading firms to introduce too few products with too little differentiation. With substitutes, the two forces push in opposite directions, in which case, the net effect on product variety (relative to the social optimum) is ambiguous (Spence 1976).

⁵This is not limited to firms with market power. It holds for any profit-maximizing firm that is unable to perfectly price discriminate (Spence 1975).

interactions when choosing fuel efficiency for each vehicle, but manufacturers may over or under supply energy efficiency in different products in response to heterogeneity in consumer valuation of fuel efficiency (Fischer 2010). This is reminiscent of quality distortion arising in models of price discrimination: manufacturers provide too much fuel efficiency in vehicle classes demanded by consumers who value fuel efficiency highly, and too little fuel efficiency in vehicle classes demanded by consumers who value fuel efficiency less. This allows manufacturers to extract surplus from consumers according to consumers' tastes, while reducing the likelihood that consumers defect to other vehicle classes. But theory does not offer clear predictions about welfare impacts, and empirical analysis is lacking in the energy-efficiency context.

Other research on automobiles has explored the responsiveness of suppliers to changes in energy costs. Increases in fuel prices should (weakly) increase demand for more efficient vehicles relative to demand for inefficient vehicles by creating differential variation in operating costs for vehicles with different fuel efficiencies. As a result, equilibrium prices and product characteristics could change. Indeed, automobile manufacturers appear to respond to short-run fluctuations in fuel prices by offering cash incentives (Langer and Miller 2013). The responsiveness of product offerings to long-run trends in energy prices is less clear because it is confounded by simultaneous fuel-economy mandates. Fuel economy increased significantly following increases in oil prices and coincident with the introduction of Corporate Average Fuel Economy (CAFE) standards in the 1970s (Pakes, Berry, and Levinsohn 1993; Berry, Kortum, and Pakes 1996).

Changes in market structure can also affect producer incentives, but anticipated effects on product variety are ambiguous. In

the case of firm mergers, the ambiguity is due to countervailing forces of cost reduction, leading to lower prices; and reduced competition, leading to higher prices (Berry and Waldfogel 2001). Changes in the demand side of the market can also affect product quality and variety. In particular, variation in market size can alter incentives for suppliers, leading to changes in the variety and quality of products available.⁶

Public policies may also interact with and influence energy-efficient product market offerings, possibly in unanticipated ways. Recent empirical evidence from the appliance industry suggests that firms employ the Energy Star logo as a price discrimination tool, as some consumers have a high willingness to pay for this certification. This allows firms to extract surplus from consumers, and may have distributional impacts that were not widely anticipated (Houde 2014a). Engineering-economic analysis of CAFE standards highlights the quantitative importance of considering firm compliance decisions to change product characteristics—not just prices—when estimating the net benefits of regulations (Whitefoot, Fowlie, and Skerlos 2017). Another example of unanticipated consequences is found in the response of automobile manufacturers to the “notched” Gas Guzzler Tax, which distorts manufacturer incentives and is less efficient than a smooth linear tax (Sallee and Slemrod 2012).⁷ Attribute-based

⁶In the presence of horizontal differentiation but no vertical differentiation, market concentration will decrease with market size and a greater variety of products will be offered. In a market with both horizontal and vertical differentiation, this result no longer holds. If increases in product quality require an increase in fixed costs, the highest quality offered will increase with market size, while the market will remain concentrated (Shaked and Sutton 1987).

⁷This comparison of notched and smooth taxes hinges on the assumption of consumer rationality. Under alternative assumptions (see below), the choice between notched and smooth policies becomes considerably less clear. For example, the benefits of certifications may outweigh these

regulations—regulations designed conditional on product attributes other than the target of regulations—generate similar supply distortions (Ito and Sallee 2014).

A tension can exist between optimal innovation and product offerings, on the one hand, and optimal adoption of energy-efficient products, on the other hand. Firms incur fixed costs to generate energy-efficiency improvements in their products, and firms may not invest if they do not expect to recover these costs. However, innovators pricing above marginal cost, which is necessary to recoup fixed costs, could hamper rapid adoption of new products offering significant reductions in energy consumption. Optimal policy would seek to balance these two forces to encourage both innovation and adoption of energy-efficient products (Kamien and Schwartz 1982).

This tension, as with much of the preceding discussion, is generic; that is, the issues are not specific to energy efficiency. In other domains, R&D support and intellectual property protections are the primary tools used to encourage innovation, while antitrust regulation is intended to ameliorate problems associated with market concentration. There is no existing evidence to suggest that energy-efficiency markets exhibit unique market failures that call for tools beyond these traditional policies.

The limitations of theoretical results and the small quantity of empirical evidence in this realm are striking. While empirical evidence from some sectors generally supports theoretical findings,⁸ relevance for energy efficiency is unclear. Hence, empirical

analysis is needed to assess the role of these factors for energy-efficient product markets. In particular, empirical research with structural models is needed to understand and predict impacts of energy-efficiency policy, particularly in industries that are highly concentrated and highly regulated.

2.3 *Are There Too Few New Energy-Efficient Product Offerings Due to Demand Spillovers?*⁹

Product offerings may be suboptimal in number due to demand spillovers. Product innovations may exhibit information asymmetries between consumers and producers, with consumers needing to be convinced to try a new product. Firms try to generate demand with advertising and/or promotional pricing, the cost of which must be recouped through sales. The consequent learning by consumers can spill over to other consumers, benefiting the innovating firm. Importantly, however, the firm's competitors can also capture these demand spillovers—without paying the costs to educate consumers. The net effect of these two forces is ambiguous. If the latter effect dominates, firms will introduce too few new products.

Existing research provides little insight into the contributions of such demand spillovers to the energy-efficiency gap, possibly due to the empirical challenge of identifying demand spillovers.⁹ Hybrid vehicles are a rare example of an energy-efficient technology that has been well studied and that may be associated with learning spillovers among consumers. Empirical evidence that market penetration rates of hybrid vehicles affect future purchases is consistent with this hypothesis. Furthermore, these learning spillovers may not be fully appropriated by the original producer; higher penetration rates for the Toyota Prius have led to greater

supply distortions if consumers are inattentive to energy efficiency (Sallee 2014).

⁸For example, in the restaurant industry, increasing market size is associated with lower concentration, greater variety, and more quality differentiation. In the newspaper industry, where improving quality requires higher fixed costs, larger markets remain concentrated and average quality improves (Berry and Waldfogel 2010).

⁹See the section on learning-by-using spillovers for discussion of the difficulty of identifying demand spillovers.

purchases of hybrids of all makes (Heutel and Muehlegger 2015).¹⁰

The impact of demand spillovers on product offerings is inherently difficult to study, because researchers do not observe potentially innovative energy-efficient products that firms decide not to introduce. In the absence of such data, researchers can study the impact of learning spillovers across products that *are* introduced, which can serve as a guide for whether these spillovers appear to be significant enough to prevent the introduction of candidate products. Such research could follow the approach of research on the pharmaceutical industry (Crawford and Shum 2005; Coscelli and Shum 2004; Berndt, Pindyck, and Azoulay 2003).¹¹ The existence and magnitude of spillovers across products appear to be correlated with the degree of substitutability of the products (Janakiraman, Sismeiro, and Dutta 2009). This finding accords with theory and provides a useful guide for evaluating the importance of learning spillovers among energy-efficient products. Implementing government or utility programs that educate consumers about innovative energy-saving technologies is one possible response to significant demand spillovers.

2.4 *Does Adverse Selection Due to Asymmetric Information Inhibit Energy-Efficient Product Offerings?*²

In theory, asymmetric information could lead to adverse selection in the marketplace, which in turn might lead to underinvestment in energy efficiency. Such underinvestment would occur if buyers cannot observe

perfectly the energy efficiency of products, and as a result are unwilling to pay for its true expected value. If sellers have private information they cannot credibly communicate, some energy-efficient products may not be offered in the market (Akerlof 1970). This problem of asymmetric information tends to be more pronounced in the secondary market, as consumers who invest in energy-efficient capital, such as home weatherization, may have difficulty capitalizing on these investments when reselling. But adverse selection in secondary markets can affect incentives for adoption of efficient technologies in primary markets. Asymmetric information is sometimes cited as a justification for disclosure policies and standards—such as energy-efficiency testing and labels.¹²

Despite widespread acceptance of the theoretical argument for adverse selection due to information asymmetries, there is little empirical evidence of this phenomenon in the context of energy efficiency, particularly in the period since energy-efficiency product testing and labeling became the norm for many energy-using appliances. By its very nature, adverse selection is difficult to study. Like an uninformed buyer, researchers are often unable to observe perfectly the energy-efficiency characteristics of a product. Unobserved heterogeneity among buyers and sellers, particularly in buyers' demand functions, complicates analysis. It is also challenging to separate, in practice, adverse selection from moral hazard. One model research design is the use of randomized experiments to isolate adverse selection from moral hazard in energy consumption (for example, Munley, Taylor, and Formby

¹⁰Of course, just as learning spillovers can increase demand for similar products, such spillovers can also dampen demand. Heutel and Muehlegger (2015) found that higher market penetration by the Honda Insight led to fewer purchases of all hybrid models, consistent with anecdotal evidence that the Insight was of lower quality.

¹¹Research in pharmaceuticals examines both competition between branded and generic drugs following patent expiration and competition among branded drugs. The latter is more relevant to energy-efficient technologies.

¹²For example, the US government cited asymmetric information as a justification for its recent medium- and heavy-duty vehicle fuel economy standards, projecting that these standards will save industry money after accounting for both up-front costs and fuel savings (US Environmental Protection Agency and US Department of Transportation National Highway Traffic Safety Administration 2011).

1990). In the absence of relevant experiments, theory does provide some qualitative guidance for policy and research efforts: outcomes depend on disclosure technology; in markets where disclosure is low-cost and effective, there may be less rationale for policy intervention.¹³

2.5 *Do Consumers Have Inadequate Information Regarding Energy-Efficient Products?*

Lack of information could lead to private decisions to invest less in energy-efficient technologies than would otherwise be the case. Such a lack of information is one of the most commonly cited justifications for policy intervention in this realm (Palmer et al. 2013; Sanstad, Hanemann, and Auffhammer 2006). Two alternative interpretations fit the available evidence: consumers may be inattentive to, or have difficulty using, readily available information; or they may have imperfect information on product availability or product characteristics. We focus here on the classic market failure of imperfect information. We turn to inattention, bounded rationality, and heuristic decision making in later sections.

Information provision has been documented to affect consumer decisions. In a recent artefactual field experiment, provision of information about the energy use of alternative light bulbs increases consumer willingness-to-pay for efficient bulbs (Allcott and Taubinsky 2015). However, these effects were attenuated in the context of a parallel natural field experiment, possibly due to information already available in the marketplace.

¹³See Jovanovic (1982) for an analysis of how disclosure costs affect welfare. Recent empirical evidence on the impact of disclosure costs on equilibrium prices comes from online automobile sales (Lewis 2011). Several companies have recently faced sanctions by the US Department of Energy (DOE) for overstating the efficiency of their products, failing to meet minimum efficiency standards, or both.

Furthermore, few studies disentangle the effects of imperfect information from competing explanations of consumer behavior (e.g., inattention). One recent study attempts to do this using a stated-choice experiment to understand the relative importance of various elements of information labels—including the EnergyGuide, Energy Star, and European Union (EU)-style labels—while controlling for other relevant factors, such as discounting behavior (Newell and Siikamäki 2014). This research finds that a lack of relevant information can lead to significant undervaluation of energy efficiency, and that providing simple information on the economic value of saving energy was the most important element guiding more cost-effective energy-efficiency decisions.

Past evidence in the United States and recent evidence from India suggests that imperfect information also exists among firms (as consumers of energy-efficiency technology), and that firms may fail to undertake profitable investments because they are simply unaware of them (Anderson and Newell 2004; Bloom et al. 2013). Anderson and Newell (2004) examine industrial energy audits and find that while plants accept only half of recommended projects, most plants respond to the costs and benefits presented in energy audits and, with the additional information, adopt investments that meet hurdle rates consistent with standard investment criteria.

In theory and in practice, an informed third party can fill the information gap, as many government and private labeling programs seek to do. Examples include EnergyGuide labels, Energy Star logos, automobile fuel economy labels, and Leadership in Energy and Environmental Design (LEED) certification.¹⁴ A number of studies have analyzed

¹⁴LEED is a building rating system designed by the US Green Building Council, a non-governmental organization. See: www.usgbc.org/leed.

the effect of such information policies. For example, Davis and Metcalf (2014) use a stated-choice experiment to quantify the welfare gains of using tailored, state-specific EnergyGuide labels rather than one label based on nationwide averages. Sallee (2014) highlights the possible supply distortions caused by coarse energy-efficiency certifications, such as the binary certification employed in the Energy Star program. But the benefits of coarse certifications may outweigh supply distortions, given limits on consumer attention to detail about performance. Houde (2014b) evaluated the welfare effects of the Energy Star certification program and found that consumers rely heavily on the certification, indicating that the program does provide new information to the market. However, he also found that some consumers *over-rely* on the binary label, as opposed to considering actual energy savings. This induces suppliers to bunch at the certification point and could crowd out some efficiency investments (Houde 2014a).

Hedonic analyses of two building certifications, LEED and Energy Star, suggest that certifications provide information to the market, as certification status explains some of the residual variation in rental and sales prices after conditioning on prominent property characteristics (Eichholtz, Kok, and Quigley 2010, 2013). Residential certifications are associated with higher sales prices in both the Netherlands and the United States (Brounen and Kok 2011; Kahn and Kok 2014; Walls et al. 2013).

Experimental research on point-of-sale interventions for energy-consuming products has found heterogeneity in consumer beliefs about possible energy-cost savings. Providing information to consumers could, in theory, lead some consumers to increase energy use—or invest in inefficient technology—in response to information, in a mean-reverting pattern. Carefully designed information provision may eliminate this

effect (Schultz et al. 2007). In practice, some information provision interventions may generate negligible demand effects (Allcott and Sweeney 2014).

Further research is needed to distinguish the effects of incomplete information from competing explanations of the energy-efficiency gap, such as inattention and heuristic decision making. Randomized control trials, including both revealed- and stated-choice experiments, may be the most promising method to isolate and test these mechanisms. Likewise, targeted, randomized research designs could provide practical guidance for existing and potential new policy interventions. In particular, research on the effects of online information provision is merited, because consumers increasingly obtain information about and purchase energy-consuming (and other) products online.

3. *Are Energy Operating Costs Inefficiently Priced, Understood, and/or Analyzed?*

Even if energy-consuming durable goods are available on the market and appropriately priced, energy operating costs could be inefficiently priced, understood, or analyzed. In fact, even if consumers make privately optimal decisions, energy-saving technology could—in the absence of corrective policy—diffuse more slowly than the socially optimal rate, due to negative externalities from energy production and use. In other words, even if the private energy-efficiency gap is not present, a social energy-efficiency gap might exist.

For example, the combustion of fossil fuels is associated with numerous environmental pollutants, including greenhouse gases, sulfur dioxide, oxides of nitrogen, and particulate matter, and the environmental and human health effects of these pollutants are not fully incorporated into the price of fossil fuels (and electricity generation). Such unpriced

externalities and/or utility regulation can, in principle, lead to a divergence between the energy prices consumers face and the prices that would guide efficient decisions.

In addition, regardless of whether energy prices are set at efficient levels, consumers who hold biased beliefs about energy prices or their expected energy use will make decisions that do not appear optimal, given observed prices. On the other hand, analysts who overestimate the savings associated with efficiency investments or ignore consumer heterogeneity will identify an energy-efficiency gap even where none exists.

As in the previously examined realm, the theoretical arguments in this area are robust. However, unlike in the previous case, here the empirical evidence is considerable, and in some cases quite compelling. In most cases, data are likely to be available for additional research, with the exception of those sub-questions below (3.4 and 3.5) that refer to beliefs, which are challenging to recover with a sufficient degree of reliability. Furthermore, in several cases, existing policies (for example, gasoline taxes, carbon pricing, and electricity price structures) appear not to provide sufficient incentives for energy efficiency from an economic perspective, suggesting that further research is warranted. We view further research in this realm as a relatively high priority; specifically, empirical estimates of the incremental monetized social damages from energy production and use, and the degree to which such damages are already accounted for in energy prices. Where appropriate, it is useful for such estimates to be location and time-specific.

3.1 *Are Retail Electricity or Natural Gas Prices Too Low (or High) Due to Regulation?*

Evidence is mixed regarding whether the regulation of electricity and natural gas prices helps to explain the energy-efficiency gap, due to a divergence of prices from

marginal cost. On the one hand, a lack of time-varying electricity pricing suggests that prices are sometimes too low and sometimes too high. On the other hand, average-cost pricing and other features of electricity and gas price regulation could lead to prices that exceed marginal cost systematically. The net effect of these different factors is unclear.

The dynamics of electricity markets can cause prices to be below marginal cost, particularly during peak periods. The marginal cost of electricity generation varies over time, and many pricing schemes do not reflect this variation, leading to inefficient utilization decisions (Joskow and Wolfram 2012). Real-time electricity pricing could correct this, particularly if consumers have access to real-time feedback on consumption (Jessoe and Rapson 2014), which could yield large efficiency gains (Borenstein 2005), but the impact of time-of-use pricing and associated load shifting on energy-efficiency investment is ambiguous (Gillingham, Newell, and Palmer 2009).

Many utilities use multipart tariffs to recover fixed costs while preserving marginal incentives (Coase 1946). But marginal (or usage) prices are typically set above marginal costs. Natural gas customers in the United States face prices inclusive of fixed distribution costs that are well above marginal cost, with one study estimating that these additional costs are comparable to a tax of over \$50 per ton of carbon dioxide (Davis and Muehlegger 2010). Pricing above short-run marginal cost is also present in the electricity sector (Naughton 1986; Borenstein 2012). Equity considerations are one explanation for these markups in regulated industries (Borenstein and Davis 2012), but this issue is not restricted to regulated firms; utilities in restructured markets facing imperfect retail competition also diverge from optimal two-part tariffs (Puller and West 2013).

A second possible reason for inefficiently *high* prices of energy for regulated utilities comes from a principal-agent

problem—regulated utilities may not minimize capital costs on behalf of consumers, and these costs cannot be perfectly observed by regulators. Under rate-of-return regulation, utilities may overcapitalize in order to increase profits (Averch and Johnson 1962), a phenomenon that has been confirmed empirically (Spann 1974). Comparisons of electricity generators subject to different regulatory regimes following deregulation have validated this phenomenon (Fowlie 2010; Cicala 2015).

Other research, however, has not supported the theory that utilities overinvest to increase profits (Boyes 1976), and recasting this problem in a dynamic framework highlights the possibility of “regulatory hold-up” (Gilbert and Newbery 1994), where firms may strategically limit investment if they expect regulators to refuse to allow a fair rate of return after the investment is sunk. There is empirical evidence that, due to such regulatory hold-up, utilities underinvest in infrastructure that improves reliability (Lim and Yurukoglu 2015); this could lead to inefficiently low prices.

Inattention, rational or otherwise, may also influence consumer decisions. Recent empirical research provides evidence that retail electricity customers respond to average prices rather than marginal prices (Ito 2014), and that feedback about electricity consumption influences the price elasticity of demand (Jessoe and Rapson 2014). Further empirical research directed at understanding how alternative pricing schemes affect investment in energy efficiency would be valuable.

3.2 *Are Electricity Prices Too Low Due to Unpriced Externalities?*⁹

Electric power production is also associated with environmental externalities. Quantitative estimates of the magnitude of these externalities are limited, and only a subset of these account for marginal emissions and damages being both location and

time specific (Muller and Mendelsohn 2009; Graff Zivin, Kotchen, and Mansur 2014).

Coal and natural gas combustion for electric power production have received the most attention, with estimates suggesting the (non-carbon) damages from coal-powered electricity cost society about three to four cents per kilowatt-hour (kWh), and those from natural gas-powered electricity cost society much less than 1 cent per kWh on average (National Research Council 2010). Carbon dioxide emissions from these sources approximately double these cost estimates, depending on choices of the social cost of carbon and the discount rate.¹⁵

In general, the full incorporation of environmental externalities into the price of electricity would likely raise electricity prices in most US regions. However, many of these externalities are already regulated and thereby indirectly—and sometimes directly—priced. But other market distortions—such as electricity price regulation—make it difficult to judge overall whether electricity prices are too low, and the answer seems certain to vary by region (and time of day). More research is needed to quantify and monetize electricity generation externalities, including comprehensive assessments of which externalities are currently unpriced or underpriced and which are effectively addressed by existing policy.

3.3 *Are Gasoline Prices Too Low Due to Unpriced Externalities?*⁹

Some unpriced transportation-related externalities are a direct function of gasoline

¹⁵Other fuel sources (for example, nuclear and renewable energy) and stages of production (for example, fuel extraction) produce externalities that are more difficult to quantify, but also potentially important. Qualitative discussions of these impacts abound, but there is little knowledge of the economic magnitudes of the externalities. See, for example, National Research Council (2010). Table 2-2 on page 70 summarizes the discussion.

consumption. These include the effects of greenhouse gas emissions and oil dependency (National Research Council 2010). Available estimates place these external costs at about thirty to forty cents per gallon (Parry, Walls, and Harrington 2007). Local pollution, congestion, and accident externalities can be approximated as mileage-related costs, and converted to per gallon costs; estimates for these are as great as \$2.40 per gallon (Parry, Walls, and Harrington 2007; Anderson and Auffhammer 2014). These externality estimates are more than five times larger than current gasoline taxes in the United States.¹⁶ Furthermore, complementarities between gasoline consumption and leisure justify a gasoline tax significantly larger than marginal damages from externalities, due to interactions with labor taxes (West and Williams III 2007). These inefficiencies are exacerbated by fuel subsidies in some countries (Clements et al. 2013), while in others, prices may actually be inefficiently high due to existing taxes (Parry and Small 2005).

Raising gasoline prices (whether through taxation or reduction of subsidies) is not necessarily the optimal policy response to all of these externalities. For example, the damages created by congestion are both location and time dependent and would optimally be priced accordingly. Accident externalities may be best regulated by weight-specific mileage taxes, although this could be approximated by a simpler gasoline tax (Anderson and Auffhammer 2014).

Competing goals present another complication. Due to the rebound effect,¹⁷

¹⁶As of July 1, 2015, the federal excise tax on gasoline was 18.4 cents per gallon and the average state excise tax was 26.49 cents per gallon (www.eia.gov/tools/faqs/faq.cfm?id=10&t=5).

¹⁷The rebound (or take-back) effect refers to the reduction in energy savings from the adoption of an energy-efficiency technology that is due to behavioral response, such as raising the temperature setting on a

improvements in energy efficiency could lead to more vehicle miles traveled, resulting in larger external costs due to congestion and accidents. Addressing congestion and accidents through gasoline taxes would provide an incentive for energy-efficiency improvements to vehicles, but would fail to satisfy economic efficiency due to interactions with other externalities.

On net, economists agree that the price of gasoline in the United States is inefficiently low, and that this contributes to the divergence between observed and socially optimal adoption of energy-efficient technology.

3.4 *Are Beliefs about Current and Future Fuel Prices and/or Usage Systematically Uninformed or Biased Downward?*

Imperfect understanding of energy operating costs on the part of consumers is another possible contributor to the energy-efficiency gap, but biased beliefs about fuel prices do not seem to be a major factor.

Consumer Beliefs about Fuel Prices.—Downward-biased beliefs about fuel prices would tend to lead to underinvestment in energy-efficient technology. Qualitative interviews suggest that people may know current gasoline prices, but lack other essential inputs to valuing vehicle fuel economy (Turrentine and Kurani 2007). Quantitative survey evidence suggests that, on average, consumers forecast future gasoline prices using current prices (Allcott 2011a; Anderson, Kellogg, and Sallee 2013).¹⁸

Is the current price an unbiased predictor of future prices? It is crucial to compare ex ante consumer beliefs with other

home thermostat after installing better thermal insulation in the home.

¹⁸Allcott (2011a) compares survey respondents' fuel-price forecasts to futures prices, not current prices. However, futures prices at the time of the survey were almost identical to a scenario of constant real prices.

possible *ex ante* beliefs, rather than using outcomes to judge the beliefs of consumers *ex post*, because beliefs can turn out to be mistaken after the fact, even when they are unbiased in expectation. Some empirical evidence suggests that this no-change forecast is a better predictor of future prices than predictions derived from econometric models, professional survey forecasts, and oil futures (Alquist and Kilian 2010). Together, these two findings—that consumers forecast using current prices, and that current prices are more accurate than other conventional forecasting techniques—do not support the argument that downwardly biased beliefs about fuel prices contribute to the energy-efficiency gap.¹⁹

Consumer Beliefs about Fuel Usage.—There is little evidence on gasoline usage forecasts or the contribution of inaccurate usage forecasts to the energy-efficiency gap. There is evidence from other settings, however. For example, consumer decisions about mobile phone and health club contracts suggest biased beliefs about product usage (DellaVigna and Malmendier 2006; Grubb 2009). But in the context of automobile purchases, consumers may be less likely to misestimate future fuel usage, due to the salience of gasoline expenditures and relative stability of driving patterns for a given individual.

Future research to understand the impact of fuel-price beliefs on investments in energy-efficient technology outside the transportation sector could be valuable.

¹⁹Although average beliefs about prices may not be biased, consumer forecasts of future gasoline prices display substantial heterogeneity (Allcott 2011a; Anderson, Kellogg, and Sallee 2013). One survey elicited upper and lower bounds on future fuel prices, with responses exhibiting significant uncertainty. The spread between the mean response for each bound was almost two dollars, or 45 percent of the midpoint between these means (Greene, Evans, and Hiestand 2013). These findings could explain underinvestment by some consumers.

Likewise, studies of the beliefs of firms, or of key decision makers within firms, could aid understanding of the energy-efficiency gap. Little research has been carried out on consumers' predictions of future usage. Without eliciting or recovering these beliefs, assessing the optimality of consumer purchases requires strong assumptions. A research design that combines elicited price and usage forecasts with choice data could possibly recover preferences without bias from heterogeneity in beliefs among consumers.

3.5 *Are Beliefs about Current and Future Electricity Prices and/or Usage Systematically Uninformed or Biased Downward?*

Consumer Beliefs about Electricity Prices.—Limited evidence suggests that consumers may be misinformed about current electricity prices, but there is no evidence of systematic bias. Consumers respond to average, rather than marginal price (Ito 2014), but in one study appear to *reduce* consumption in response to a reduction in price, in contrast to theoretical predictions (Jesso, Rapson, and Smith 2014). This could be a product of consumer inattentiveness, but research is needed to distinguish this from competing explanations (Faruqui and Sergici 2011; Ito, Ida, and Tanaka 2015). In contrast, other research has provided evidence that consumers value changes in physical energy use (for example, kWh of electricity and therms of natural gas) at close to their price (Newell and Siikamäki 2014).

Consumer Beliefs about Electricity Usage.—Experimental-choice data suggest that consumers are also misinformed about electricity usage or how daily activities translate into usage; consumers provided with real-time usage feedback become significantly more price responsive than consumers

without such feedback (Jessoe and Rapson 2014).²⁰ In consumer surveys, respondents systematically overestimate the energy costs of low-usage goods (for example, computers) and underestimate the energy costs of high-usage goods (for example, water heaters) (Attari et al. 2010).

Separately identifying beliefs and preferences is certainly challenging. Economic research in this area typically makes assumptions—sometimes quite strong assumptions—about beliefs in order to recover preferences. Future research could begin by eliciting beliefs from economic agents, and then using these beliefs to recover preferences (Manski 2004). In some contexts, this approach could enable the researcher to isolate multiple effects of information policies (for example, isolate the effect of salience from the effect of information that alters beliefs).

3.6 *Do Analysts Systematically Overestimate Energy Savings from Efficiency Investments?*²

Incomplete understanding of energy operating costs on the part of analysts—rather than consumers—can also help reconcile conflicting estimates of the magnitude of the energy-efficiency gap. In the past, analysts' predictions of energy savings from efficiency investments have tended to overstate the magnitude of the energy-efficiency gap. We distinguish between ex ante engineering-economic analyses,²¹ which rely primarily

on physical models to predict energy savings, and ex post impact evaluations, which typically rely on observed energy consumption to estimate net savings associated with energy-efficiency investments. Hybrid models combine the technological detail of engineering models with economic evaluations (Murphy and Jaccard 2011).

Ex post economic evaluations, using actual energy usage, are generally thought to be more credible than ex ante engineering-economic analyses,²² and comparisons provide evidence of a seemingly systematic bias in ex ante predictions (Nadel and Keating 1991). Several explanations for the divergence between engineering models and impact evaluations have been offered: erroneous assumptions about usage; complex interactions omitted from engineering estimates (for example, the rebound effect in some cases); quality control problems (for example, problems with equipment installation); and adoption of energy-saving measures by nonparticipants (which lowers net savings attributable to utility programs).

A meta-analysis of forty-two utility conservation programs in the residential, commercial, and industrial sectors found that actual energy-savings estimates for residential retrofit programs ranged from 15 to 117 percent of ex ante

²⁰In this experiment, the treatment and control groups received the same day-ahead notifications of price changes. This research design isolates the effect of usage feedback and eliminates the potentially confounding effect of salience.

²¹These are also called “bottom-up” or “technology-based” approaches. They typically utilize detailed information about the relative efficiency of various types of energy-using equipment, existing deployment, and assumptions about usage patterns, in order to estimate how energy usage, expenditures, and pollutant emissions would change in response to changes in the mix of capital

goods. By making assumptions about opportunities for substitution, switching costs, and infra-marginal behavioral responses, these studies have been used to predict the effects of policies. For an early critique of these studies, see Joskow and Marron (1993). In a particularly influential engineering-economic study, McKinsey & Company estimated a supply curve of carbon-emission reductions in the United States (Granade et al. 2009) and concluded that a substantial amount of reductions could be achieved at negative cost by investing in greater energy efficiency. This result generated considerable interest, and also substantial criticism, partly on the grounds that some costs of adoption were not included in the analysis.

²²However, ex ante studies offer something ex post approaches do not, namely predictions, which are critical for evaluating proposed energy-efficiency investments on cost-effectiveness grounds, as well as for projecting energy savings associated with a given policy.

engineering–economic estimates (Nadel and Keating 1991). Commercial retrofit programs exhibited energy savings ranging from 36 to 248 percent of engineering predictions, while a majority of programs failed to meet savings benchmarks from ex ante analysis (Nadel and Keating 1991). These direct comparisons suggest that caution is warranted when interpreting ex ante engineering–economic evidence of the energy–efficiency gap, although this research has documented some cases in which ex ante analyses underestimated energy savings.

Home energy auditors use engineering-based tools to predict energy savings. These tools are one potential source of systematically biased energy-savings estimates, for reasons that include user error (for example, incorrect inputs or inaccurate assumptions about post-audit thermostat settings) and improper accounting for residents' behavioral responses, even when the underlying engineering models are correct.

In empirical research, two groups of participants in a utility-weatherization program in the 1980s achieved 47 and 78 percent of predicted savings on average (Hirst 1986),²³ while realized savings from another utility program ranged from 50 to 81 percent of predicted electricity savings, and 14 to 42 percent of predicted natural gas savings (Sebold and Fox 1985). In another study, a tool used for weatherization home audits overpredicted savings by 186 percent, despite accurate engineering calculations (Ternes and Gettings 2008). Likewise, weatherization projects in New York State achieved only 57 to 69 percent of the savings predicted by the National Energy Audit Tool, and studies

from other states have reached qualitatively similar conclusions (Berry and Gettings 1998). In a randomized-utility experiment providing insulation and HVAC appliances to certain households, ex ante engineering estimates overstated actual conservation by 13 percent (Dubin, Miedema, and Chandran 1986).

Analyses that significantly overestimate energy savings persist, despite substantial improvements in ex ante engineering–economic methods over time. For example, ex post analysis of the “Cash for Coolers” program in Mexico, which provided subsidies for the replacement of inefficient household appliances, indicates that refrigerator replacement achieved only one-quarter of the annual savings predicted by the World Bank. Replacement of air conditioners led to increased electricity consumption, in stark contrast to engineering predictions of energy savings (Davis, Fuchs, and Gertler 2014). A randomized evaluation of the Weatherization Assistance Program in the United States found model projections exceeded realized savings by a factor of 2.5 (Fowle, Greenstone, and Wolfram 2015b). Nonetheless, care must be taken in generalizing these findings, as weatherization may not be representative of other energy–efficiency programs, which have been found to vary significantly in cost effectiveness (Hoffman et al. 2015).

Scrutiny of the rates of return predicted by ex ante engineering–economic analyses also provides evidence of bias in energy-savings estimates. Econometric analysis of home energy–efficiency investments by Metcalf and Hassett (1999) suggests the median rate of return for insulation improvements was 9.7 percent, consistent with reasonable discount rates, but far below the ex ante estimates of Blasnik (1990). A combined engineering/econometric approach to estimating these rates of return finds broadly similar results: Dubin and Henson (1988) estimate average rates of return of

²³Hirst (1986) reviews possible causes of differences between predicted and actual energy savings, including errors in audit methodology, data collection and interpretation, installation of inappropriate retrofit measures, use of poor materials, low-quality installation work, changes in occupant behavior, errors in electricity usage data, and errors in analysis of electricity-billing data.

4.9 percent for ceiling insulation and 8.3 percent for wall insulation.²⁴

There are significant opportunities for research in this area. First, more attention is needed to ex post analysis in the transportation, commercial, and industrial sectors. The preponderance of evidence brought to bear on this question of accuracy in ex ante energy-savings predictions has come from the residential sector, presumably because of the large number of government and utility programs that provide existing engineering analysis and rich data for ex post assessment. More ex post analyses of model predictions are needed to better judge whether ex ante engineering–economic analyses continue to systematically overstate the savings associated with energy-efficiency investments, or whether these approaches have truly improved over time.²⁵ It is at least conceivable that selection bias has come about through researchers having chosen to evaluate engineering–economic analyses that have most exaggerated the savings potential of efficiency investments.

²⁴Simulation-based studies, which use energy-market models to trace out energy-efficiency supply curves, improve on simpler ex ante analyses. These models explicitly model complex adoption decisions, consumer heterogeneity, uncertainty, and feedback effects. As a result, even if these models begin with the same technology assumptions as simpler engineering–economic models, the general equilibrium effects of these interrelationships lead to different, typically lower, predicted levels of end-use energy efficiency. One study (Huntington 2011) found that incorporating these factors reduces by three-quarters the size of the energy-efficiency gap identified in the McKinsey & Company study (Granade et al. 2009).

²⁵Some assessments have been improved by accounting for “free riders” (i.e., inframarginal consumers) that would have adopted technologies even in the absence of certain programs, and by incorporating a utilization elasticity termed the “rebound effect” (Davis, Fuchs, and Gertler 2014; Dubin and Henson 1988; Gillingham and Palmer 2014; Greening, Greene, and Difiglio 2000; Houde and Aldy 2014; Sorrell, Dimitropoulos, and Sommerville 2009).

3.7 *Do Analysts Insufficiently Account for Consumer Heterogeneity?*[?]

For any energy-efficiency technology, the benefits and costs of adoption can vary substantially across potential adopters (Jaffe and Stavins 1994a, 1994b, 1995; Metcalf and Hassett 1999; Alberini, Gans, and Towe 2013). Even when engineering predictions correctly find that, on average, the benefits of adoption exceed the costs of adoption, this will not be true for some potential adopters.

Differences in benefits and costs across agents generate variation in adoption patterns. These differences can explain low adoption rates for technologies that appear cost effective (Griliches 1957), especially if benefits and costs are correlated (Suri 2011). Similarly, heterogeneity across consumers may explain variation in the adoption of energy-efficient technology. For example, Hausman and Joskow (1982) pointed out that heterogeneity in usage profiles, capital stock, or consumer preferences could result in realized savings below average predicted savings. Failure to model heterogeneity correctly can introduce bias in estimates of the size of the energy-efficiency gap.

If the bias due to heterogeneity is systematic, analyses ignoring heterogeneity could overstate the magnitude of the energy-efficiency gap. The sign of the bias is ambiguous, but can be identified. Neglecting consumer heterogeneity appears to have produced empirical estimates that overstate the extent to which vehicle purchasers undervalue fuel economy (Bento, Li, and Roth 2012). Ignoring heterogeneity can bias energy-savings estimates upward: systematic differences between past and future adopters can drive a wedge between observed and potential returns for a given investment. This wedge is likely positive in a context where consumers and firms have selected the most profitable projects first, as prospective returns will likely be below

historical average returns. Heterogeneity in individual time preferences will also alter the estimated attractiveness of energy-efficiency investments, which will tend to be more problematic for analyses where a larger share of benefits are estimated to come from households with relatively high discount rates (Newell and Siikamäki 2015).

One potential area for future research involves using randomized experiments to better understand the distribution of energy savings associated with given investments by comparing the distribution of energy outcomes for treated and control groups. This could help improve *ex ante* predictions for future decision making. Wider use of techniques from industrial organization (for example, random coefficient logit models) could improve predictions by modeling heterogeneity explicitly.

4. *Are Product Choices Cost Minimizing in Present-Value Terms?*

The framework we posited in part 1 is one of cost-minimizing energy-efficiency decisions, and so it is natural to ask whether market failures and/or behavioral phenomena inhibit cost minimization in present-value terms.

Here the empirical evidence ranges from strong (split incentives/agency issues and inattention/saliency phenomena) to moderate (heuristic decision making/bounded rationality, systematic risk, myopia/short-sightedness, and option value) to weak (learning-by-using, loss aversion, and capital-market failures). And here, as elsewhere in our review, we find that most previous work has focused on the residential sector, with much less attention given to the commercial and industrial sectors—presumably because of lack of available data. That said, the availability of data for further research varies by subtopic, with split incentives/agency issues and effects of myopia offering

the most promising opportunities for further investigation.

Given the wide use of building codes and energy-efficiency standards, split incentives/agency problems in the residential, commercial, and industrial sectors may not be as severe as one would expect in the absence of interventions. Some areas merit priority for future research, such as empirical analysis of split incentives/agency issues in markets for technologies that are not subject to efficiency standards. Much more work can be done in the behavioral realm on issues such as inattention/saliency, loss aversion/reference points, heuristic decision making, and myopia.

4.1 *Do Split Incentives/Agency Issues Due to Asymmetric Information Inhibit Energy-Efficient Decisions?*

Differences in interests between economic agents frequently arise, causing problems of agency or split incentives. In the energy-efficiency realm, prominent examples include landlord–tenant and builder–buyer problems, in which capital investors may make decisions that are not optimal from the perspective of the end user. Similarly, agency conflicts are possible within firms when investment and operating decisions are divided among individuals or business units (Tietenberg 2009). Research has long cited these conflicts as potential explanations for the energy-efficiency gap (Blumstein et al. 1980; Fisher and Rothkopf 1989; DeCanio 1993; Jaffe and Stavins 1994a; Jaffe and Stavins 1994b; Gillingham, Newell, and Palmer 2009; Tietenberg 2009; Gillingham and Palmer 2014).

Empirical evidence has confirmed the existence of the principal–agent problem, and comprehensive accounting exercises have sought to estimate the potential importance of this market failure by quantifying the amount of energy consumption subject to incentive conflicts (IEA 2007). As much

as 35 percent of US residential energy use may be affected (Murtishaw and Sathaye 2006). Some research has compared owner-occupied and rental properties to estimate directly the impacts of split incentives. Results are compelling: even after controlling for household income and other household characteristics, renters are significantly less likely to have energy-efficient refrigerators, clothes washers, and dishwashers, based on data from the Residential Energy Consumption Survey (Davis 2012). Owner-occupied dwellings in California are 13 to 20 percent more likely to have exterior wall and ceiling insulation (Gillingham, Harding, and Rapson 2012).²⁶

Other evidence supports the hypothesis that information asymmetries exist in housing markets. Data from the United States show that landlords frequently include utility costs in rental prices even when units are individually metered. This may be because landlords with energy-efficient units cannot credibly communicate this information and instead include utilities as a signal of the units' efficiency (Levinson and Niemann 2004). Landlords may even use utility-included rental contracts to attract renters or as a signal of other unobservable forms of quality unrelated to energy efficiency. The empirical correlation between how well-maintained a unit is and the inclusion of utilities in rent provides some support for this hypothesis (Choi and Kim 2012).

Further insight can be gleaned by assessing the link between information asymmetries and new investment in energy efficiency. Recent work on residential housing markets finds that patterns of investment in conversion from inefficient oil heating to more efficient natural gas heating are consistent with the hypothesis of asymmetric information

between landlords and tenants. The potential gains from these missed investments are not trivial: back-of-the-envelope calculations suggest the annualized cost savings from converting from oil to gas heating are 12 to 24 percent of annual heating expenditure on average (Myers 2015).

More support for the hypothesis of asymmetric information comes from stated preferences. Responding to a survey, New Zealand tenants stated that they would be willing to pay higher rents in exchange for improved energy efficiency and, in many cases, respondents' willingness to pay appears to justify landlord investments in energy-efficiency improvements. Asymmetric information could explain why landlords do not make such seemingly profitable efficiency investments (Phillips 2012). In contrast, recent research on commercial buildings finds little evidence of asymmetric information between building owners and prospective buyers or tenants (Papineau 2015).

Although such studies provide evidence regarding the hypothesis of asymmetric information, they do not provide direct estimates of the impact of information asymmetries on investments in energy efficiency. While a market failure exists, the magnitude may be small, because the energy impacts of inefficient appliances and less insulation only amount to a few percent of total energy consumption in rental units (Davis 2012; Gillingham, Harding, and Rapson 2012).

Alternative contract structures can contribute to another, less cited outcome: moral hazard. Tenants who sign energy-inclusive rental agreements face zero marginal cost from energy consumption, and therefore may use too much energy, relative to the social optimum. Indeed, tenants appear to keep indoor temperatures higher during winter months and when their homes are unoccupied when utilities are included in their leases (Maruejols and Young 2011; Levinson and Niemann 2004). Likewise, tenants who

²⁶In contrast, a hedonic regression analysis of survey data in Australia failed to find evidence of split incentives in rental housing (Wood, Ong, and McMurray 2012).

pay for utilities are more likely to adjust heating temperatures at night than tenants who face zero marginal cost (Gillingham, Harding, and Rapson 2012). Such findings do not relate directly to investment in energy efficiency, except to the degree that landlords respond strategically to such behavior. However, even if landlords do respond strategically, they are more likely to invest in high-efficiency appliances or decouple rental agreements and energy use than they are to underinvest in energy efficiency. Thus, moral hazard is unlikely to contribute to the energy-efficiency gap.

The best available evidence is from the residential sector, but agency problems due to information asymmetries could also play a role in commercial and industrial-sector energy-efficiency decisions. Indeed, research confirms that firms are susceptible to internal principal-agent problems. Green Lights, a program that provides technical assistance to (voluntarily) participating firms, enabled cost-saving lighting upgrades that these firms had not installed independently. Program experience suggests that firms failed to install these cost-effective measures before the program due to internal principal-agent conflicts: capital rationing by managers and split incentives across divisions (Howarth, Haddad, and Paton 2000). Likewise, case studies of the electric-motor market in Europe identified split incentives as a barrier to investments in energy efficiency (de Almeida 1998; Ostertag 2003).

Despite the frequency with which the principal-agent problem is named as a contributor to the energy-efficiency gap, there are few formal agency models adapted to this setting. Experimental work is difficult in many settings, since researchers cannot randomly assign landlords and tenants to properties. Therefore, creative empirical strategies (e.g., Myers 2015) and new data sources may be needed.

The structure of the principal-agent problem may also create opportunities for creative policy responses. Eliminating information asymmetries or innovation in the form of contracts could allow private markets to overcome misaligned incentives. For example, Japan requires vending-machine operators—rather than owners of properties where machines are installed—to pay for the machines' energy use (IEA 2007). Despite this, vending machines are also subject to minimum efficiency standards in Japan.

4.2 *Do Learning-By-Using Spillovers Inhibit More Energy-Efficient Decisions?*

In many cases, consumers learn about the benefits of a given technology by adopting and experiencing it. In some cases, other consumers benefit from this information without having to adopt the technology. A positive information spillover could slow the rate of technology adoption relative to the social optimum, as each consumer has an incentive to delay adoption in order to learn from others. Put another way, the opportunity for individuals to substitute their peers' experiences for their own creates an incentive to free ride (Foster and Rosenzweig 2010). At least in theory, this phenomenon could contribute to the energy-efficiency gap.²⁷

Empirical research in other domains emphasizes the prevalence of social learning and peer effects (Case and Katz 1991; Ammermueller and Pischke 2009; Duflo and Saez 2002; Foster and Rosenzweig 1995; Emerick 2014; Conley and Udry 2010), but there is limited evidence regarding how information spillovers affect energy-efficient technology, and—if positive spillovers exist—whether consumers respond by free

²⁷These spillovers are related to the effects of demand spillovers on innovation by firms, discussed above, in that they also affect product offerings.

riding. The bulk of the evidence on information spillovers comes from the introduction of hybrid vehicles, drawing on both stated-preference (Mau et al. 2008) and revealed-preference studies (Axsen, Mountain, and Jaccard 2009; Narayanan and Nair 2013).²⁸ In the residential sector, a study of thermal insulation choices by homebuilders found no evidence of large knowledge externalities among builders, suggesting builders do not learn from the adoption of these technologies by competitors (Jaffe and Stavins 1995).²⁹

Theoretical research from other fields highlights the potential importance of social learning and peer effects (Manski 1993a), and underscores the potential for social learning to lead to inefficient technology-adoption decisions, even irrespective of free ridership. Information spillovers in the context of irreversible technology choice with network externalities can result in proven technologies being chosen over alternatives with higher expected value (Choi 1997). Similarly, a model in which it is rational to adopt technology based on the adoption decisions of others (for example, because the decisions of others may reflect information the agent lacks) predicts herd behavior in which agents make decisions that depart from the decision they would make using only private information. This can lead to inefficient outcomes, as agents collectively undermine the benefits of learning by taking cues from others, rather than relying on private information (Banerjee 1992).

²⁸ Learning spillovers from hybrid technology are not always positive. Analysis of both the Toyota Prius and the Honda Insight suggests that while higher market penetration by the Prius has led to increased adoption of all hybrids, higher market penetration by the Insight has led to *reduced* adoption (Heutel and Muehlegger 2015).

²⁹ An alternative explanation acknowledged by Jaffe and Stavins (1995) is that builders have complete (or close to complete) information, so there is little or no scope for learning from the adoption decisions of others.

Previous research illustrates the challenge of credibly identifying spillovers using observational data (Narayanan and Nair 2013; Manski 1993b). The challenge is to disentangle spillover effects from unobservables (Foster and Rosenzweig 2010). Even then, empirically testing for the presence of learning spillovers does not indicate whether the spillovers contribute to the energy-efficiency gap, such as through individuals free riding and thus slowing the overall rate of technology adoption. Further research will be needed to determine the effect of learning spillovers on the adoption of energy-efficient technology, potentially through the use of experimental techniques (Baird et al. 2014).

4.3 *Does Inattention to and/or a Lack of Salience of Energy Operating Costs Inhibit Energy-Efficient Decisions?*

Broadly speaking, there is considerable evidence that consumer inattention to non-salient costs affects decisions. Experiments and observational data reveal that consumers are inattentive to sales taxes (Chetty, Looney, and Kroft 2009), shipping charges (Hossain and Morgan 2006), and out-of-pocket costs for health care (Abaluck and Gruber 2011). Conceptually, inattention may contribute to the energy-efficiency gap to the degree that energy costs are not salient for the investment decision. In some markets, this contribution could be substantial. Almost half of surveyed vehicle buyers report making their decisions without considering fuel costs (Allcott 2011a), which is consistent with research that found that consumers largely ignored replacement ink prices when making printer purchase decisions (Hall 1997).

There are two fundamental ways to frame research on inattention. One is a reduced-form approach, empirically estimating an attentiveness parameter without taking a stance on the underlying structural model of inattention (DellaVigna 2009). This

approach can produce credible estimates of the relative importance of inattention in a given context, but it falls short of identifying the mechanisms that underlie inattention. The other approach is to develop a model of the decision process itself, making explicit the underlying factors at play.³⁰

Intuition suggests that consumers will only allocate attention to an attribute if the cognitive costs of doing so are less than the expected utility gains. Thus, the level of inattentiveness should vary across individuals and decision environments. Modeling inattention to energy efficiency as a result of costly information acquisition offers one way to explain decisions that are *apparently* privately suboptimal (Howarth and Andersson 1993; Sallee 2014).

There are two leading methods for testing for inattention to energy efficiency in empirical research. First, the reduced form of attentiveness suggests comparing demand elasticities with respect to prices and energy costs from market data, the empirical approach taken in many studies of discrete choice, which assess the trade-off consumers make between purchase price and future energy operating costs (Hausman 1979; Dubin and McFadden 1984; Jaffe and Stavins 1995; Goldberg 1998; Anderson and Newell 2004; Sallee, West, and Fan 2015; Busse, Knittel, and Zettelmeyer 2013; Allcott and Wozny 2014).³¹ The primary shortcoming of this method—which these researchers acknowledge—is that price and

energy-cost elasticities can diverge for multiple reasons, including discounting behavior.

Experimental manipulations of salience provide an alternative means of studying inattention to energy efficiency. Field experiments designed to study lightbulb choice provide mixed evidence on the impact of an intervention that targets both salience and information: an online intervention increased average willingness to pay for compact fluorescent lightbulbs (CFLs) by over two dollars, while an in-store intervention had no statistically significant effect on CFL demand (Allcott and Taubinsky 2015).³² Stated-choice experiments that vary the type of information available to consumers, be it economic, physical energy, or environmental, can also help assess which of these is most salient to consumers. However, experimental studies are limited by concerns about distinguishing inattention from incomplete information, demand effects, and external validity. Complementary use of experimental and nonexperimental techniques can ameliorate the shortcomings of each approach (Chetty, Looney, and Kroft 2009).

Economic theory and empirical research provide some guidance for policies to address inattention to energy efficiency. Targeting inattentive consumers could enhance policy cost effectiveness. Information disclosure could target consumers with biased beliefs and those inattentive to future energy costs. The success of information disclosure policies depends crucially on salience, as well as on other context-specific factors. In contrast to information disclosure, subsidies may be poorly targeted for combating inattention if the consumers who know about them also tend to be attentive to future energy costs

³⁰ Research following this approach from other domains could provide guidance for future work on energy efficiency. For example, one common approach is to model inattention as a result of costly information acquisition and processing (see Conlisk 1996 for background and Gabaix et al. 2006 for experimental evidence), while other strands of research describe how salience affects consumer decisions (e.g., Bordalo, Gennaioli, and Shleifer 2013), and formulate alternative frameworks for consumer optimization (e.g., Gabaix 2014).

³¹ We discuss these and other studies in more detail later, in the context of consumer discount rates.

³² Recent field experiments demonstrate the potential for experimental research to advance knowledge of the energy-efficiency gap in additional markets. See Price (2015) for a summary of this literature.

(Allcott, Knittel, and Taubinsky 2015).³³ That said, there is an alternative argument for poorly targeted taxes and subsidies if these interventions do raise salience or otherwise reduce inattention; such interventions can generate first-order welfare gains for inattentive consumers and only second-order distortions for attentive consumers (O'Donoghue and Rabin 2006).

Public policies can also lower the cost of attention, and even fairly blunt policies could be justified if they lower the cost of attention sufficiently (Sallee 2014). Several recent studies investigate firm responses to coarse policy designs, and attempt to quantify the welfare impacts of these policies (Sallee and Slemrod 2012; and Houde 2014a, 2014b).

Debates over price and information interventions to address inattention highlight a broader question of instrument choice. A number of recent studies provide evidence on the effects of different policy instruments on welfare and energy-efficiency outcomes. Pigouvian taxes on fuels are a natural economic response to the externalities associated with energy use. There may also be a case for product-market price interventions if consumers are inattentive to energy costs (Allcott, Mullainathan, and Taubinsky 2014). Minimum efficiency standards are another alternative used by regulators; in some cases, such standards can lead to an effective ban on certain classes of products (Allcott and Taubinsky 2015). In addition to regulatory mandates for disclosure and product certification, information interventions by utilities and, in particular, peer comparisons, have been successful in reducing residential energy use and may be applicable elsewhere

³³The literature on retirement savings also speaks to this problem of targeting: for example, Chetty et al. (2014) conclude that automatic retirement account contributions are more effective than subsidies in promoting retirement savings, because subsidies only affect the savings of attentive workers.

(Allcott 2011b; Ayres, Raseman, and Shih 2013; Allcott and Rogers 2014).³⁴

Experimental techniques, including belief elicitation, offer promising opportunities for future research. Researchers can also directly test models of inattention, where they offer testable predictions that are unlikely to be confounded by alternative explanations (Sallee 2014).

4.4 *Does Myopia/Short-Sightedness Inhibit More Energy-Efficient Decisions?*

A key issue surrounding the question of whether myopia contributes to the energy-efficiency gap involves identifying the discount rates used by consumers and analyzing whether these discount rates are consistent with maximizing present-value net benefits. There is a long history of observing consumers' choices of energy-consuming durable goods to examine the trade-off between upfront capital costs and operating costs. If consumers are seeking to minimize discounted lifecycle costs, it becomes possible to estimate implicit discount rates.³⁵

The seminal study of this kind was by Hausman (1979), which found average implicit discount rates in excess of 20 percent. Many other researchers subsequently found implicit discount rates much higher than market interest rates (Dubin and McFadden 1984; Gately 1980).³⁶ Such findings have been interpreted as evidence of myopia, the existence of other behavioral issues or

³⁴These interventions may operate through multiple channels other than raising salience (e.g., providing new information, changing reference points, etc.). Allcott and Rogers (2014) estimate how the effects of these treatments change over time and discuss multiple mechanisms consistent with the estimates.

³⁵Of course, it is also possible that consumers are not minimizing aggregate costs because of errors regarding time horizons, their beliefs, or due to inattention, in which case such studies would not reveal true consumer discount rates (Allcott and Wozny 2014).

³⁶Train (1985) and Sanstad, Hanemann, and Auffhammer (2006) review other examples.

market failures, or alternatively as evidence of rational discounting subject to liquidity constraints. Studies that identify a discount rate while assuming cost-minimizing behavior cannot, however, distinguish myopia as an underlying cause of the energy-efficiency gap from other possible causes. For example, high implicit discount rates for home energy investments could also be rationalized by moral hazard: contractors may provide low-quality services, and consumers may use high hurdle rates to insulate themselves from this risk (Giraudet and Houde 2014).³⁷

Automobile purchases provide a good setting to study these questions because such purchases are major decisions, about which consumers presumably think carefully, and because the cost of gasoline has varied substantially over time. Yet the evidence on consumer valuation of fuel economy is mixed (Greene 2010; Helfand and Wolverson 2011). One study has found that consumers are indifferent between \$0.76 now and \$1.00 of discounted future gasoline expenditures, suggesting mild undervaluation of fuel economy that could be due to myopia (Allcott and Wozny 2014). On the other hand, other studies have found that market outcomes are consistent with dynamically cost-minimizing behavior (Busse, Knittel, and Zettelmeyer 2013; Sallee, West, and Fan 2015). Evidence from gasoline and diesel car purchases in Europe in the early 1990s suggests an implicit discount rate of about 11.5 percent, only slightly above automobile loan rates at the time (Verboven 2002). However,

research has not always taken into account the fact that automobile markets have been subject to fuel economy regulation for many years, which tends to reduce the possibility for high implicit discount rates by constraining consumers' choice sets.

To assess the implications of these studies for the energy-efficiency gap, it is necessary to identify a benchmark discount rate, which depends on the cost of capital. One structured-choice experiment found that—conditional on information labeling—elicited discount rates rationalized participant decision making on average, but the use of a common discount rate of five percent for all subjects tended to lead to a conclusion that consumers significantly undervalued energy efficiency (Newell and Siikamäki 2014). In related work, Newell and Siikamäki (2015) found considerable heterogeneity in individual discount rates and also found that individual time preferences systematically influence willingness to invest in energy efficiency, as measured through product choices, required payback periods, and energy efficiency tax credit claims.

Direct research on intertemporal trade-offs in energy-efficiency investment decisions might clarify the contribution of myopia to the energy-efficiency gap. For example, researchers could manipulate intertemporal trade-offs through information provision and pricing interventions, and examine decision making. Another approach may be to combine elicitation of time preferences with choice data and compare choices observed across multiple domains (Bradford et al. 2014).

Strategic responses by firms to consumer myopia present another area for potential research. If firms believe consumers are myopic and therefore undervalue energy efficiency, product offerings will not be optimal from a social perspective, even if firms hold incorrect beliefs about consumer preferences. Studies of the automotive industry

³⁷An alternative way to frame the consideration of myopia is with experimental research and alternative theories at the intersection of psychology and economics. Research on intertemporal decision making from other contexts provides robust evidence that individuals are dynamically inconsistent (Loewenstein and Thaler 1989), and delay costly up-front action even when they acknowledge that it is in their long-run interest (Akerlof 1991). Quasi-hyperbolic discounting provides a theoretical alternative to exponential discounting to explain these empirical anomalies (Laibson 1997).

posit several explanations for the apparently suboptimal level of fuel economy that manufacturers provide (Helfand and Wolverton 2011).

4.5 *Do Other Cognitive Limitations Inhibit More Energy-Efficient Decisions?*

Cognitive limitations other than inattention and myopia could conceivably contribute to the energy-efficiency gap by preventing individuals (or possibly firms) from properly balancing present-value benefits and costs when investing in energy-using capital goods (Gillingham, Newell, and Palmer 2009). This could manifest itself in the use of heuristics or simple optimization errors. Many empirical studies are consistent with these explanations (Sanstad and Howarth 1994). However, it is difficult to disentangle the role of heuristics and bounded rationality from competing explanations, because consumers' decision processes cannot be observed directly and because there is no unified theory of decision making subject to cognitive limitations from which to draw testable hypotheses (Conlisk 1996).

That said, studies of vehicle fuel economy provide some support for the hypothesis of bounded rationality. First, experimental evidence has revealed that consumers systematically misperceive the information contained in fuel economy ratings, due to the inverse relationship between gasoline consumption and miles per gallon ("the MPG illusion") (Larrick and Soll 2008; Allcott 2013). Other research has shown that stated preferences for cars of various efficiencies depend on the metric and scale of information provided on energy labels (Camilleri and Larrick 2014). Translations of fuel economy into multiple perfectly correlated metrics (that is, gallons per mile, estimated annual fuel cost, and greenhouse gas rating) alter stated preferences (Ungemach et al. forthcoming).

This research may provide guidance for regulatory changes that would encourage

greater energy efficiency. The findings suggest that tailoring the scale of energy labels based on the expected lifetime of a given product or providing multiple translations of energy-efficiency metrics could help guide decisions (Camilleri and Larrick 2014; Ungemach et al. forthcoming). To some extent, this is already happening: the US Environmental Protection Agency recently redesigned new vehicle labels to include gallons per miles, multiple cost estimates, comparisons with other vehicles in the same class, and environmental ratings (US Environmental Protection Agency 2015).

There are numerous opportunities to study the effects of cognitive limitations on energy-efficiency decisions. Most direct evidence is from laboratory studies of stated preferences. More research on revealed preferences in real decision environments could complement these studies, but—as noted above—the key research-design challenge, particularly in revealed-preference studies, is credibly distinguishing the effects of heuristic decision making and bounded rationality from other explanations of behavior.

4.6 *Do Loss Aversion or Reference Points Inhibit More Energy-Efficient Decisions?*

Research in psychology has highlighted the importance of reference points and loss aversion (i.e., people's tendency to strongly prefer avoiding losses to acquiring gains) in economic decision making. Empirical insights have been formalized in prospect theory and other alternatives to expected-utility theory (Kahneman and Tversky 1979; Thaler 1985; Tversky and Kahneman 1991; Kőszegi and Rabin 2006).³⁸ Yet despite

³⁸ See also Tversky and Kahneman (1981) and (1992). More recent theoretical and experimental work in psychology also highlights the importance of reference dependence. Query theory hypothesizes that consumers consider discrete arguments for or against a given alternative, and that the number of considerations and the order in which

strong evidence in other decision environments and general theoretical frameworks for analysis, very little is known about the impacts of loss aversion and reference points on energy-efficiency investments.

The most relevant evidence comes from an electric utility that offered residential consumers the opportunity to enroll in a nonbinding goal-setting program to reduce energy consumption (Harding and Hsiaw 2014). Two findings from this study are consistent with reference-dependent preferences: consumers voluntarily enrolled in the program, setting personal conservation goals, and many of these consumers reduced energy use to meet their own goals.

If the importance of goal-based reference points holds in practice, governments and businesses could stimulate investments in energy efficiency by encouraging personal goal-setting or otherwise influencing reference points (Heath, Larrick, and Wu 1999). Two experiments have attempted to affect reference points by providing tailored information, goals, and personalized feedback about energy consumption (Abrahamse et al. 2007; Carrico and Riemer 2011). These studies suggest that providing goals can lead to reductions in energy use, but further research is needed to determine whether goals or tailored information drove observed energy use reductions and to extend this approach to interventions that encourage investment in energy-efficiency technology.

Consumers and firms considering energy-efficiency improvements are almost certainly susceptible to reference points and loss aversion, but empirical research would

be needed to better quantify the importance of these phenomena. Research focused on assessing the importance of loss aversion in the context of energy-efficiency decisions has received virtually no attention, so some initial research would be of value. Such research could help determine, for example, whether evidence that consumers value energy savings less than the investment costs of energy efficiency is due to inattention, myopia, or loss aversion. Future work could synthesize previous experimental techniques to study how different types of information displayed on energy labels influence reference points. Challenges to implementing policy based on existing research include heterogeneity—that no one level of energy efficiency is right for every consumer—and concerns over paternalism, which is a valid concern if reference points can be manipulated. Research on policy interventions (such as energy labels) could inform the design of uniform interventions that minimize the welfare cost of providing blunt guidance. Carefully targeted interventions could shift reference points for some consumers without creating incentives for other consumers to alter their behavior.

4.7 *Do Capital-Market Failures Influence Consumer Discount Rates for Energy-Efficiency Investments?*

Capital-market failures could in principle help explain a divergence between estimated implicit discount rates and typical market interest rates. Prospective investors facing capital constraints may be unable to finance energy-efficiency investments, even if future returns would justify the up-front cost. This could result in an estimated implicit discount rate that is above normal market rates. Information asymmetries could prevent efficient lending even for collateralized investments; firms that possess private information about future cost savings from a particular investment may be unable to convince

they come to mind affects decision making (Weber and Johnson 2009; Weber et al. 2007). This theory underscores the importance of defaults. As another example, Hardisty, Appelt, and Weber (2013) study the combination of loss aversion and intertemporal decision making. In general, this work highlights the need to strive for a comprehensive understanding of decision making to explain the energy-efficiency gap.

lenders of its financial potential if such savings are costly for the lender to evaluate.

In the future, theoretical and empirical findings from consumer-finance research may shed light on specific capital-market failures that are most important for energy efficiency. The actual distribution of market interest rates faced by consumers and firms through various lending mechanisms is critical to identifying the appropriate benchmark market interest rate (or range of rates) in order to quantify its impact on energy-efficiency investments. However, it may be difficult to distinguish empirically between capital-market failures leading to high discount rates and lack of underlying demand for energy-saving technology (Palmer, Walls, and Gerarden 2012). While we encourage research on capital markets generally, we do not assign a high priority to future research on the impact of capital-market failures on energy-efficiency investments. Where capital-market failures do exist, it seems unlikely that policies specific to energy efficiency would be the best response, given the broad set of financial decisions that would be affected.

4.8 *Does Systematic Risk Affect the Appropriate Discount Rate for Energy-Efficiency Analysis?*²

The capital asset pricing model (CAPM) presents one way to frame debate about the “correct” discount rate to use for energy-efficiency analysis (Fama and French 2004). The CAPM provides a static optimization framework for determining the appropriate hurdle rate for an investment, based on the risk-free rate of interest, expected returns from a diversified portfolio of assets, and the normalized covariance (β) between the investment’s returns and that of the diversified portfolio. Optimal investment depends on the *opportunity cost* of capital, not simply the nominal cost of capital.

Under the CAPM, a positive (negative) correlation between energy prices and the

rest of the economy would suggest hurdle rates for energy-efficiency investments that are higher (lower) than the returns on a diversified portfolio. A negative relationship between energy prices and the greater economy ($\beta < 0$) supports the use of low hurdle rates, because energy-efficient investments can serve as a hedge. One study found such a negative correlation between the consumer price index for fuels and the S&P 500 index (Metcalf 1994). Likewise, more recent research argues that applying the CAPM to an analysis of vehicle purchases would lower the discount rate due to the low correlation between annual changes in gasoline prices and market returns (Allcott and Wozny 2014). For some end uses, the correlation between fuel prices and market returns is artificially low due to regulation. This could also lead to a lower discount rate under the CAPM.

However, the CAPM may fail as an appropriate benchmark for discount rates for energy-efficiency investment for two reasons. First, the model is not ideal for many energy-efficiency investments because of the CAPM’s static nature, meaning that the investment choice set, expected investment returns, and covariances among investments are treated as fixed over time. In contrast, energy-efficiency investment opportunities, expected returns, and risk relationships likely vary substantially with technological change and other exogenous factors. Second, the CAPM assumes that transaction costs are zero, that the investment can be resold on a secondary market, and that investors already hold diversified portfolios when considering a new investment (Sutherland 1991). These assumptions may be tenable in certain contexts (for example, for sizable businesses), but not in others (for example, for low-income households). Third, the model has failed numerous empirical tests (Fama and French 2004).

On the other hand, the CAPM’s simplicity generates useful intuition and sharp, testable

predictions that enable researchers to assess its utility for energy-efficiency investments. One possible approach would be to use observational data on similar investments utilizing different fuels. Prices for various fuels covary heterogeneously with the greater economy. As a result, investment hurdle rates should vary across fuel types. Estimating and comparing these hurdle rates could directly test the CAPM in this realm. However, it may be difficult to eliminate correlated unobservables.

4.9 Can Option Value Help Explain the Energy-Efficiency Gap?

Option value—the net benefit of delaying an investment even when the investment's net present value is positive—is a general feature of dynamic-optimization problems with uncertainty, irreversible investment, and timing flexibility (Dixit and Pindyck 1994; Kellogg 2014). Consumers and firms commonly face decision problems of this type when investing in energy-consuming durable goods with little or no resale value.

This presents an alternative explanation of the energy-efficiency gap: the difference between *apparently* optimal investment and observed investment may be due to the option value of waiting. Failure to account for this option value could bias estimates of the energy-efficiency gap. In an analysis of irreversible investment in residential energy-efficiency measures under conditions of energy-price uncertainty, Hassett and Metcalf (1993) explained observed technology adoption rates without any reference to market failures.³⁹ Potential technological innovation, which would reduce future adoption costs, can also yield option value for delaying energy-efficiency

investments (Jaffe and Stavins 1995; Ansar and Sparks 2009).

Energy-price uncertainty is important in some industries. Direct computation, reduced form estimation, and simulations have found large hurdle rates due to energy-price volatility based on observed investment decisions (Metcalf and Rosenthal 1995; Diederer, van Tongeren, and van der Veen 2003; Löfgren, Millock, and Nauges 2008).⁴⁰ Technological change is the other prominent explanation for investment delay. Evidence from air conditioner purchases indicates that purchase timing depends on expectations about future developments in product efficiency (Rapson 2014). Other relevant sources of uncertainty include future product use, product efficiency, and product life.

The option value of waiting due to uncertainty regarding future energy prices or technological change may explain part of the apparently suboptimal investment in energy-efficient technologies, but probably not a large part, in most cases (Baker 2012). The option-value explanation hinges on four assumptions: irreversibility, uncertainty, flexible timing, and lumpiness of investment (McDonald and Siegel 1986). In practice, one or more of these conditions can fail. Not all energy-efficient investments are irreversible. There are active resale markets for many types of consumer goods and producer capital. Uncertainty may be irrelevant, as in the case of firms that have long-term energy-procurement contracts in place, which provide price certainty. In other cases, energy-price

³⁹Sanstad, Blumstein, and Stoft (1995) maintained that the option value analysis of Hassett and Metcalf (1993) suggested an implicit discount rate much lower than actually observed, even when taking irreversibility into account.

⁴⁰In this context, the hurdle rate is the multiplier on the cost of capital that corresponds to the minimum acceptable rate of return for a project to be undertaken. Diederer, van Tongeren, and van der Veen (2003) find hurdle rates of 1.76 for Dutch greenhouses based on simulation, and Löfgren, Millock, and Nauges (2008) econometrically estimate hurdle rates of 3.4 to 3.6 for the Swedish energy and heating sector.

uncertainty may be relatively unimportant, as in the case of energy-consuming goods with relatively short lifetimes or in the face of other, dominant sources of uncertainty (Abadie, Chamorro, and González-Eguino 2013). Finally, the timing of investments in energy-consuming durables is not always flexible (for example, replacement of a broken water heater).

One possible way to assess the relative importance of the option value of waiting due to energy-price uncertainty would be to survey consumers and firms directly. The evidence here is mixed. Energy-price uncertainty ranked fourth out of fifteen reported reasons firms did not undertake energy-efficiency investments recommended by auditors in a survey of small- and medium-sized businesses (Fleiter, Schleich, and Ravivanpong 2012). On the other hand, a stated-choice experiment in the residential sector revealed a correlation between energy-price uncertainty and a preference for the status quo over energy-efficiency improvements (Alberini, Banfi, and Ramseier 2013). This result is consistent with the basic prediction of the option-value model, but does not quantify its relative importance.

5. *Do Other Unobserved Costs Inhibit Energy-Efficient Decisions?*

We turn to the final term in the cost-minimization equation described above in section 1, and ask whether other costs inhibit more energy-efficient decisions. We find that the empirical evidence in this realm is generally sound, and that data for additional research are available. We assign a relatively high priority to research in this area, particularly research aimed at better understanding of consumer demand (willingness to pay) for product attributes, which can be useful for improving regulatory design.

5.1 *Do Analysts Take Sufficient Account of Product Attributes?*

Products of varying efficiencies differ from each other in ways that are often omitted from engineering and econometric analysis, potentially contributing to the misidentification of an energy-efficiency gap. Producers may generate efficiency improvements by trading off other product attributes for enhanced energy efficiency. For example, the color, sound, and start-up time of fluorescent lights differ from those of incandescent lights. In such a case, consumers may face opportunity costs of decreased product quality, in addition to any price change, when considering energy-efficient products. Ignoring these opportunity costs would bias estimates of consumer choice and welfare, and also bias estimates of the magnitude of the energy-efficiency gap.

The fundamental challenge to inference is omitted-variable bias. Analyses can be classified in terms of information sets: (1) attributes observed by both the analyst and the consumer; (2) attributes observed by the consumer, but not by the analyst; (3) attributes observed by the analyst, but not the consumer; and (4) attributes observed by neither the analyst nor the consumer. Engineering techniques can recover unbiased estimates unless the consumer observes attributes that the engineer does not. In contrast, appropriate econometric techniques can succeed in all four cases. Thus, the second and arguably most important case necessitates the use of econometric techniques.

Early engineering-economic studies compared capital investment and lifetime operating costs to identify cost-effective investments or infer consumer discount rates, disregarding or only partially correcting for nonenergy attributes. The prominent McKinsey & Company study treated compact fluorescent lightbulbs as interchangeable with other forms of lighting (Granade

et al. 2009), thus ignoring a potentially important source of (unobserved) opportunity costs.

In principle, econometric methods can improve on such engineering methods by including product attributes in analyses of choice data. In practice, however, econometric analysis has been limited by the impracticality of observing and accurately measuring all product characteristics. These characteristics are typically subsumed into error terms. Instrumental variables provide researchers an opportunity to weaken identifying assumptions needed for work with cross-sectional data by isolating variation in energy-efficiency characteristics that are uncorrelated with the error term.⁴¹

Modern econometric techniques improve on previous work by explicitly accounting for product attributes unobserved by the econometrician in discrete-choice models. These models can be estimated using either cross-sectional or panel data. Studies employing the random-coefficients model provide examples of this type of cross-sectional estimation. An early application found significant heterogeneity in demand for automobile fuel economy, suggesting small negative willingness to pay for fuel economy improvements in relatively inefficient vehicles (Berry, Levinsohn, and Pakes 1995), reflecting heterogeneity in the distribution of consumer preferences.

Subsequent research incorporating micro data in the random-coefficients estimation strategy confirmed the importance of

heterogeneity, but also found that consumers have a negative willingness to pay for fuel economy, on average (Petrin 2002). However, the primary focus of these early studies using random coefficients was on modeling unobserved consumer heterogeneity, rather than quantifying fuel economy valuation. These studies did not instrument for fuel economy, so these coefficients are likely biased. More recent estimation strategies that focused on identifying average demand for fuel economy have used alternative instruments and have not found a negative willingness to pay for fuel economy (Verboven 2002; Klier and Linn 2012; Whitefoot, Fowlie, and Skerlos 2017). One study of appliance purchases using transactions data and geographic variation in operating costs (that is, electricity prices) found that consumers undervalue operating costs, on average (Houde 2014b).

Panel data provide another credible way to account for unobserved product attributes. Researchers using panel data can effectively condition on all unobserved product attributes that are time-invariant using differencing or fixed-effects models. Recent studies of this type provide limited evidence for an energy-efficiency gap (Allcott and Wozny 2014; Busse, Knittel, and Zettelmeyer 2013; Sallee, West, and Fan 2015).⁴²

Choice experiments offer another possible way to control for unobserved product characteristics. One approach in a stated-preference context would be to ask subjects to treat all products they consider as identical in nonenergy attributes. This holds promise for stated-preference studies but is infeasible for revealed-preference analysis. Analyses that assess the correlation between energy and nonenergy attributes for different

⁴¹Instruments have been employed in models of energy-efficiency technology adoption for decades to address concerns about price endogeneity and selection on expected usage that could generate a correlation between product efficiency and the error term in a discrete-choice model (for example, Hausman 1979; Dubin and McFadden 1984). However, these early studies did not directly address the possibility of additional product characteristics that are observed by the consumer, but not the econometrician, and could therefore generate omitted variable bias.

⁴²The earlier section on myopia contains a more detailed discussion of the findings of these three papers. Also, see Bento et al. (2009), Greene (2010), and Helfand and Wolverton (2011) for more detailed discussions of automobile choice models and consumer valuation of fuel economy.

products could help identify where the bias from ignoring nonenergy attributes is most likely to be present.

5.2 *Do Analysts Take Sufficient Account of the Costs of Implementing Energy-Efficient Options?*

Omitting any (opportunity) cost of adoption from a comparison of the benefits and costs associated with a given energy-efficiency technology will contribute to the impression of an energy-efficiency gap. Such omitted costs can take many forms, including time spent researching investment alternatives, unobserved implementation costs, and reallocation of resources within a firm. In particular, costs that are less easily quantified are more likely to be omitted by analysts (Granade et al. 2009; Huntington 2011). But these costs may serve as real barriers to investment—not optimization errors or market failures—and should be included in an unbiased analysis of the energy-efficiency gap. This has been a key criticism of the McKinsey study (Granade et al. 2009).

Consumers face a set of adoption costs beyond the most obvious costs of a technology's purchase price and direct installation charges. For example, homeowners have attributed the decision not to install or upgrade attic insulation to the hassle of clearing stored items from the attic space (Caird, Roy, and Herring 2008). A policy experiment in the United Kingdom found that lowering such costs by offering attic cleaning would increase insulation investments (UK Department of Energy and Climate Change 2013). Another study estimated opportunity costs for adopting thermal insulation to be more than twice the costs of materials and labor (Sharma 2011). One possible interpretation of low participation rates in subsidized weatherization programs is that there are high nonmonetary costs associated with these improvements (Fowlie, Greenstone, and Wolfram 2015a).

In the commercial and industrial sectors, case studies and survey evidence provide the bulk of the empirical evidence (Fleiter, Schleich, and Ravivanpong 2012), with firms indicating that production disruptions and inconvenience can preclude investment in energy efficiency (Rohdin and Thollander 2006, Thollander and Ottosson 2008). Survey respondents also cite lack of time as a barrier, highlighting the role of opportunity cost in simply considering investments (Sorrell et al. 2004; Thollander, Danestig, and Rohdin 2007; Schleich 2009; Trianni and Cagno 2012). Furthermore, recipients of industrial energy audits who failed to undertake recommended investments attributed their decisions to unmeasured costs and risks not considered in the audit analysis (Anderson and Newell 2004).

In principle, there is no reason analysts cannot incorporate these additional costs, but in practice, data and measurement challenges often inhibit their ability to do so. One route forward may be to treat such costs as unobservables to be recovered using structural, experimental, and quasi-experimental research designs.

6. *Conclusion*

Energy-efficient technologies offer promise for reducing the costs and environmental damages associated with energy use, but these technologies appear not to be used by consumers and businesses to the degree that would be justified, even on the basis of their private financial net benefits. With this in mind, we have examined the private energy-efficiency gap, the apparent reality that some energy-efficiency technologies that would pay off for adopters are nevertheless not adopted, as well as the broader phenomenon we characterize as the social energy-efficiency gap, the apparent reality that some energy-efficiency technologies that would be socially efficient are not adopted.

The economic literature on explanations of the energy-efficiency gap continues to evolve from its origins in Hausman's 1979 article in the *Bell Journal of Economics*. Concerns about energy conservation and independence in the 1980s brought more attention to the existence of the apparent gap, with the mid-1990s seeing greatly renewed interest, due in part to economists' attention to the issue of global climate change. In this century, concerns about energy security and climate change have combined with developments in behavioral economics, as well as increasing numbers of environmental economists, to produce a massive increase in research on the energy-efficiency gap.

We began our review and assessment of this literature by decomposing cost-minimizing energy-efficiency decisions into their fundamental elements, which allowed us to identify four major questions, the answers to which are germane to sorting out the causes (and reality or lack thereof) of the energy-efficiency gap. First, we asked whether the energy efficiency and associated pricing of products on the market are economically efficient. To answer this question, we examined the variety of energy-efficient products on the market, their energy-efficiency levels, and their pricing. Although the theory is clear, empirical evidence is quite limited. More data that could facilitate potential future empirical research are becoming available, although firm-level data are much less plentiful than data on consumers. We do not see this area as meriting high priority for future research, with the exception of research that evaluates the effectiveness and efficiency of existing energy-efficiency information policies and examines options for improving these policies.

Second, we asked whether energy operating costs are inefficiently priced and/or understood. Even if consumers make privately optimal decisions, energy-saving

technology may diffuse more slowly than the socially optimal rate, because of negative externalities. So, even if the private energy-efficiency gap is not present, the social energy-efficiency gap may be. As in the first realm, the theoretical arguments are strong. Empirical evidence is considerable, and in many cases data are likely to be available for additional research. Existing policies appear not to be sufficient from an economic perspective, suggesting that further research is warranted. Indeed, we assign high priority to the pursuit of research in this realm.

Third, we asked whether product choices are cost-minimizing in present-value terms, or whether various market failures and/or behavioral phenomena inhibit such cost-minimization. We found that the empirical evidence ranges from strong (split incentives/agency issues and inattention/salience phenomena) to moderate (heuristic decision making/bounded rationality, systematic risk, myopia/shortsightedness, and option value) to weak (learning-by-using, loss aversion, and capital-market failures). Importantly, here, as elsewhere in our review, the bulk of previous work has focused on the residential sector and much less attention has been given to the commercial and industrial sectors. Much more work can be done in the behavioral realm, and we view this as a priority for future research.

Fourth, we asked whether other unobserved costs may inhibit energy-efficient decisions. We found that the empirical evidence is generally sound, and that data needed for more research are available. We assign a relatively high priority to future research, particularly to aid understanding of consumer demand for product attributes that are correlated with energy efficiency, thereby informing policy and product-development decisions.

Finally, we can ask what these findings suggest about our three categories of explanations for the apparent underinvestment in

energy-efficient technologies, relative to the predictions of some engineering and economic models: (1) market failures, (2) behavioral explanations, and (3) modeling flaws. It turns out that all three categories of explanations are theoretically sound and that limited empirical evidence exists for each category as well, although the empirical research is by no means consistently strong across all of the specific explanations, as we highlight above.

The validity of each of these explanations—and the degree to which each contributes to the energy-efficiency gap—are relevant for crafting sensible policies, so we hope this review can help inform both future research and future policy. Given the many energy-efficiency policies and programs that are already in place, we also place a high priority on research that evaluates the effectiveness, cost effectiveness, and overall economic efficiency of existing energy-efficiency policies, as well as options for their improvement.

REFERENCES

- Abadie, Luis M., José M. Chamorro, and Mikel González-Eguino. 2013. "Valuing Uncertain Cash Flows from Investments that Enhance Energy Efficiency." *Journal of Environmental Management* 116: 113–24.
- Abaluck, Jason, and Jonathan Gruber. 2011. "Heterogeneity in Choice Inconsistencies among the Elderly: Evidence from Prescription Drug Plan Choice." *American Economic Review* 101 (3): 377–81.
- Abrahamse, Wokje, Linda Steg, Charles Vlek, and Talib Rothengatter. 2007. "The Effect of Tailored Information, Goal Setting, and Tailored Feedback on Household Energy Use, Energy-Related Behaviors, and Behavioral Antecedents." *Journal of Environmental Psychology* 27 (4): 265–76.
- Akerlof, George A. 1970. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics* 84 (3): 488–500.
- Akerlof, George A. 1991. "Procrastination and Obedience." *American Economic Review* 81 (2): 1–19.
- Alberini, Anna, Silvia Banfi, and Celine Ramseier. 2013. "Energy Efficiency Investments in the Home: Swiss Homeowners and Expectations about Future Energy Prices." *Energy Journal* 34 (1).
- Alberini, Anna, Will Gans, and Charles Towe. 2013. "Free Riding, Upsizing, and Energy Efficiency Incentives in Maryland Homes." *Fondazione Eni Enrico Mattei Nota di Lavoro* 82.2013.
- Allcott, Hunt. 2011a. "Consumers' Perceptions and Misperceptions of Energy Costs." *American Economic Review* 101 (3): 98–104.
- Allcott, Hunt. 2011b. "Social Norms and Energy Conservation." *Journal of Public Economics* 95 (9–10): 1082–95.
- Allcott, Hunt. 2013. "The Welfare Effects of Misperceived Product Costs: Data and Calibrations from the Automobile Market." *American Economic Journal: Economic Policy* 5 (3): 30–66.
- Allcott, Hunt, and Michael Greenstone. 2012. "Is There an Energy Efficiency Gap?" *Journal of Economic Perspectives* 26 (1): 3–28.
- Allcott, Hunt, Christopher Knittel, and Dmitry Taubinsky. 2015. "Tagging and Targeting of Energy Efficiency Subsidies." *American Economic Review* 105 (5): 187–91.
- Allcott, Hunt, Sendhil Mullainathan, and Dmitry Taubinsky. 2014. "Energy Policy with Externalities and Internalities." *Journal of Public Economics* 112: 72–88.
- Allcott, Hunt, and Todd Rogers. 2014. "The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation." *American Economic Review* 104 (10): 3003–37.
- Allcott, Hunt, and Richard Sweeney. 2014. "The Role of Sales Agents in Information Disclosure: Evidence from a Field Experiment." National Bureau of Economic Research Working Paper 20048.
- Allcott, Hunt, and Dmitry Taubinsky. 2015. "Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market." *American Economic Review* 105 (8): 2501–38.
- Allcott, Hunt, and Nathan Wozny. 2014. "Gasoline Prices, Fuel Economy, and the Energy Paradox." *Review of Economics and Statistics* 96 (5): 779–95.
- Alquist, Ron, and Lutz Kilian. 2010. "What Do We Learn from the Price of Crude Oil Futures?" *Journal of Applied Econometrics* 25 (4): 539–73.
- Ammermueller, Andreas, and Jorn-Steffen Pischke. 2009. "Peer Effects in European Primary Schools: Evidence from the Progress in International Reading Literacy Study." *Journal of Labor Economics* 27 (3): 315–48.
- Anderson, Michael L., and Maximilian Auffhammer. 2014. "Pounds That Kill: The External Costs of Vehicle Weight." *Review of Economic Studies* 81 (2): 535–71.
- Anderson, Soren T., Ryan Kellogg, and James M. Sallee. 2013. "What Do Consumers Believe about Future Gasoline Prices?" *Journal of Environmental Economics and Management* 66 (3): 383–403.
- Anderson, Soren T., and Richard G. Newell. 2004. "Information Programs for Technology Adoption: The Case of Energy-Efficiency Audits." *Resource and Energy Economics* 26 (1): 27–50.
- Ansar, Jasmin, and Roger Sparks. 2009. "The Experience Curve, Option Value, and the Energy Paradox." *Energy Policy* 37 (3): 1012–20.
- Arrow, Kenneth J. 1962. "The Economic Implications of Learning by Doing." *Review of Economic Studies*

- 29 (3): 155–73.
- Attari, Shahzeen Z., Michael L. DeKay, Cliff I. Davidson, and Wändi Bruine de Bruin. 2010. “Public Perceptions of Energy Consumption and Savings.” *Proceedings of the National Academy of Sciences* 107 (37): 16054–59.
- Averch, Harvey, and Leland L. Johnson. 1962. “Behavior of the Firm under Regulatory Constraint.” *American Economic Review* 52 (5): 1052–69.
- Axsen, Jonn, Dean C. Mountain, and Mark Jaccard. 2009. “Combining Stated and Revealed Choice Research to Simulate the Neighbor Effect: The Case of Hybrid-Electric Vehicles.” *Resource and Energy Economics* 31 (3): 221–38.
- Ayres, Ian, Sophie Raseman, and Alice Shih. 2013. “Evidence from Two Large Field Experiments that Peer Comparison Feedback Can Reduce Residential Energy Usage.” *Journal of Law, Economics, and Organization* 29 (5): 992–1022.
- Baird, Sarah J. Aislinn Bohren, Craig McIntosh, and Berk Özler. 2014. “Designing Experiments to Measure Spillover Effects.” Penn Institute for Economic Research Working Paper 14-006.
- Baker, Erin. 2012. “Option Value and the Diffusion of Energy Efficient Products.” *Energy Journal* 33 (4).
- Banerjee, Abhijit V. 1992. “A Simple Model of Herd Behavior.” *Quarterly Journal of Economics* 107 (3): 797–817.
- Bankard, C. Lanier. 2004. “A Dynamic Analysis of the Market for Wide-Bodied Commercial Aircraft.” *Review of Economic Studies* 71 (3): 581–611.
- Bento, Antonio M., Lawrence H. Goulder, Mark R. Jacobsen, and Roger H. von Haefen. 2009. “Distributional and Efficiency Impacts of Increased US Gasoline Taxes.” *American Economic Review* 99 (3): 667–99.
- Bento, Antonio M., Shanjun Li, and Kevin Roth. 2012. “Is There an Energy Paradox in Fuel Economy? A Note on the Role of Consumer Heterogeneity and Sorting Bias.” *Economics Letters* 115 (1): 44–48.
- Berndt, Ernst R., Robert S. Pindyck, and Pierre Azoulay. 2003. “Consumption Externalities and Diffusion in Pharmaceutical Markets: Antiulcer Drugs.” *Journal of Industrial Economics* 51 (2): 243–70.
- Berry, Linda G., and Michael B. Gettings. 1998. “Realization Rates of the National Energy Audit.” Prepared for the Thermal Performance of the Exterior Envelopes of Buildings VII Conference, Clearwater Beach FL, December 7–11.
- Berry, Steven T., Samuel Kortum, and Ariel Pakes. 1996. “Environmental Change and Hedonic Cost Functions for Automobiles.” *Proceedings of the National Academy of Sciences* 93 (23): 12731–38.
- Berry, Steven T., James Levinsohn, and Ariel Pakes. 1995. “Automobile Prices in Market Equilibrium.” *Econometrica* 63 (4): 841–90.
- Berry, Steven T., and Joel Waldfoegel. 2001. “Do Mergers Increase Product Variety? Evidence from Radio Broadcasting.” *Quarterly Journal of Economics* 116 (3): 1009–25.
- Berry, Steven T., and Joel Waldfoegel. 2010. “Product Quality and Market Size.” *Journal of Industrial Economics* 58 (1): 1–31.
- Blasnik, Michael. 1990. “Attic Insulation Performance, Air Leakage, and Ventilation: Measured Results in Flat Roof Rowhouses.” ACEEE 1990 Summer Study on Energy Efficiency in Buildings Final Report.
- Bloom, Nicholas, Benn Eifert, Aprajit Mahajan, David McKenzie, and John Roberts. 2013. “Does Management Matter? Evidence from India.” *Quarterly Journal of Economics* 128 (1): 1–51.
- Blumstein, Carl, Betsy Krieg, Lee Schipper, and Carl York. 1980. “Overcoming Social and Institutional Barriers to Energy Conservation.” *Energy* 5 (4): 355–71.
- Bordalo, Pedro, Nicola Gennaioli, and Andrei Shleifer. 2013. “Salience and Consumer Choice.” *Journal of Political Economy* 121 (5): 803–43.
- Borenstein, Severin. 2005. “The Long-Run Efficiency of Real-Time Electricity Pricing.” *Energy Journal* 26 (3): 93–116.
- Borenstein, Severin. 2012. “The Redistributive Impact of Nonlinear Electricity Pricing.” *American Economic Journal: Economic Policy* 4 (3): 56–90.
- Borenstein, Severin, and Lucas W. Davis. 2012. “The Equity and Efficiency of Two-Part Tariffs in U.S. Natural Gas Markets.” *Journal of Law and Economics* 55 (1): 75–128.
- Boyes, William J. 1976. “An Empirical Examination of the Averch–Johnson Effect.” *Economic Inquiry* 14 (1): 23–35.
- Bradford, David, Charles Courtemanche, Garth Heutel, Patrick McAlvanah, and Christopher Ruhm. 2014. “Time Preferences and Consumer Behavior.” National Bureau of Economic Research Working Paper 20320.
- Brounen, Dirk, and Nils Kok. 2011. “On the Economics of Energy Labels in the Housing Market.” *Journal of Environmental Economics and Management* 62 (2): 166–79.
- Busse, Meghan R., Christopher R. Knittel, and Florian Zettelmeyer. 2013. “Are Consumers Myopic? Evidence from New and Used Car Purchases.” *American Economic Review* 103 (1): 220–56.
- Caird, Sally, Robin Roy, and Horace Herring. 2008. “Improving the Energy Performance of UK Households: Results from Surveys of Consumer Adoption and Use of Low- and Zero-Carbon Technologies.” *Energy Efficiency* 1 (2): 149–66.
- Camilleri, Adrian R., and Richard P. Larrick. 2014. “Metric and Scale Design as Choice Architecture Tools.” *Journal of Public Policy and Marketing* 33 (1): 108–25.
- Carrico, Amanda R., and Manuel Riemer. 2011. “Motivating Energy Conservation in the Workplace: An Evaluation of the Use of Group-Level Feedback and Peer Education.” *Journal of Environmental Psychology* 31 (1): 1–13.
- Case, Anne C., and Lawrence F. Katz. 1991. “The Company You Keep: The Effects of Family and Neighborhood on Disadvantaged Youths.” National Bureau of Economic Research Working Paper 3705.

- Chetty, Raj, John N. Friedman, Søren Leth-Petersen, Torben Heien Nielsen, and Tore Olsen. 2014. "Active vs. Passive Decisions and Crowd-Out in Retirement Savings Accounts: Evidence from Denmark." *Quarterly Journal of Economics* 129 (3): 1141–219.
- Chetty, Raj, Adam Looney, and Kory Kroft. 2009. "Salience and Taxation: Theory and Evidence." *American Economic Review* 99 (4): 1145–77.
- Choi, Jay Pil. 1997. "Herd Behavior, the 'Penguin Effect,' and the Suppression of Informational Diffusion: An Analysis of Informational Externalities and Payoff Interdependency." *RAND Journal of Economics* 28 (3): 407–25.
- Choi, Seok Joon, and Sangsin Kim. 2012. "Why Do Landlords Include Utilities in Rent? Evidence from the 2000 Housing Discrimination Study (HDS) and the 2002 American Housing Survey (AHS)." *Journal of Housing Economics* 21 (1): 28–40.
- Cicala, Steve. 2015. "When Does Regulation Distort Costs? Lessons from Fuel Procurement in US Electricity Generation." *American Economic Review* 105 (1): 411–44.
- Clements, Benedict, et al. 2013. *Energy Subsidy Reform: Lessons and Implications*. Washington, DC: International Monetary Fund.
- Coase, Ronald H. 1946. "The Marginal Cost Controversy." *Economica* 13 (51): 169–82.
- Conley, Timothy G., and Christopher R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100 (1): 35–69.
- Conlisk, John. 1996. "Why Bounded Rationality?" *Journal of Economic Literature* 34 (2): 669–700.
- Coscelli, Andrea, and Matthew Shum. 2004. "An Empirical Model of Learning and Patient Spillovers in New Drug Entry." *Journal of Econometrics* 122 (2): 213–46.
- Costa, Dora L., and Matthew E. Kahn. 2013. "Energy Conservation 'Nudges' and Environmentalist Ideology: Evidence from a Randomized Residential Electricity Field Experiment." *Journal of the European Economic Association* 11 (3): 680–702.
- Crawford, Gregory S., and Matthew Shum. 2005. "Uncertainty and Learning in Pharmaceutical Demand." *Econometrica* 73 (4): 1137–73.
- Davis, Lucas W. 2012. "Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances?" In *The Design and Implementation of US Climate Policy*, edited by Don Fullerton and Catherine Wolfram, 301–18. Chicago and London: University of Chicago Press.
- Davis, Lucas W., Alan Fuchs, and Paul Gertler. 2014. "Cash for Coolers: Evaluating a Large-Scale Appliance Replacement Program in Mexico." *American Economic Journal: Economic Policy* 6 (4): 207–38.
- Davis, Lucas W., and Gilbert E. Metcalf. 2014. "Does Better Information Lead to Better Choices? Evidence from Energy-Efficiency Labels." National Bureau of Economic Research Working Paper 20720.
- Davis, Lucas W., and Erich Muehlegger. 2010. "Do Americans Consume Too Little Natural Gas? An Empirical Test of Marginal Cost Pricing." *RAND Journal of Economics* 41 (4): 791–810.
- De Almeida, Edmar Luiz Fagundes. 1998. "Energy Efficiency and the Limits of Market Forces: The Example of the Electric Motor Market in France." *Energy Policy* 26 (8): 643–53.
- DeCanio, Stephen J. 1993. "Barriers within Firms to Energy-Efficient Investments." *Energy Policy* 21 (9): 906–14.
- DellaVigna, Stefano. 2009. "Psychology and Economics: Evidence from the Field." *Journal of Economic Literature* 47 (2): 315–72.
- DellaVigna, Stefano, and Ulrike Malmendier. 2006. "Paying Not to Go to the Gym." *American Economic Review* 96 (3): 694–719.
- Diederer, Paul, Frank van Tongeren, and Hennie van der Veen. 2003. "Returns on Investments in Energy-Saving Technologies under Energy Price Uncertainty in Dutch Greenhouse Horticulture." *Environmental and Resource Economics* 24 (4): 379–94.
- Dixit, Avinash K., and Robert S. Pindyck. 1994. *Investment under Uncertainty*. Princeton and Oxford: Princeton University Press.
- Dubin, Jeffrey A., and Steven E. Henson. 1988. "An Engineering/Econometric Analysis of Seasonal Energy Demand and Conservation in the Pacific Northwest." *Journal of Business and Economic Statistics* 6 (1): 121–34.
- Dubin, Jeffrey A., and Daniel L. McFadden. 1984. "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption." *Econometrica* 52 (2): 345–62.
- Dubin, Jeffrey A., Allen K. Miedema, and Ram V. Chandran. 1986. "Price Effects of Energy-Efficient Technologies: A Study of Residential Demand for Heating and Cooling." *RAND Journal of Economics* 17 (3): 310–25.
- Duflo, Esther, and Emmanuel Saez. 2002. "Participation and Investment Decisions in a Retirement Plan: The Influence of Colleagues' Choices." *Journal of Public Economics* 85 (1): 121–48.
- Eichholtz, Piet, Nils Kok, and John M. Quigley. 2010. "Doing Well By Doing Good? Green Office Buildings." *American Economic Review* 100 (5): 2492–509.
- Eichholtz, Piet, Nils Kok, and John M. Quigley. 2013. "The Economics of Green Building." *Review of Economics and Statistics* 95 (1): 50–63.
- Emerick, Kyle. 2014. "The Efficiency of Trading in Social Networks: Experimental Measures from India." UC Berkeley. Unpublished.
- Fama, Eugene F., and Kenneth R. French. 2004. "The Capital Asset Pricing Model: Theory and Evidence." *Journal of Economic Perspectives* 18 (3): 25–46.
- Faruqui, Ahmad, and Sanem Sergici. 2011. "Dynamic Pricing of Electricity in the Mid-Atlantic Region: Econometric Results from the Baltimore Gas and Electric Company Experiment." *Journal of Regulatory Economics* 40 (1): 82–109.
- Fischer, Carolyn. 2010. "Imperfect Competition, Consumer Behavior, and the Provision of Fuel Efficiency

- in Light-Duty Vehicles.” Resources for the Future Discussion Paper 10-60.
- Fisher, Anthony C., and Michael H. Rothkopf. 1989. “Market Failure and Energy Policy: A Rationale for Selective Conservation.” *Energy Policy* 17 (4): 397–406.
- Fleiter, Tobias, Joachim Schleich, and Ployplearn Ravivanpong. 2012. “Adoption of Energy-Efficiency Measures in SMEs—An Empirical Analysis Based on Energy Audit Data from Germany.” *Energy Policy* 51: 863–75.
- Foster, Andrew D., and Mark R. Rosenzweig. 1995. “Learning By Doing and Learning from Others: Human Capital and Technical Change in Agriculture.” *Journal of Political Economy* 103 (6): 1176–209.
- Foster, Andrew D., and Mark R. Rosenzweig. 2010. “Microeconomics of Technology Adoption.” *Annual Review of Economics* 2: 395–424.
- Fowle, Meredith. 2010. “Emissions Trading, Electricity Restructuring, and Investment in Pollution Abatement.” *American Economic Review* 100 (3): 837–69.
- Fowle, Meredith, Michael Greenstone, and Catherine Wolfram. 2015a. “Are the Non-monetary Costs of Energy Efficiency Investments Large? Understanding Low Take-Up of a Free Energy Efficiency Program.” *American Economic Review* 105 (5): 201–04.
- Fowle, Meredith, Michael Greenstone, and Catherine Wolfram. 2015b. “Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program.” National Bureau of Economic Research Working Paper 21331.
- Gabaix, Xavier. 2014. “A Sparsity-Based Model of Bounded Rationality.” *Quarterly Journal of Economics* 129 (4): 1661–710.
- Gabaix, Xavier, David Laibson, Guillermo Moloche, and Stephen Weinberg. 2006. “Costly Information Acquisition: Experimental Analysis of a Boundedly Rational Model.” *American Economic Review* 96 (4): 1043–68.
- Gately, Dermot. 1980. “Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables: Comment.” *Bell Journal of Economics* 11 (1): 373–74.
- Gilbert, Richard J., and David M. Newbery. 1994. “The Dynamic Efficiency of Regulatory Constitutions.” *RAND Journal of Economics* 25 (4): 538–54.
- Gillingham, Kenneth, Matthew Harding, and David Rapson. 2012. “Split Incentives in Residential Energy Consumption.” *Energy Journal* 33 (2): 37–62.
- Gillingham, Kenneth, Richard G. Newell, and Karen Palmer. 2009. “Energy Efficiency Economics and Policy.” *Annual Review of Resource Economics* 1: 597–620.
- Gillingham, Kenneth, and Karen Palmer. 2014. “Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence.” *Review of Environmental Economics and Policy* 8 (1): 18–38.
- Giraudet, Louis-Gaëtan, and Sébastien Houde. 2014. “Double Moral Hazard and the Energy Efficiency Gap.” Evidence for Action on Energy and Efficiency (E2e) Working Paper 009.
- Goldberg, Pinelopi Koujianou. 1998. “The Effects of the Corporate Average Fuel Efficiency Standards in the US.” *Journal of Industrial Economics* 46 (1): 1–33.
- Graff Zivin, Joshua S., Matthew J. Kotchen, and Erin T. Mansur. 2014. “Spatial and Temporal Heterogeneity of Marginal Emissions: Implications for Electric Cars and Other Electricity-Shifting Policies.” *Journal of Economic Behavior and Organization* 107 (Part A): 248–68.
- Granade, Hannah Choi, Jon Creyts, Anton Derkach, Philip Farese, Scott Nyquist, and Ken Ostrowski. 2009. “Unlocking Energy Efficiency in the U.S. Economy.” McKinsey & Company.
- Greene, David L. 2010. “How Customers Value Fuel Economy: A Literature Review.” U.S. Environmental Protection Agency EPA-420-R-10-008.
- Greene, David L., David H. Evans, and John Hiestand. 2013. “Survey Evidence on the Willingness of U.S. Consumers to Pay for Automotive Fuel Economy.” *Energy Policy* 61: 1539–50.
- Greening, Lorna A., David L. Greene, and Carmen Difiglio. 2000. “Energy Efficiency and Consumption—The Rebound Effect—A Survey.” *Energy Policy* 28 (6–7): 389–401.
- Griliches, Zvi. 1957. “Hybrid Corn: An Exploration in the Economics of Technological Change.” *Econometrica* 25 (4): 501–22.
- Griliches, Zvi. 1992. “The Search for R&D Spillovers.” *Scandinavian Journal of Economics* 94 (Supplement): S29–47.
- Grubb, Michael D. 2009. “Selling to Overconfident Consumers.” *American Economic Review* 99 (5): 1770–807.
- Hall, Bronwyn H., Jacques Mairesse, and Pierre Mohnen. 2010. “Measuring the Returns to R&D.” In *Handbook of the Economics of Innovation: Volume 1*, edited by Bronwyn H. Hall and Nathan Rosenberg, 1033–82. Amsterdam and Boston: Elsevier, North-Holland.
- Hall, Bronwyn H., and Nathan Rosenberg, eds. 2010. *Handbook of the Economics of Innovation: Volume 1*. Amsterdam and Boston: Elsevier, North-Holland.
- Hall, Robert E. 1997. “The Inkjet Aftermarket: An Economic Analysis.” <https://web.stanford.edu/~rehall/Inkjet%20Aftermarket%201997.pdf>.
- Harding, Matthew, and Alice Hsiaw. 2014. “Goal Setting and Energy Conservation.” *Journal of Economic Behavior and Organization* 107 (Part A): 209–27.
- Hardisty, David J., Kirstin C. Appelt, and Elke U. Weber. 2013. “Good or Bad, We Want It Now: Fixed-Cost Present Bias for Gains and Losses Explains Magnitude Asymmetries in Intertemporal Choice.” *Journal of Behavioral Decision Making* 26 (4): 348–61.
- Hassett, Kevin A., and Gilbert E. Metcalf. 1993. “Energy Conservation Investment: Do Consumers Discount the Future Correctly?” *Energy Policy* 21 (6): 710–16.
- Hausman, Jerry A. 1979. “Individual Discount Rates

- and the Purchase and Utilization of Energy-Using Durables." *Bell Journal of Economics* 10 (1): 33–54.
- Hausman, Jerry A., and Paul L. Joskow. 1982. "Evaluating the Costs and Benefits of Appliance Efficiency Standards." *American Economic Review* 72 (2): 220–25.
- Heath, Chip, Richard P. Larrick, and George Wu. 1999. "Goals as Reference Points." *Cognitive Psychology* 38 (1): 79–109.
- Helfand, Gloria, and Ann Wolverton. 2011. "Evaluating the Consumer Response to Fuel Economy: A Review of the Literature." *International Review of Environmental and Resource Economics* 5 (2): 103–46.
- Heutel, Garth, and Erich Muehlegger. 2015. "Consumer Learning and Hybrid Vehicle Adoption." *Environmental and Resource Economics* 62 (1): 125–61.
- Hirst, Eric. 1986. "Actual Energy Savings after Retrofit: Electrically Heated Homes in the Pacific Northwest." *Energy* 11 (3): 299–308.
- Hoffman, Ian M., et al. 2015. "The Total Cost of Saving Electricity through Utility Customer-Funded Energy Efficiency Programs: Estimates at the National, State, Sector and Program Level." Berkeley Lab Technical Brief.
- Hossain, Tanjim, and John Morgan. 2006. ". . . Plus Shipping and Handling: Revenue (Non) Equivalence in Field Experiments on eBay." *Advances in Economic Analysis and Policy* 5 (2).
- Houde, Sébastien. 2014a. "Bunching with the Stars: How Firms Respond to Environmental Certification." Unpublished.
- Houde, Sébastien. 2014b. "How Consumers Respond to Environmental Certification and the Value of Energy Information." National Bureau of Economic Research Working Paper 20019.
- Houde, Sébastien, and Joseph E. Aldy. 2014. "Belt and Suspenders and More: The Incremental Impact of Energy Efficiency Subsidies in the Presence of Existing Policy Instruments." National Bureau of Economic Research Working Paper 20541.
- Howarth, Richard B., and Bo Andersson. 1993. "Market Barriers to Energy Efficiency." *Energy Economics* 15 (4): 262–72.
- Howarth, Richard B., Brent M. Haddad, and Bruce Paton. 2000. "The Economics of Energy Efficiency: Insights from Voluntary Participation Programs." *Energy Policy* 28 (6–7): 477–86.
- Howell, Sabrina T. 2017. "Financing Innovation: Evidence from R&D Grants." *American Economic Review* 107 (4): 1136–64.
- Huntington, Hillard G. 2011. "The Policy Implications of Energy-Efficiency Cost Curves." *Energy Journal* 32 (1): 7–21.
- International Energy Agency. 2007. *Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency*. Paris: IEA Publications.
- Irwin, Douglas A., and Peter J. Klenow. 1994. "Learning-by-Doing Spillovers in the Semiconductor Industry." *Journal of Political Economy* 102 (6): 1200–1227.
- Ito, Koichiro. 2014. "Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing." *American Economic Review* 104 (2): 537–63.
- Ito, Koichiro, Takanori Ida, and Makoto Tanaka. 2015. "The Persistence of Moral Suasion and Economic Incentives: Field Experimental Evidence from Energy Demand." National Bureau of Economic Research Working Paper 20910.
- Ito, Koichiro, and James M. Sallee. 2014. "The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel-Economy Standards." National Bureau of Economic Research Working Paper 20500.
- Jaffe, Adam B., Richard G. Newell, and Robert N. Stavins. 2002. "Environmental Policy and Technological Change." *Environmental and Resource Economics* 22 (1–2): 41–70.
- Jaffe, Adam B., Richard G. Newell, and Robert N. Stavins. 2005. "A Tale of Two Market Failures: Technology and Environmental Policy." *Ecological Economics* 54 (2–3): 164–74.
- Jaffe, Adam B., and Robert N. Stavins. 1994a. "The Energy-Efficiency Gap: What Does It Mean?" *Energy Policy* 22 (10): 804–10.
- Jaffe, Adam B., and Robert N. Stavins. 1994b. "The Energy Paradox and the Diffusion of Conservation Technology." *Resource and Energy Economics* 16 (2): 91–122.
- Jaffe, Adam B., and Robert N. Stavins. 1995. "Dynamic Incentives of Environmental Regulations: The Effects of Alternative Policy Instruments on Technology Diffusion." *Journal of Environmental Economics and Management* 29 (3): S43–63.
- Janakiraman, Ramkumar, Catarina Sismeiro, and Shantanu Dutta. 2009. "Perception Spillovers across Competing Brands: A Disaggregate Model of How and When." *Journal of Marketing Research* 46 (4): 467–81.
- Jessoe, Katrina, and David Rapson. 2014. "Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use." *American Economic Review* 104 (4): 1417–38.
- Jessoe, Katrina, David Rapson, and Jeremy B. Smith. 2014. "Towards Understanding the Role of Price in Residential Electricity Choices: Evidence from a Natural Experiment." *Journal of Economic Behavior and Organization* 107 (Part A): 191–208.
- Joskow, Paul L., and Donald B. Marron. 1993. "What Does Utility-Subsidized Energy Efficiency Really Cost?" *Science* 260 (5106): 281–370.
- Joskow, Paul L., and Catherine D. Wolfram. 2012. "Dynamic Pricing of Electricity." *American Economic Review* 102 (3): 381–85.
- Jovanovic, Boyan. 1982. "Truthful Disclosure of Information." *Bell Journal of Economics* 13 (1): 36–44.
- Kahn, Matthew E., and Nils Kok. 2014. "The Capitalization of Green Labels in the California Housing Market." *Regional Science and Urban Economics* 47: 25–34.
- Kahneman, Daniel, and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk."

- Econometrica* 47 (2): 263–92.
- Kamien, Morton, and Nancy L. Schwartz. 1982. *Market Structure and Innovation*. Cambridge and New York: Cambridge University Press.
- Kellogg, Ryan. 2014. “The Effect of Uncertainty on Investment: Evidence from Texas Oil Drilling.” *American Economic Review* 104 (6): 1698–734.
- Klier, Thomas, and Joshua Linn. 2012. “New-Vehicle Characteristics and the Cost of the Corporate Average Fuel Economy Standard.” *RAND Journal of Economics* 43 (1): 186–213.
- Kőszegi, Botond, and Matthew Rabin. 2006. “A Model of Reference-Dependent Preferences.” *Quarterly Journal of Economics* 121 (4): 1133–65.
- Laibson, David. 1997. “Golden Eggs and Hyperbolic Discounting.” *Quarterly Journal of Economics* 112 (2): 443–78.
- Langer, Ashley, and Nathan H. Miller. 2013. “Automakers’ Short-Run Responses to Changing Gasoline Prices.” *Review of Economics and Statistics* 95 (4): 1198–211.
- Larrick, Richard P., and Jack B. Soll. 2008. “The MPG Illusion.” *Science* 320 (5883): 1593–94.
- Levinson, Arik, and Scott Niemann. 2004. “Energy Use By Apartment Tenants When Landlords Pay for Utilities.” *Resource and Energy Economics* 26 (1): 51–75.
- Levitt, Steven D., John A. List, and Chad Syverson. 2013. “Toward an Understanding of Learning By Doing: Evidence from an Automobile Assembly Plant.” *Journal of Political Economy* 121 (4): 643–81.
- Lewis, Gregory. 2011. “Asymmetric Information: Adverse Selection and Online Disclosure: The Case of eBay Motors.” *American Economic Review* 101 (4): 1535–46.
- Lieberman, Marvin B. 1984. “The Learning Curve and Pricing in the Chemical Processing Industries.” *RAND Journal of Economics* 15 (2): 213–28.
- Lim, Claire S. H., and Ali Yurukoglu. 2015. “Dynamic Natural Monopoly Regulation: Time Inconsistency, Moral Hazard, and Political Environments.” http://web.stanford.edu/~ayurukog/main_infrastructure.pdf.
- Loewenstein, George, and Richard H. Thaler. 1989. “Anomalies: Intertemporal Choice.” *Journal of Economic Perspectives* 3 (4): 181–93.
- Löfgren, Åsa, Katrin Millock, and Céline Nauges. 2008. “The Effect of Uncertainty on Pollution Abatement Investments: Measuring Hurdle Rates for Swedish Industry.” *Resource and Energy Economics* 30 (4): 475–91.
- Manski, Charles F. 1993a. “Dynamic Choice in Social Settings: Learning from the Experiences of Others.” *Journal of Econometrics* 58 (1–2): 121–36.
- Manski, Charles F. 1993b. “Identification of Endogenous Social Effects: The Reflection Problem.” *Review of Economic Studies* 60 (3): 531–42.
- Manski, Charles F. 2004. “Measuring Expectations.” *Econometrica* 72 (5): 1329–76.
- Maruejols, Lucie, and Denise Young. 2011. “Split Incentives and Energy Efficiency in Canadian Multi-family Dwellings.” *Energy Policy* 39 (6): 3655–68.
- Mau, Paulus, Jimena Eyzaguirre, Mark Jaccard, Colleen Collins-Dodd, and Kenneth Tiedemann. 2008. “The ‘Neighbor Effect’: Simulating Dynamics in Consumer Preferences for New Vehicle Technologies.” *Ecological Economics* 68 (1–2): 504–16.
- McDonald, Robert, and Daniel Siegel. 1986. “The Value of Waiting to Invest.” *Quarterly Journal of Economics* 101 (4): 707–27.
- Metcalf, Gilbert E. 1994. “Economics and Rational Conservation Policy.” *Energy Policy* 22 (10): 819–25.
- Metcalf, Gilbert E., and Kevin A. Hassett. 1999. “Measuring the Energy Savings from Home Improvement Investments: Evidence from Monthly Billing Data.” *Review of Economics and Statistics* 81 (3): 516–28.
- Metcalf, Gilbert E., and Donald Rosenthal. 1995. “The ‘New’ View of Investment Decisions and Public Policy Analysis: An Application to Green Lights and Cold Refrigerators.” *Journal of Policy Analysis and Management* 14 (4): 517–31.
- Muller, Nicholas Z., and Robert Mendelsohn. 2009. “Efficient Pollution Regulation: Getting the Prices Right.” *American Economic Review* 99 (5): 1714–39.
- Munley, Vincent G., Larry W. Taylor, and John P. Formby. 1990. “Electricity Demand in Multi-family, Renter-Occupied Residences.” *Southern Economic Journal* 57 (1): 178–94.
- Murphy, Rose, and Mark Jaccard. 2011. “Energy Efficiency and the Cost of GHG Abatement: A Comparison of Bottom-Up and Hybrid Models for the US.” *Energy Policy* 39 (11): 7146–55.
- Murtishaw, Scott, and Jayant Sathaye. 2006. “Quantifying the Effect of the Principal-Agent Problem on US Residential Energy Use.” Lawrence Berkeley National Laboratory 59773.
- Myers, Erica. 2015. “Asymmetric Information in Residential Rental Markets: Implications for the Energy Efficiency Gap.” Energy Institute at Haas Working Paper 246R.
- Nadel, Steve, and Kenneth Keating. 1991. “Engineering Estimates vs. Impact Evaluation Results: How Do They Compare and Why?” American Council for an Energy-Efficient Economy Research Report U915.
- Narayanan, Sridhar, and Harikesh S. Nair. 2013. “Estimating Causal Installed-Based Effects: A Bias-Correction Approach.” *Journal of Marketing Research* 50 (1): 70–94.
- National Research Council. 2010. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. Washington, DC: National Academies Press.
- Naughton, Michael C. 1986. “The Efficiency and Equity Consequences of Two-Part Tariffs in Electricity Pricing.” *Review of Economics and Statistics* 68 (3): 406–14.
- Newell, Richard G., Adam B. Jaffe, and Robert N. Stavins. 1999. “The Induced Innovation Hypothesis and Energy-Saving Technological Change.” *Quarterly Journal of Economics* 114 (3): 941–75.
- Newell, Richard G., and Juha Siikamäki. 2014. “Nudging Energy Efficiency Behavior: The Role

- of Information Labels." *Journal of the Association of Environmental and Resource Economists* 1 (4): 555–98.
- Newell, Richard G., and Juha Siikamäki. 2015. "Individual Time Preferences and Energy Efficiency." *American Economic Review* 105 (5): 196–200.
- Nordhaus, William. 2011. "Designing a Friendly Space for Technological Change to Slow Global Warming." *Energy Economics* 33 (4): 665–73.
- O'Donoghue, Ted, and Matthew Rabin. 2006. "Optimal Sin Taxes." *Journal of Public Economics* 90 (10–11): 1825–49.
- Ostertag, Katrin. 2003. *No-regret Potentials in Energy Conservation: An Analysis of Their Relevance, Size and Determinants*. Heidelberg and New York: Physica-Verlag.
- Pakes, Ariel, Steven Berry, and James A. Levinsohn. 1993. "Applications and Limitations of Some Recent Advances in Empirical Industrial Organization: Price Indexes and the Analysis of Environmental Change." *American Economic Review* 83 (2): 240–46.
- Palmer, Karen L., Margaret A. Walls, and Todd Gerarden. 2012. "Borrowing to Save Energy: An Assessment of Energy-Efficiency Financing Programs." Resources for the Future Report.
- Palmer, Karen L., Margaret A. Walls, Hal Gordon, and Todd Gerarden. 2013. "Assessing the Energy-Efficiency Information Gap: Results from a Survey of Home Energy Auditors." *Energy Efficiency* 6 (2): 271–92.
- Papineau, Maya. 2015. "Energy Codes and the Landlord–Tenant Problem." Carleton Economic Paper 15-03.
- Parry, Ian W. H., and Kenneth A. Small. 2005. "Does Britain or the United States Have the Right Gasoline Tax?" *American Economic Review* 95 (4): 1276–89.
- Parry, Ian W. H., Margaret Walls, and Winston Harrington. 2007. "Automobile Externalities and Policies." *Journal of Economic Literature* 45 (2): 373–99.
- Petrin, Amil. 2002. "Quantifying the Benefits of New Products: The Case of the Minivan." *Journal of Political Economy* 110 (4): 705–29.
- Phillips, Yvonne. 2012. "Landlords versus Tenants: Information Asymmetry and Mismatched Preferences for Home Energy Efficiency." *Energy Policy* 45: 112–21.
- Popp, David, Richard G. Newell, and Adam B. Jaffe. 2010. "Energy, the Environment, and Technological Change." In *Handbook of the Economics of Innovation: Volume 2*, edited by Bronwyn H. Hall and Nathan Rosenberg, 873–937. Amsterdam and Boston: Elsevier, North-Holland.
- Price, Michael. 2015. "Using Field Experiments to Address Environmental Externalities and Resource Scarcity: Major Lessons Learned and New Directions for Future Research." National Bureau of Economic Research Working Paper 20870.
- Puller, Steven L., and Jeremy West. 2013. "Efficient Retail Pricing in Electricity and Natural Gas Markets." *American Economic Review* 103 (3): 350–55.
- Rapson, David. 2014. "Durable Goods and Long-Run Electricity Demand: Evidence from Air Conditioner Purchase Behavior." *Journal of Environmental Economics and Management* 68 (1): 141–60.
- Rohdin, P., and P. Thollander. 2006. "Barriers to and Driving Forces for Energy Efficiency in the Non-energy Intensive Manufacturing Industry in Sweden." *Energy* 31 (12): 1836–44.
- Sallee, James M. 2014. "Rational Inattention and Energy Efficiency." *Journal of Law and Economics* 57 (3): 781–820.
- Sallee, James M., and Joel Slemrod. 2012. "Car Notches: Strategic Automaker Responses to Fuel Economy Policy." *Journal of Public Economics* 96 (11–12): 981–99.
- Sallee, James M., Sarah West, and Wei Fan. 2015. "Do Consumers Recognize the Value of Fuel Economy? Evidence from Used Car Prices and Gasoline Price Fluctuations." National Bureau of Economic Research Working Paper 21441.
- Sanstad, Alan H., Carl Blumstein, and Steven E. Stoff. 1995. "How High Are Option Values in Energy-Efficiency Investments?" *Energy Policy* 23 (9): 739–43.
- Sanstad, Alan H., W. Michael Hanemann, and Maximilian Auffhammer. 2006. "End-Use Energy Efficiency in a 'Post-carbon' California Economy: Policy Issues and Research Frontiers." In *Managing Greenhouse Gas Emissions in California*, edited by W. Michael Hanemann and Alexander E. Farrell, 6-1–6-32. Berkeley: California Climate Change Center.
- Sanstad, Alan H., and Richard B. Howarth. 1994. "Consumer Rationality and Energy Efficiency." *Proceedings of the ACEEE* 1: 175–83.
- Schleich, Joachim. 2009. "Barriers to Energy Efficiency: A Comparison across the German Commercial and Services Sector." *Ecological Economics* 68 (7): 2150–59.
- Schultz, P. Wesley, Jessica M. Nolan, Robert B. Cialdini, Noah J. Goldstein, and Vladas Griskevicius. 2007. "The Constructive, Destructive, and Reconstructive Power of Social Norms." *Psychological Science* 18 (5): 429–34.
- Sebold, Frederick D., and Eric W. Fox. 1985. "Realized Savings from Residential Conservation Activity." *Energy Journal* 6 (2): 73–88.
- Shaked, Avner, and John Sutton. 1987. "Product Differentiation and Industrial Structure." *Journal of Industrial Economics* 36 (2): 131–46.
- Shama, Avraham. 1983. "Energy Conservation in US Buildings: Solving the High Potential/Low Adoption Paradox from a Behavioural Perspective." *Energy Policy* 11 (2): 148–67.
- Sharma, Dhruv N. 2011. "Economic Efficiency and Distributional Impacts of Policies for Increasing U.S. Residential Insulation." Ph.D. Stanford University.
- Sorrell, Steve, John Dimitropoulos, and Matt Sommerville. 2009. "Empirical Estimates of the Direct Rebound Effect: A Review." *Energy Policy* 37 (4): 1356–71.
- Sorrell, Steve, Eoin O'Malley, Joachim Schleich, and

- Sue Scott. 2004. "Standing on a Burning Platform: Barriers to Energy Efficiency in the UK Brewing Industry." In *The Economics of Energy Efficiency: Barriers to Cost-Effective Investment*. Cheltenham, UK and Northampton, MA: Edward Elgar Publishing.
- Spann, Robert M. 1974. "Rate of Return Regulation and Efficiency in Production: An Empirical Test of the Averch-Johnson Thesis." *Bell Journal of Economics and Management Science* 5 (1): 38–52.
- Spence, A. Michael. 1975. "Monopoly, Quality, and Regulation." *Bell Journal of Economics* 6 (2): 417–29.
- Spence, A. Michael. 1976. "Product Selection, Fixed Costs, and Monopolistic Competition." *Review of Economic Studies* 43 (2): 217–35.
- Spence, A. Michael. 1981. "The Learning Curve and Competition." *Bell Journal of Economics* 12 (1): 49–70.
- Suri, Tavneet. 2011. "Selection and Comparative Advantage in Technology Adoption." *Econometrica* 79 (1): 159–209.
- Sutherland, Ronald J. 1991. "Market Barriers to Energy-Efficiency Investments." *Energy Journal* 12 (3): 15–34.
- Ternes, Mark P., and Michael B. Gettings. 2008. "Analyses to Verify and Improve the Accuracy of the Manufactured Home Energy Audit (MHEA)." http://weatherization.ornl.gov/pdfs/ORNL_CON-506.pdf.
- Thaler, Richard. 1985. "Mental Accounting and Consumer Choice." *Marketing Science* 4 (3): 199–214.
- Thollander, Patrik, Maria Danestig, and Patrik Rohdin. 2007. "Energy Policies for Increased Industrial Energy Efficiency: Evaluation of a Local Energy Programme for Manufacturing SMEs." *Energy Policy* 35 (11): 5774–83.
- Thollander, Patrik, and Mikael Ottosson. 2008. "An Energy Efficient Swedish Pulp and Paper Industry—Exploring Barriers to and Driving Forces for Cost-Effective Energy Efficiency Investments." *Energy Efficiency* 1 (1): 21–34.
- Thornton, Rebecca Achee and Peter Thompson. 2001. "Learning from Experience and Learning from Others: An Exploration of Learning and Spillovers in Wartime Shipbuilding." *American Economic Review* 91 (5): 1350–68.
- Tietenberg, Tom. 2009. "Reflections—Energy Efficiency Policy: Pipe Dream or Pipeline to the Future?" *Review of Environmental Economics and Policy* 3 (2): 304–20.
- Train, Kenneth. 1985. "Discount Rates in Consumers' Energy-Related Decisions: A Review of the Literature." *Energy* 10 (12): 1243–53.
- Trianni, A., and E. Cagno. 2012. "Dealing with Barriers to Energy Efficiency and SMEs: Some Empirical Evidences." *Energy* 37 (1): 494–504.
- Turrentine, Thomas S., and Kenneth S. Kurani. 2007. "Car Buyers and Fuel Economy?" *Energy Policy* 35 (2): 1213–23.
- Tversky, Amos, and Daniel Kahneman. 1981. "The Framing of Decisions and the Psychology of Choice." *Science* 211 (4481): 453–58.
- Tversky, Amos, and Daniel Kahneman. 1991. "Loss Aversion in Riskless Choice: A Reference-Dependent Model." *Quarterly Journal of Economics* 106 (4): 1039–61.
- Tversky, Amos, and Daniel Kahneman. 1992. "Advances in Prospect Theory: Cumulative Representation of Uncertainty." *Journal of Risk and Uncertainty* 5 (4): 297–323.
- UK Department of Energy and Climate Change. 2013. "Removing the Hassle Factor Associated with Loft Insulation: Results of a Behavioural Trial." https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/236858/DECC_loft_clearance_trial_report_final.pdf.
- Ungemach, Christoph, Adrian R. Camilleri, Eric J. Johnson, Richard P. Larrick, and Elke U. Weber. Forthcoming. "Translated Attributes as Choice Architecture: Aligning Objectives and Choices through Decision Signposts." *Management Science*.
- US Department of Energy. 1991/1992. *National Energy Strategy: Powerful Ideas for America*, First edition. Washington, DC: US Government Printing Office.
- US Environmental Protection Agency. 2015. "Learn about the Fuel Economy Label." <https://www.epa.gov/greenvehicles/learn-about-fuel-economy-label>.
- US Environmental Protection Agency and US Department of Transportation, National Highway Traffic Safety Administration. 2011. "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule." *Federal Register* 76 (179): 57105–513.
- Verboven, Frank. 2002. "Quality-Based Price Discrimination and Tax Incidence: Evidence from Gasoline and Diesel Cars." *RAND Journal of Economics* 33 (2): 275–97.
- Walls, Margaret, Karen Palmer, Todd Gerarden, and Xian Bak. 2013. "Is Energy Efficiency Capitalized into Home Prices? Evidence from Three US Cities." Resources for the Future Discussion Paper 13-18.
- Weber, Elke U., and Eric J. Johnson. 2009. "Mindful Judgment and Decision Making." *Annual Review of Psychology* 60: 53–85.
- Weber, Elke U., Eric J. Johnson, K. F. Milch, H. Chang, J. C. Brodscholl, and D. G. Goldstein. 2007. "Asymmetric Discounting in Intertemporal Choice: A Query-Theory Account." *Psychological Science* 18 (6): 516–23.
- West, Sarah E., and Robertson C. Williams, III. 2007. "Optimal Taxation and Cross-Price Effects on Labor Supply: Estimates of the Optimal Gas Tax." *Journal of Public Economics* 91 (3–4): 593–617.
- Whitefoot, Kate S., Meredith Fowle, and Steven J. Skerlos. 2017. "Compliance by Design: Influence of Acceleration Trade-offs on CO₂ Emissions and Costs of Fuel Economy and Greenhouse Gas Regulations." *Environmental Science and Technology* 51 (18): 10307–15.
- Wood, Gavin, Rachel Ong, and Clinton McMurray. 2012. "Housing Tenure, Energy Consumption and the Split-Incentive Issue in Australia." *International Journal of Housing Policy* 12 (4): 439–69.

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1. Nina L. Frings, Jessica F. Helm, Ulf J. J. Hahnel. 2024. The energy crisis differentially impacted Swiss and German citizens' energy literacy and efficiency preferences but not their support for climate policies. *Communications Earth & Environment* 5:1. . [[Crossref](#)]
2. Mark Toccock, Darla Hatton MacDonald, John M. Rose. 2024. Risk preferences, bill increases and the future reliability of electricity networks in Australia. *Energy Research & Social Science* 118, 103763. [[Crossref](#)]
3. James Carroll, Eleanor Denny, Ronan C. Lyons, Ivan Petrov. 2024. Better energy cost information changes household property investment decisions: Evidence from a nationwide experiment. *Energy Economics* 139, 107909. [[Crossref](#)]
4. Qingyang Wu, Yaqi Wang, Guangjun Shen. 2024. The green bonus of tax incentives: Evidence from China. *Journal of Economic Behavior & Organization* 227, 106740. [[Crossref](#)]
5. Limor Hatsor, Artyom Jelnov. 2024. How to successfully apply industrial symbiosis. *Managerial and Decision Economics* 45:7, 4814-4827. [[Crossref](#)]
6. Daniel Leuthe, Jonas Mirlach, Simon Wenninger, Christian Wieth. 2024. Leveraging explainable AI for informed building retrofit decisions: Insights from a survey. *Energy and Buildings* 318, 114426. [[Crossref](#)]
7. Tim Mandel, Zsuzsanna Pató. 2024. Towards effective implementation of the energy efficiency first principle: a theory-based classification and analysis of policy instruments. *Energy Research & Social Science* 115, 103613. [[Crossref](#)]
8. Ray Galvin. 2024. How Not to Reduce Carbon Dioxide Emissions: An Unbalanced Focus on Energy Efficiency in Germany's Building Rehabilitation Policies. *Energies* 17:17, 4524. [[Crossref](#)]
9. J. Bonan, C. Cattaneo, G. d'Adda, A. Galliera, M. Tavoni. 2024. Widening the scope: The direct and spillover effects of nudging water efficiency in the presence of other behavioral interventions. *Journal of Environmental Economics and Management* 127, 103037. [[Crossref](#)]
10. Robert Lundmark. 2024. Examining the inaction in energy renovation decisions: The role of transaction costs in single-family households in Sweden. *Energy Research & Social Science* 114, 103591. [[Crossref](#)]
11. Morakinyo O. Adetutu, Kayode A. Odusanya, Eleni Stathopoulou, Thomas G. Weyman-Jones. 2024. The Impact of Firm Technology on Carbon Disclosure: The Critical Role of Stakeholder Pressure. *Oxford Bulletin of Economics and Statistics* 102. . [[Crossref](#)]
12. Thiemo Fetzter, Ludovica Gasse, Menna Bishop. 2024. Distributional and climate implications of policy responses to energy price shocks. *Economic Policy* . [[Crossref](#)]
13. Fateh Belaïd, Véronique Flambard. 2024. Ecological-behavioral economics: Impact of information on energy-renovation decision through third-party investing. *Ecological Economics* 221, 108196. [[Crossref](#)]
14. Kenneth T. Gillingham, Asa Watten. 2024. How is rooftop solar capitalized in home prices?. *Regional Science and Urban Economics* 107, 104006. [[Crossref](#)]
15. Kelly C. Bishop, Ozgen Kiribrahim-Sarikaya. 2024. Energy-efficient investments in housing. *Regional Science and Urban Economics* 107, 103994. [[Crossref](#)]

16. Yu Gao, Massimo Tavoni. 2024. Forget-Me-Not: The Persistent Effect of Information Provision for Adopting Climate-Friendly Goods. *Management Science* **70**:7, 4480-4501. [[Crossref](#)]
17. Michela Faccioli, Caterina Lucarelli, Camilla Mazzoli, Sabrina Severini. 2024. What are the Policy Drivers to Undertake Green Retrofitting Investments? The Role of Tax Incentives and Communication in Italian Households' Decision-Making. *Italian Economic Journal* **25**. . [[Crossref](#)]
18. Lisa Sieger. 2024. Investigating inefficiencies in the German rental housing market: The impact of disclosing total costs on energy efficiency appreciation. *Energy and Buildings* **312**, 114183. [[Crossref](#)]
19. Sébastien Foudi. 2024. Are risk attitude, impatience, and impulsivity related to the individual discount rate? Evidence from energy-efficient durable goods. *Theory and Decision* **96**:4, 627-661. [[Crossref](#)]
20. Raj Dash, Biplab Bhattacharjee. 2024. Consumer uptake of energy-efficient appliances in India's online marketplace: An electronic word-of-mouth (eWOM) process model. *Utilities Policy* **88**, 101750. [[Crossref](#)]
21. Samaneh Azimi, Carol K. H. Hon, Tanja Tyvimaa, Martin Skitmore. 2024. Adoption of energy-efficiency measures by Australian low-income households. *Journal of Housing and the Built Environment* **39**:2, 909-936. [[Crossref](#)]
22. Ray Galvin. 2024. Deep energy efficiency renovation of Germany's residential buildings: is this as economically viable as Germany's policymakers and popular promoters often claim?. *Energy Efficiency* **17**:5. . [[Crossref](#)]
23. Chennan Liu, Chao Wang, Shuwang Yang, Wenjuan Wang, Lidong Zhao, Qiming Li. 2024. Catalyst or Obstacle? Green innovation and total factor energy efficiency. *Frontiers in Environmental Science* **12**. . [[Crossref](#)]
24. Célia Escribe, Lucas Vivier, Louis-Gaëtan Giraudet, Philippe Quirion. 2024. How to allocate mitigation efforts between home insulation, fuel switch and fuel decarbonization? Insights from the French residential sector. *Environmental Research Letters* **19**:5, 054018. [[Crossref](#)]
25. Tije van Casteren, Ioulia V. Ossokina, Theo A. Arentze. 2024. Do you listen to your neighbour? The role of block leaders in community-led energy retrofits. *Energy Research & Social Science* **111**, 103472. [[Crossref](#)]
26. Puja Singhal. 2024. Inform me when it matters: Cost salience, energy consumption, and efficiency investments. *Energy Economics* **133**, 107484. [[Crossref](#)]
27. Leon Bremer, Sacha den Nijs, Henri L.F. de Groot. 2024. The energy efficiency gap and barriers to investments: Evidence from a firm survey in The Netherlands. *Energy Economics* **133**, 107498. [[Crossref](#)]
28. Sabine Pelka, Anne Kesselring, Sabine Preuß, Emile Chappin, Laurens de Vries. 2024. Can behavioral interventions optimize self-consumption? Evidence from a field experiment with prosumers in Germany. *Smart Energy* **14**, 100140. [[Crossref](#)]
29. Justin Contat, Carrie Hopkins, Luis Mejia, Matthew Suandi. 2024. When climate meets real estate: A survey of the literature. *Real Estate Economics* **52**:3, 618-659. [[Crossref](#)]
30. Lukas Tomberg. 2024. Resource conservation through improved efficiency, behavioral change, or both: Willingness to pay for (smart) efficient shower heads. *Resources, Conservation and Recycling* **203**, 107387. [[Crossref](#)]

31. Heather Klemick, Ann Wolverton, Bryan Parthum, Kristin Epstein, Sandra Kutzing, Sarah Armstrong. 2024. Factors Influencing Customer Participation in a Program to Replace Lead Pipes for Drinking Water. *Environmental and Resource Economics* **87**:3, 791-832. [[Crossref](#)]
32. Robert Lundmark. 2024. Understanding transaction costs of energy efficiency renovations in the Swedish residential sector. *Energy Efficiency* **17**:3. . [[Crossref](#)]
33. José Carlos Pereira de Morais, Nelson Castro Neves, Luís Abranches Soveral, João Lima. 2024. Innovation in higher education institutions towards sustainability using LED technology. *International Journal of Innovation Science* **16**:2, 296-319. [[Crossref](#)]
34. Thiess Buettner, Anne Kesselring. 2024. Banning Products with Low Energy Efficiency: Market Response and Adjustment Cost. *Journal of the Association of Environmental and Resource Economists* **9**. . [[Crossref](#)]
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37. Jihyo Kim. 2024. Cost-Effectiveness of Energy Efficiency Investments and Their Determinants in Korean Manufacturing Firms. *SSRN Electronic Journal* **84**. . [[Crossref](#)]
38. Janez Dolšak, Nevenka Hrovatin, Jelena Zorić. 2024. What Impacts the strength of perceived barriers to and drivers of energy efficiency in manufacturing SMEs?. *Heliyon* **10**:1, e24020. [[Crossref](#)]
39. Aries Susanty, Sarsa Surya Rizkita, Bamban Purwanggono, Hery Suliantoro, Bahaa Alldin Aladib. 2024. Analysis of the Willingness to Pay for Energy-Efficient Inverter AC using the Contingent Valuation Method (CVM). *Procedia Computer Science* **241**, 280-287. [[Crossref](#)]
40. Aymeric Bellon, Cameron LaPoint, Francesco Mazzola, Guosong Xu. 2024. Picking Up the Pace: Loans for Residential Climate-Proofing. *SSRN Electronic Journal* **15**. . [[Crossref](#)]
41. H. Klemick, A. Wolverton. Energy-efficiency gap . [[Crossref](#)]
42. Sumit Kumar Maji, Puja Chakraborty. 2023. Energy-related financial literacy and energy consumption: a study of residential households in West Bengal, India. *International Journal of Energy Sector Management* **26**. . [[Crossref](#)]
43. Nuredin Juhar, Gunnar Köhlin, Alemu Mekonnen. 2023. Residential fuel consumption and technology choices: an application of FG-NLS and random effects binary logit model. *Environmental Systems Research* **12**:1. . [[Crossref](#)]
44. Anne Kesselring. 2023. Willingness-to-Pay for Energy Efficiency: Evidence from the European Common Market. *Environmental and Resource Economics* **86**:4, 893-945. [[Crossref](#)]
45. Gabriella Francesca Amalia Pernice, Valeria Orso, Luciano Gamberini. 2023. Is This Right for You?: The Key Role of Shop Assistants in Promoting Energy-Efficient Household Appliances. *Sustainability* **15**:24, 16630. [[Crossref](#)]
46. Matthew J. Kotchen, James A. Rising, Gernot Wagner. 2023. The costs of “costless” climate mitigation. *Science* **382**:6674, 1001-1003. [[Crossref](#)]
47. Catherine Chen. 2023. Framing energy-efficiency programs: A survey experiment. *Energy Policy* **183**, 113776. [[Crossref](#)]

48. Thiess Buettner, Boryana Madzharova. 2023. Promoting Sales of Energy Efficient Household Appliances: Outcomes and Cost Effectiveness of Rebate Programs. *Journal of the Association of Environmental and Resource Economists* . [\[Crossref\]](#)
49. Attila Bai, Ibolya Czibere, Imre Kovách, Boldizsár Megyesi, Péter Balogh. 2023. The monetary value of convenience and environmental features in residential heat energy consumption, in particular its social determinants. *Energy Strategy Reviews* **50**, 101192. [\[Crossref\]](#)
50. Xingqi Zhao, Sheng Zeng, Xiaojun Ke, Songyu Jiang. 2023. The impact of green credit on energy efficiency from a green innovation perspective: Empirical evidence from China based on a spatial Durbin model. *Energy Strategy Reviews* **50**, 101211. [\[Crossref\]](#)
51. Kausik Chaudhuri, Gissell Huaccha. 2023. Who bears the energy cost? Local income deprivation and the household energy efficiency gap. *Energy Economics* **127**, 107062. [\[Crossref\]](#)
52. Binhua Qian. 2023. Financial subsidies, tax incentives, and new energy vehicle enterprises' innovation efficiency: Evidence from Chinese listed enterprises. *PLOS ONE* **18**:10, e0293117. [\[Crossref\]](#)
53. Féidhlim P. McGowan, Eleanor Denny, Peter D. Lunn. 2023. Looking beyond time preference: Testing potential causes of low willingness to pay for fuel economy improvements. *Resource and Energy Economics* **75**, 101404. [\[Crossref\]](#)
54. Bryan Coyne, Eleanor Denny, Desta Z. Fitiwi. 2023. The benefits of low-carbon energy efficiency technology adoption for data centres. *Energy Conversion and Management: X* **20**, 100447. [\[Crossref\]](#)
55. Xueyue Liu, Yu Liu, Ruili Zhao. 2023. Import competition and energy efficiency: Firms' responses to the WTO accession in China. *Journal of Economic Behavior & Organization* **214**, 670-690. [\[Crossref\]](#)
56. Miguel A. Tovar Reaños, David Meier, John Curtis, Arya Pillai. 2023. The role of energy, financial attitudes and environmental concerns on perceived retrofitting benefits and barriers: Evidence from Irish home owners. *Energy and Buildings* **297**, 113448. [\[Crossref\]](#)
57. Hafiz Saeed Ur Rehman, Muhammad Aamer Raza, Rehan Masood, Muhammad Arif Khan, Sabahat Alamgir, Muhammad Afzal Javed, Krishanu Roy, James B. P. Lim. 2023. A multi-facet BIM based approach for Green Building design of new multi-family residential building using LEED system. *International Journal of Construction Management* **23**:12, 2024-2038. [\[Crossref\]](#)
58. Tobias Wekhof, Sébastien Houde. 2023. Using narratives to infer preferences in understanding the energy efficiency gap. *Nature Energy* **8**:9, 965-977. [\[Crossref\]](#)
59. Karen Clay, Edson Severnini, Xiaochen Sun. 2023. Does LEED certification save energy? Evidence from retrofitted federal buildings. *Journal of Environmental Economics and Management* **121**, 102866. [\[Crossref\]](#)
60. Gissell Huaccha. 2023. Regional persistence of the energy efficiency gap: Evidence from England and Wales. *Energy Economics* **8**, 107042. [\[Crossref\]](#)
61. Antonella Biscione, Dorothee Boccanfuso, Annunziata de Felice, Francesco Porcelli. 2023. Barriers to firms' energy efficiency in transition countries. *Applied Economics* **55**:36, 4258-4272. [\[Crossref\]](#)
62. Joshua A. Blonz. 2023. The Costs of Misaligned Incentives: Energy Inefficiency and the Principal-Agent Problem. *American Economic Journal: Economic Policy* **15**:3, 286-321. [\[Abstract\]](#) [\[View PDF article\]](#) [\[PDF with links\]](#)
63. Rachel Glennerster, Seema Jayachandran. 2023. Think Globally, Act Globally: Opportunities to Mitigate Greenhouse Gas Emissions in Low- and Middle-Income Countries. *Journal of Economic Perspectives* **37**:3, 111-135. [\[Crossref\]](#)

64. Valeria Fanghella, Marie-Charlotte Guetlein, Joachim Schleich, Carine Sebi. 2023. Preferences on financing mechanisms for thermal retrofit measures in multi-owner buildings: A discrete choice experiment with landlords and owner-occupiers in France. *Resource and Energy Economics* **70**, 101392. [[Crossref](#)]
65. Mitsutsugu Hamamoto. 2023. Estimating consumers' discount rates in energy-saving investment decisions: a comparison of revealed and stated approaches. *SN Business & Economics* **3**:7. . [[Crossref](#)]
66. Ģirts Bohvalovs, Antra Kalnbalķīte, Ieva Pakere, Ruta Vanaga, Vladimirs Kirsanovs, Dace Lauka, Toms Prodanuks, Krista Laktuka, Kristiāna Dolģe, Zigmārs Zundāns, Ingūna Brēmane, Dagnija Blumberga, Andra Blumberga. 2023. Driving Sustainable Practices in Vocational Education Infrastructure: A Case Study from Latvia. *Sustainability* **15**:14, 10998. [[Crossref](#)]
67. Yuyuan Che, Hongli Feng, David A. Hennessy. 2023. Will adoption occur if a practice is win-win for profit and the environment? An application to a rancher's grazing practice choices. *Ecological Economics* **209**, 107826. [[Crossref](#)]
68. Bwei Guo. 2023. The spillover effect of peak pricing. *Journal of Environmental Economics and Management* **33**, 102845. [[Crossref](#)]
69. Manisha Jain. 2023. Estimates of energy savings from energy efficiency improvements in India using Index Decomposition Analysis. *Energy for Sustainable Development* **74**, 285-296. [[Crossref](#)]
70. Aleksandar Vučković, Marija Džunić. 2023. The Influence of Organizational Factors on the Adoption of Energy Efficiency Measures in Companies. *Naše gospodarstvo/Our economy* **69**:2, 41-49. [[Crossref](#)]
71. Todd D. Gerarden, Muxi Yang. 2023. Using Targeting to Optimize Program Design: Evidence from an Energy Conservation Experiment. *Journal of the Association of Environmental and Resource Economists* **10**:3, 687-716. [[Crossref](#)]
72. SORABH TOMAR. 2023. Greenhouse Gas Disclosure and Emissions Benchmarking. *Journal of Accounting Research* **61**:2, 451-492. [[Crossref](#)]
73. Nathan W. Chan, Isla Globus-Harris. 2023. On consumer incentives for energy-efficient durables. *Journal of Environmental Economics and Management* **119**, 102813. [[Crossref](#)]
74. Pranay Kumar, Holly Caggiano, Rachael Shwom, Frank A. Felder, Clinton J. Andrews. 2023. Saving from home! How income, efficiency, and curtailment behaviors shape energy consumption dynamics in US households?. *Energy* **271**, 126988. [[Crossref](#)]
75. Mirika Knuutila, Anna Vuorio. 2023. Temporal-orientation in organizational decision-making: Factors affecting willingness to execute energy efficiency investments in business premises. *Energy* **271**, 127076. [[Crossref](#)]
76. Paolo Renna. 2023. Switch-Off Policies in Job Shop Controlled by Workload Control Concept. *Applied Sciences* **13**:8, 5210. [[Crossref](#)]
77. Reyes Calderón, María Ortiz De Urbina, Luis Expósito. 2023. Follow the genuine leader: The “green imitation”. *Business Ethics, the Environment & Responsibility* **32**:2, 570-581. [[Crossref](#)]
78. Janez Dolšak. 2023. Determinants of energy efficient retrofits in residential sector: A comprehensive analysis. *Energy and Buildings* **282**, 112801. [[Crossref](#)]
79. Louis-Gaëtan Giraudet, Antoine Missemer. 2023. The history of energy efficiency in economics: Breakpoints and regularities. *Energy Research & Social Science* **97**, 102973. [[Crossref](#)]
80. Xiang Ye, Pengpeng Yue. 2023. Financial literacy and household energy efficiency: An analysis of credit market and supply chain. *Finance Research Letters* **52**, 103563. [[Crossref](#)]

81. Claude Crampes, Thomas-Olivier Léautier. 2023. Les certificats d'économie d'énergie entre économie et politique. *Revue économique* **Vol. 74**:1, 51-80. [[Crossref](#)]
82. Feng Yang, Zongbin Zhang. 2023. Will bidirectional FDI impact industrial electricity efficiency in China?. *Environmental Science and Pollution Research* **30**:9, 22494-22508. [[Crossref](#)]
83. Paul Blaise Issock Issock, Asphat Muposhi. 2023. Understanding energy-efficiency choices through consumption values: the central role of consumer's attention and trust in environmental claims. *Management of Environmental Quality: An International Journal* **34**:1, 250-270. [[Crossref](#)]
84. Becka Brolinson, Karen Palmer, Margaret Walls. 2023. Does Energy Star Certification Reduce Energy Use in Commercial Buildings?. *Journal of the Association of Environmental and Resource Economists* **10**:1, 55-93. [[Crossref](#)]
85. Hamza El Hafdaoui, Ahmed Khallaayoun, Kamar Ouazzani. 2023. Activity and efficiency of the building sector in Morocco: A review of status and measures in Ifrane. *AIMS Energy* **11**:3, 454-485. [[Crossref](#)]
86. Rachel Glennerster, Seema Jayachandran. 2023. Think Globally, Act Globally: Opportunities to Mitigate Greenhouse Gas Emissions in Low- and Middle-Income Countries. *SSRN Electronic Journal* **103**. . [[Crossref](#)]
87. Kathrin Kaestner, Stephan Sommer, Jessica Berneiser, Ralph Henger, Christian Oberst. 2023. Cost sharing mechanisms for carbon pricing: What drives support in the housing sector?. *SSRN Electronic Journal* **80**. . [[Crossref](#)]
88. Lisa Sieger. 2023. Investigating Inefficiencies in the German Rental Housing Market: The Impact of Disclosing Total Costs on Energy Efficiency Appreciation. *SSRN Electronic Journal* **26**. . [[Crossref](#)]
89. Nelson Neves, João Lima, Luis Soveral, José Carlos Morais. The Double Benefit of Environmental Sustainability – The Case of ISPGAYA 107-118. [[Crossref](#)]
90. Xueyue Liu, Yu Liu, Ruili Zhao. 2023. Import Competition and Energy Efficiency: Firms' Responses to the WTO Accession in China. *SSRN Electronic Journal* **83**. . [[Crossref](#)]
91. Md Altab Hossin, Patrick Kwashie Akorsu, Hermas Abudu. 2023. Regional energy and carbon emissions concerns: Towards cleaner energy transition in Middle East and North Africa. *Social Sciences & Humanities Open* **8**:1, 100705. [[Crossref](#)]
92. Cristina Peñasco, Laura Díaz Anadón. 2023. Assessing the effectiveness of energy efficiency measures in the residential sector gas consumption through dynamic treatment effects: Evidence from England and Wales. *Energy Economics* **117**, 106435. [[Crossref](#)]
93. Jiyong Park, WooJin Son, HyungBin Moon, JongRoul Woo. 2023. Nudging energy efficiency behavior: The effect of message framing on implicit discount rate. *Energy Economics* **117**, 106485. [[Crossref](#)]
94. Bwei Guo, Ao Sun, Feng Song. 2023. Time is Money: The Social Benefits of Time-of-Use Tariffs. *SSRN Electronic Journal* **105**. . [[Crossref](#)]
95. María del Mar Solà, Marta Escapa, Ibon Galarraga. 2023. Effectiveness of monetary information in promoting the purchase of energy-efficient appliances: Evidence from a field experiment in Spain. *Energy Research & Social Science* **95**, 102887. [[Crossref](#)]
96. Lucas W. Davis. 2023. Evidence of a Homeowner-Renter Gap for Electric Appliances. *The Energy Journal* **44**:4, 53-64. [[Crossref](#)]

97. Pan He, Pengfei Liu, Yueming Qiu, Lufan Liu. 2022. The weather affects air conditioner purchases to fill the energy efficiency gap. *Nature Communications* **13**:1. . [[Crossref](#)]
98. Jiyong Park, JongRoul Woo, Taeyoung Jin. 2022. Estimating implicit discount rate for energy efficiency investment using the contingent valuation method: a case study in South Korea. *Energy Efficiency* **15**:8. . [[Crossref](#)]
99. Elena López-Bernabé, Pedro Linares, Ibon Galarraga. 2022. Energy-efficiency policies for decarbonising residential heating in Spain: A fuzzy cognitive mapping approach. *Energy Policy* **171**, 113211. [[Crossref](#)]
100. Severin Borenstein, James B. Bushnell. 2022. Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency. *American Economic Journal: Economic Policy* **14**:4, 80-110. [[Abstract](#)] [[View PDF article](#)] [[PDF with links](#)]
101. Erica Myers, Steven L. Puller, Jeremy West. 2022. Mandatory Energy Efficiency Disclosure in Housing Markets. *American Economic Journal: Economic Policy* **14**:4, 453-487. [[Abstract](#)] [[View PDF article](#)] [[PDF with links](#)]
102. Eleanya Nduka. 2022. Reducing carbon footprint by replacing generators with solar PV systems: a contingent valuation study in Lagos, Nigeria. *Environment and Development Economics* **19**, 1-22. [[Crossref](#)]
103. Chiradip Chatterjee, Nafisa Halim, Pallab Mozumder. 2022. Energy conservation and health risk reduction: an experimental investigation of punishing vs. rewarding incentives. *Environmental Economics and Policy Studies* **24**:4, 551-570. [[Crossref](#)]
104. Fatih Cemil Ozbugday, Onder Ozgur, Derya Findik. 2022. Drivers of energy efficiency for manufacturing SMEs in Eurasian countries: a profiling analysis using machine learning techniques. *Energy Efficiency* **15**:7. . [[Crossref](#)]
105. Puja Singhal, Michael Pahle, Matthias Kalkuhl, Antoine Levesque, Stephan Sommer, Jessica Berneiser. 2022. Beyond good faith: Why evidence-based policy is necessary to decarbonize buildings cost-effectively in Germany. *Energy Policy* **169**, 113191. [[Crossref](#)]
106. Jon Fernandez-Luzuriaga, Iván Flores-Abascal, Luis del Portillo-Valdes, Petr Mariel, David Hoyos. 2022. Accounting for homeowners' decisions to insulate: A discrete choice model approach in Spain. *Energy and Buildings* **273**, 112417. [[Crossref](#)]
107. Robert Lundmark. 2022. Time-adjusted transaction costs for energy renovations for single-family house-owners. *Energy Economics* **114**, 106327. [[Crossref](#)]
108. Pranay Kumar, Holly Caggiano, Cara Cuite, Clinton J. Andrews, Frank A. Felder, Rachael Shwom, Kristin Floress, Sonya Ahamed, Chelsea Schelly. 2022. Behaving or not? Explaining energy conservation via identity, values, and awareness in U.S. suburban homes. *Energy Research & Social Science* **92**, 102805. [[Crossref](#)]
109. Joachim Geske. 2022. The value of energy efficiency in residential buildings – a matter of heterogeneity?!. *Energy Economics* **113**, 106173. [[Crossref](#)]
110. Marten Ovaere, Stef Proost. 2022. Cost-effective reduction of fossil energy use in the European transport sector: An assessment of the Fit for 55 Package. *Energy Policy* **168**, 113085. [[Crossref](#)]
111. Carrie A. Gill, Stephen A. Atlas, David J. Hardisty, Shawn P. Scott. 2022. Consumer matching costs to context: Status quo bias, temporal framing, and household energy decisions. *Journal of Consumer Behaviour* **21**:5, 1018-1027. [[Crossref](#)]

112. Ben Gilbert, Jacob LaRiviere, Kevin Novan. 2022. Uncertainty and additionality in energy efficiency programs. *Journal of Environmental Economics and Management* **115**, 102700. [[Crossref](#)]
113. Graham Beattie, Iza Ding, Andrea La Nauze. 2022. Is there an energy efficiency gap in China? Evidence from an information experiment. *Journal of Environmental Economics and Management* **115**, 102713. [[Crossref](#)]
114. Cindy Regnier, Paul Mathew, Jordan Shackelford, Sang Hoon Lee, Alastair Robinson, Travis Walter. 2022. Multi-technology building system retrofits for utility incentive programs: Savings, costs and baseline considerations. *Energy and Buildings* **270**, 112270. [[Crossref](#)]
115. Joachim Schleich, Marie-Charlotte Guetlein, Gengyang Tu, Corinne Faure. 2022. Household preferences for private versus public subsidies for new heating systems: insights from a multi-country discrete choice experiment. *Applied Economics* **54**:37, 4292-4309. [[Crossref](#)]
116. Tim Mandel, Zsuzsanna Pató, Jean-Sébastien Broc, Wolfgang Eichhammer. 2022. Conceptualising the energy efficiency first principle: insights from theory and practice. *Energy Efficiency* **15**:6. . [[Crossref](#)]
117. Sebastian Rockstuhl, Simon Wenninger, Christian Wiethe, Jakob Ahlrichs. 2022. The influence of risk perception on energy efficiency investments: Evidence from a German survey. *Energy Policy* **167**, 113033. [[Crossref](#)]
118. Rohan Best, Paul J. Burke. 2022. Effects of renting on household energy expenditure: Evidence from Australia. *Energy Policy* **166**, 113022. [[Crossref](#)]
119. Dumindu Soorige, Gayani Karunasena, Udayangani Kulatunga, Muhammad Nateque Mahmood, Lalith De Silva. 2022. An Energy Culture Maturity Conceptual Framework on Adopting Energy-Efficient Technology Innovations in Buildings. *Journal of Open Innovation: Technology, Market, and Complexity* **8**:2, 60. [[Crossref](#)]
120. Kiyoshi Arakawa. 2022. Assessing consumer valuations of future costs versus purchase prices in Japan's auto market. *Economics of Transportation* **30**, 100260. [[Crossref](#)]
121. Amaia de Ayala, María del Mar Solà. 2022. Assessing the EU Energy Efficiency Label for Appliances: Issues, Potential Improvements and Challenges. *Energies* **15**:12, 4272. [[Crossref](#)]
122. Giulia Chersoni, Nives DellaValle, Magda Fontana. 2022. Modelling thermal insulation investment choice in the EU via a behaviourally informed agent-based model. *Energy Policy* **163**, 112823. [[Crossref](#)]
123. Jing Ke, Nina Khanna, Nan Zhou. 2022. Indirect estimation of willingness to pay for energy technology adoption. *Applied Energy* **312**, 118701. [[Crossref](#)]
124. Cristian Huse, Nikita Koptuyug. 2022. Salience and Policy Instruments: Evidence from the Auto Market. *Journal of the Association of Environmental and Resource Economists* **9**:2, 345-382. [[Crossref](#)]
125. Seyed Vahid Vakili, Fabio Ballini, Dimitrios Dalaklis, Aykut I. Ölçer. 2022. A Conceptual Transdisciplinary Framework to Overcome Energy Efficiency Barriers in Ship Operation Cycles to Meet IMO's Initial Green House Gas Strategy Goals: Case Study for an Iranian Shipping Company. *Energies* **15**:6, 2098. [[Crossref](#)]
126. Ali Ghofrani, Esmat Zaidan, Ammar Abulibdeh. 2022. Simulation and impact analysis of behavioral and socioeconomic dimensions of energy consumption. *Energy* **240**, 122502. [[Crossref](#)]
127. Stephen Berry, Trivess Moore, Michael Ambrose. 2022. Australia's Experience of Combining Building Energy Standards and Disclosure Regulation. *Frontiers in Sustainable Cities* **4**. . [[Crossref](#)]

128. Jakob Ahlrichs, Simon Wenninger, Christian Wiethe, Björn Häckel. 2022. Impact of socio-economic factors on local energetic retrofitting needs - A data analytics approach. *Energy Policy* **160**, 112646. [[Crossref](#)]
129. Jordan Atkinson, Mahelet G. Fikru. 2022. The Role of Economic Versus Behavioral Factors in Differentiating Solar Adopters From Solar Considerers in the United States. *SSRN Electronic Journal* **25**. . [[Crossref](#)]
130. Bawei Guo. 2022. The Spillover Effect of Peak Pricing: Overreaction Due to Cognitive Strain. *SSRN Electronic Journal* **33**. . [[Crossref](#)]
131. Sven Damen, Geert Goeyvaerts, Stef Schildermans. 2022. Split incentives, asymmetric information and energy efficiency subsidies. *SSRN Electronic Journal* **37**. . [[Crossref](#)]
132. Jing Cao, Tracy Liu, Rong Ma, Ang Sun. 2022. Mandates on Household Heating and an Unintended Consequence of a Residential Energy Policy in China. *SSRN Electronic Journal* **26**. . [[Crossref](#)]
133. Amrou Awaysheh, Christopher Chen, Owen Q. Wu. 2022. Does Renewable Energy Renew the Endeavor in Energy Efficiency?. *SSRN Electronic Journal* **11**. . [[Crossref](#)]
134. Nuno Clara, João F. Cocco, S Lakshmi Naaraayanan, Varun Sharma. 2022. Investments that Make our Homes Greener: The Role of Regulation. *SSRN Electronic Journal* **26**. . [[Crossref](#)]
135. Ghislaine Lang, Bruno Lanz. 2022. Climate policy without a price signal: Evidence on the implicit carbon price of energy efficiency in buildings. *Journal of Environmental Economics and Management* **111**, 102560. [[Crossref](#)]
136. Denis Claude, Mabel Tidball. 2021. A New Rationale for Not Picking Low-Hanging Fruits: the Separation of Ownership and Control. *Environmental Modeling & Assessment* **26**:6, 985-998. [[Crossref](#)]
137. Sebastian Rockstuhl, Simon Wenninger, Christian Wiethe, Björn Häckel. 2021. Understanding the risk perception of energy efficiency investments: Investment perspective vs. energy bill perspective. *Energy Policy* **159**, 112616. [[Crossref](#)]
138. T.M. Cristino, A. Faria Neto, F. Wurtz, B. Delinchant. 2021. Barriers to the adoption of energy-efficient technologies in the building sector: A survey of Brazil. *Energy and Buildings* **252**, 111452. [[Crossref](#)]
139. Stefano Cellini. 2021. Split incentives and endogenous inattention in home retrofits uptake: a story of selection on unobservables?. *Energy Economics* **104**, 105656. [[Crossref](#)]
140. Filippos Exadaktylos, Jeroen van den Bergh. 2021. Energy-related behaviour and rebound when rationality, self-interest and willpower are limited. *Nature Energy* **6**:12, 1104-1113. [[Crossref](#)]
141. Sylwia Słupik, Joanna Kos-Łabędowicz, Joanna Trzęsiok. 2021. How to Encourage Energy Savings Behaviours? The Most Effective Incentives from the Perspective of European Consumers. *Energies* **14**:23, 8009. [[Crossref](#)]
142. Carolyn Fischer, Michael Hübler, Oliver Schenker. 2021. More birds than stones – A framework for second-best energy and climate policy adjustments. *Journal of Public Economics* **203**, 104515. [[Crossref](#)]
143. Nevenka Hrovatin, Enrico Cagno, Janez Dolšak, Jelena Zorić. 2021. How important are perceived barriers and drivers versus other contextual factors for the adoption of energy efficiency measures: An empirical investigation in manufacturing SMEs. *Journal of Cleaner Production* **323**, 129123. [[Crossref](#)]

144. Paolo Renna, Sergio Materi. 2021. Switch off policies in job-shop manufacturing systems including workload evaluation. *International Journal of Management Science and Engineering Management* **16**:4, 254-263. [[Crossref](#)]
145. S. Lindgren. 2021. A sound investment? Traffic noise mitigation and property values. *Journal of Environmental Economics and Policy* **10**:4, 428-445. [[Crossref](#)]
146. Seyed Vahid Vakili, Aykut I. Ölçer, Alessandro Schönborn. 2021. The Development of a Transdisciplinary Framework to Overcome Energy Efficiency Barriers in Shipbuilding: A Case Study for an Iranian Shipyard. *Journal of Marine Science and Engineering* **9**:10, 1113. [[Crossref](#)]
147. Jose García-Quevedo, Elisenda Jové-Llopis. 2021. Environmental policies and energy efficiency investments. An industry-level analysis. *Energy Policy* **156**, 112461. [[Crossref](#)]
148. Panu Kalmi, Gianluca Trotta, Andrius Kažukauskas. 2021. Energy-related financial literacy and electricity consumption: Survey-based evidence from Finland. *Journal of Consumer Affairs* **55**:3, 1062-1089. [[Crossref](#)]
149. Leonhard K. Lades, J. Peter Clinch, J. Andrew Kelly. 2021. Maybe tomorrow: How burdens and biases impede energy-efficiency investments. *Energy Research & Social Science* **78**, 102154. [[Crossref](#)]
150. Marcin Nowak, Aleksandra Rabczun, Paweł Łopatka. 2021. Impact of Electrification on African Development-Analysis with Using Grey Systems Theory. *Energies* **14**:16, 5181. [[Crossref](#)]
151. Jens Ewald, Thomas Sterner, Eoin Ó Broin, Érika Mata. 2021. Saving energy in residential buildings: the role of energy pricing. *Climatic Change* **167**:1-2. . [[Crossref](#)]
152. Bruno Lanz, Evert Reins. 2021. Asymmetric Information on the Market for Energy Efficiency: Insights from the Credence Goods Literature. *The Energy Journal* **42**:4, 91-110. [[Crossref](#)]
153. Mark A. Andor, David H. Bernstein, Stephan Sommer. 2021. Determining the efficiency of residential electricity consumption. *Empirical Economics* **60**:6, 2897-2923. [[Crossref](#)]
154. M. del Mar Solà, A. de Ayala, I. Galarraga. 2021. The Effect of Providing Monetary Information on Energy Savings for Household Appliances: A Field Trial in Spain. *Journal of Consumer Policy* **44**:2, 279-310. [[Crossref](#)]
155. Christian Schützenhofer. 2021. Overcoming the efficiency gap: energy management as a means for overcoming barriers to energy efficiency, empirical support in the case of Austrian large firms. *Energy Efficiency* **14**:5. . [[Crossref](#)]
156. Meredith Fowlie, Robyn Meeks. 2021. The Economics of Energy Efficiency in Developing Countries. *Review of Environmental Economics and Policy* **15**:2, 238-260. [[Crossref](#)]
157. Areti Kontogianni, Dimitris Damigos, Michail Skourtos, Christos Tourkolias, Eleanor Denny, Ibon Galarraga, Steffen Kallbekken, Edin Lakić. 2021. Model Validity and Transferability Informing Behavioral Energy Policies. *Energies* **14**:11, 3122. [[Crossref](#)]
158. Ghislaine Lang, Mehdi Farsi, Bruno Lanz, Sylvain Weber. 2021. Energy efficiency and heating technology investments: Manipulating financial information in a discrete choice experiment. *Resource and Energy Economics* **64**, 101231. [[Crossref](#)]
159. Antoine Levesque, Robert C Pietzcker, Lavinia Baumstark, Gunnar Luderer. 2021. Deep decarbonisation of buildings energy services through demand and supply transformations in a 1.5°C scenario. *Environmental Research Letters* **16**:5, 054071. [[Crossref](#)]

160. Bishwa S Koirala, Alok K Bohara. 2021. Do energy efficiency building codes help minimize the efficiency gap in the U.S.? A dynamic panel data approach. *Energy & Environment* 32:3, 506-518. [[Crossref](#)]
161. Elena López-Bernabé, Sébastien Foudi, Pedro Linares, Ibon Galarraga. 2021. Factors affecting energy-efficiency investment in the hotel industry: survey results from Spain. *Energy Efficiency* 14:4. . [[Crossref](#)]
162. Nina Boogen, Cristina Cattaneo, Massimo Filippini, Adrian Obrist. 2021. Energy efficiency and the role of energy-related financial literacy: evidence from the European residential sector. *Energy Efficiency* 14:4. . [[Crossref](#)]
163. Ruby Roberts, Rhona Flin, David Millar, Luca Corradi. 2021. Psychological factors influencing technology adoption: A case study from the oil and gas industry. *Technovation* 102, 102219. [[Crossref](#)]
164. Ming-Chung Chang, Hwai-Shuh Shieh. 2021. Comparative analysis of energy technology gap estimation in SADC, EU, and ASEAN via the energy metafrontier. *Carbon Management* 12:2, 167-181. [[Crossref](#)]
165. D. Damigos, A. Kontogianni, C. Tourkolias, M. Skourtos. 2021. Dissecting subjective discount rates and investment literacy for energy-efficient investments. *Energy Efficiency* 14:3. . [[Crossref](#)]
166. Dimitris Damigos, Christina Kaliampakou, Anastasios Balaskas, Lefkothea Papada. 2021. Does Energy Poverty Affect Energy Efficiency Investment Decisions? First Evidence from a Stated Choice Experiment. *Energies* 14:6, 1698. [[Crossref](#)]
167. Louis-Gaëtan Giraudet, Anna Petronevich, Laurent Faucheux. 2021. Differentiated green loans. *Energy Policy* 149, 111861. [[Crossref](#)]
168. Georgina Santos, Sebastian Rembalski. 2021. Do electric vehicles need subsidies in the UK?. *Energy Policy* 149, 111890. [[Crossref](#)]
169. Hongguang Nie, Ting Zhou, Haiyan Lu, Shupeng Huang. 2021. Evaluation of the efficiency of Chinese energy-saving household appliance subsidy policy: An economic benefit perspective. *Energy Policy* 149, 112059. [[Crossref](#)]
170. Walid Matar. 2021. On the incremental investment in residential energy efficiency: a Saudi perspective. *Energy Sources, Part B: Economics, Planning, and Policy* 16:2, 179-197. [[Crossref](#)]
171. Oluwatobi Adekanye, Alex Davis, Ines Azevedo. 2021. Do LED lightbulbs save natural gas? Interpreting simultaneous cross-energy program impacts using electricity and natural gas billing data. *Environmental Research Communications* . [[Crossref](#)]
172. Dumindu Soorige, Gayani Karunasena, Hong Xian Li. Energy-Efficient Technologies in the Apparel Industry: Limitations of Existing Energy Research 609-619. [[Crossref](#)]
173. María del Mar Solà, Amaia de Ayala, Ibon Galarraga, Marta Escapa. 2021. Promoting energy efficiency at household level: a literature review. *Energy Efficiency* 14:1. . [[Crossref](#)]
174. Amaia de Ayala, Sébastien Foudi, María del Mar Solà, Elena López-Bernabé, Ibon Galarraga. 2021. Consumers' preferences regarding energy efficiency: a qualitative analysis based on the household and services sectors in Spain. *Energy Efficiency* 14:1. . [[Crossref](#)]
175. Da Zhang, Jun Gao, Ding Tang, Xiaomeng Wu, Junye Shi, Jiangping Chen, Yinghong Peng, Shaojun Zhang, Ye Wu. 2021. Switching on auxiliary devices in vehicular fuel efficiency tests can help cut CO2 emissions by millions of tons. *One Earth* 26. . [[Crossref](#)]

176. T.M. Cristino, F.A. Lotufo, B. Delinchant, F. Wurtz, A. Faria Neto. 2021. A comprehensive review of obstacles and drivers to building energy-saving technologies and their association with research themes, types of buildings, and geographic regions. *Renewable and Sustainable Energy Reviews* **135**, 110191. [[Crossref](#)]
177. Tetiana Vasylieva, Oleksii Liulov, Tetiana Pimonenko, Yana Us. 2021. CONVERGENCE OF THE UKRAINIAN AND EU ENERGY POLICIES. *Scientific opinion: Economics and Management* :2(72). . [[Crossref](#)]
178. Don Fullerton, Shan He. 2021. Do Market Failures Create a 'Durability Gap' in the Circular Economy?. *SSRN Electronic Journal* **84**. . [[Crossref](#)]
179. Jiyong Park, JongRoul Woo, Taeyoung Jin. 2021. Estimating Implicit Discount Rate for Energy Efficiency Investment Using the Contingent Valuation Method: A Case Study in South Korea. *SSRN Electronic Journal* **9**. . [[Crossref](#)]
180. Graham Beattie, Iza Ding, Andrea La Nauze. 2021. Is There an Energy Efficiency Gap in China? Evidence from an Information Experiment. *SSRN Electronic Journal* **26**. . [[Crossref](#)]
181. Hendrik Schmitz, Reinhard Madlener. 2021. Preferences for Energy Retrofit Investments Among Low-income Renters. *SSRN Electronic Journal* **70**. . [[Crossref](#)]
182. Kenneth A Small, Robin Lindsey. Demand for Passenger Transportation 127-133. [[Crossref](#)]
183. Thomas Adisorn, Lena Tholen, Johannes Thema, Hauke Luetkehaus, Sibylle Braungardt, Katja Huenecke, Katja Schumacher. 2021. Towards a More Realistic Cost-Benefit Analysis—Attempting to Integrate Transaction Costs and Energy Efficiency Services. *Energies* **14**:1, 152. [[Crossref](#)]
184. M. Katic, A. Trianni. Energy Efficiency Measures and Production Resources: Towards an Integrative Classification Framework for Decision Makers 225-229. [[Crossref](#)]
185. Torsten Bornemann, Martin Klarmann, Martin Moosbrugger. 2020. Verhaltenswissenschaftliche Forschung zum organisationalen Einkaufsverhalten: Überblick über die Marketingliteratur. *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung* **72**:4, 447-478. [[Crossref](#)]
186. Janez Dolšak, Nevenka Hrovatin, Jelena Zorić. 2020. Factors impacting energy-efficient retrofits in the residential sector: The effectiveness of the Slovenian subsidy program. *Energy and Buildings* **229**, 110501. [[Crossref](#)]
187. Jakob Ahlrichs, Sebastian Rockstuhl, Timm Tränkler, Simon Wenninger. 2020. The impact of political instruments on building energy retrofits: A risk-integrated thermal Energy Hub approach. *Energy Policy* **147**, 111851. [[Crossref](#)]
188. Giovanna d'Adda, Arianna Galliera, Massimo Tavoni. 2020. Urgency and engagement: Empirical evidence from a large-scale intervention on energy use awareness. *Journal of Economic Psychology* **81**, 102275. [[Crossref](#)]
189. Lukman O. Oyelami, Sulaimon O. Adebisi, Babatunde S. Adekunle. 2020. Electronic payment adoption and consumers' spending growth: empirical evidence from Nigeria. *Future Business Journal* **6**:1. . [[Crossref](#)]
190. Christos Tourkolias, Areti Kontogianni, Dimitris Damigos, Michalis Skourtos. 2020. Exploring the factors influencing energy efficiency in the Greek hotel sector. *Acta Innovations* :37, 5-20. [[Crossref](#)]
191. Sebastian Cuadros, Yeny E. Rodríguez, Javier Contreras. 2020. Dynamic Data Envelopment Analysis Model Involving Undesirable Outputs in the Electricity Power Generation Sector: The Case of Latin America and the Caribbean Countries. *Energies* **13**:24, 6624. [[Crossref](#)]

192. Ghislaine Lang, Bruno Lanz. 2020. Energy efficiency, information, and the acceptability of rent increases: A survey experiment with tenants. *Energy Economics* **68**, 105007. [[Crossref](#)]
193. Paulo Cunha, Sónia Almeida Neves, António Cardoso Marques, Zélia Serrasqueiro. 2020. Adoption of energy efficiency measures in the buildings of micro-, small- and medium-sized Portuguese enterprises. *Energy Policy* **146**, 111776. [[Crossref](#)]
194. David L. Greene, Judith M. Greenwald, Rebecca E. Ciez. 2020. U.S. fuel economy and greenhouse gas standards: What have they achieved and what have we learned?. *Energy Policy* **146**, 111783. [[Crossref](#)]
195. Kristoffer Steen Andersen, Catharina Wiese, Stefan Petrovic, Russell McKenna. 2020. Exploring the role of households' hurdle rates and demand elasticities in meeting Danish energy-savings target. *Energy Policy* **146**, 111785. [[Crossref](#)]
196. Joachim Schleich, Corinne Faure, Thomas Meissner. 2020. Adoption of retrofit measures among homeowners in EU countries: The effects of access to capital and debt aversion. *Energy Policy* **80**, 112025. [[Crossref](#)]
197. Graeme Guthrie. 2020. Regulation, welfare, and the risk of asset stranding. *The Quarterly Review of Economics and Finance* **78**, 273-287. [[Crossref](#)]
198. A. Fattahi, J. Sijm, A. Faaij. 2020. A systemic approach to analyze integrated energy system modeling tools: A review of national models. *Renewable and Sustainable Energy Reviews* **133**, 110195. [[Crossref](#)]
199. Fiona Burlig, Christopher Knittel, David Rapson, Mar Reguant, Catherine Wolfram. 2020. Machine Learning from Schools about Energy Efficiency. *Journal of the Association of Environmental and Resource Economists* **7**:6, 1181-1217. [[Crossref](#)]
200. Cali Curley, Galib Rustamov, Nicky Harrison, Madeline Venable. 2020. Susceptibility to Inattention: Unpacking Who is Susceptible to Inattention in Energy-Based Electronic Billing. *Review of Policy Research* **37**:6, 744-764. [[Crossref](#)]
201. Howard Kunreuther. 2020. Risk Management Solutions for Climate Change-Induced Disasters. *Risk Analysis* **40**:S1, 2263-2271. [[Crossref](#)]
202. Luca Caneparo. 2020. Financing the (Environmental) Quality of Cities with Energy Efficiency Investments. *Sustainability* **12**:21, 8809. [[Crossref](#)]
203. Louis-Gaëtan Giraudet, Cyril Bourgeois, Philippe Quirion. 2020. Efficacité économique et effets distributifs de long-terme des politiques de rénovation énergétique des logements. *Économie & prévision* **n° 217**:1, 43-63. [[Crossref](#)]
204. Dayong Zhang, Jun Li, Qiang Ji. 2020. Does better access to credit help reduce energy intensity in China? Evidence from manufacturing firms. *Energy Policy* **145**, 111710. [[Crossref](#)]
205. Annamaria Bagaini, Francesco Colelli, Edoardo Croci, Tania Molteni. 2020. Assessing the relevance of barriers to energy efficiency implementation in the building and transport sectors in eight European countries. *The Electricity Journal* **33**:8, 106820. [[Crossref](#)]
206. Xueying Bian, Natalia Fabra. 2020. Incentives for information provision: Energy efficiency in the Spanish rental market. *Energy Economics* **90**, 104813. [[Crossref](#)]
207. Oleg Badunenko, Subal C. Kumbhakar. 2020. Energy Intensity and Long- and Short-Term Efficiency in US Manufacturing Industry. *Energies* **13**:15, 3954. [[Crossref](#)]
208. D. Damigos, A. Kontogianni, C. Tourkolias, M. Skourtos. 2020. Behind the scenes: Why are energy efficient home appliances such a hard sell?. *Resources, Conservation and Recycling* **158**, 104761. [[Crossref](#)]

209. Hongguang Nie, René Kemp, Jin-Hua Xu, Véronique Vasseur, Ying Fan. 2020. Split incentive effects on the adoption of technical and behavioral energy-saving measures in the household sector in Western Europe. *Energy Policy* **140**, 111424. [[Crossref](#)]
210. Gale A. Boyd, Jonathan M. Lee. 2020. Relative Effectiveness of Energy Efficiency Programs versus Market Based Climate Policies in the Chemical Industry. *The Energy Journal* **41**:3, 39-62. [[Crossref](#)]
211. John Freebairn. 2020. A Portfolio Policy Package to Reduce Greenhouse Gas Emissions. *Atmosphere* **11**:4, 337. [[Crossref](#)]
212. Tinghui Li, Gaoke Liao. 2020. The Heterogeneous Impact of Financial Development on Green Total Factor Productivity. *Frontiers in Energy Research* **8**. . [[Crossref](#)]
213. Louis-Gaëtan Giraudet. 2020. Energy efficiency as a credence good: A review of informational barriers to energy savings in the building sector. *Energy Economics* **87**, 104698. [[Crossref](#)]
214. Qianru Zhu, Benjamin D. Leibowicz. 2020. Vehicle efficiency improvements, urban form, and energy use impacts. *Cities* **97**, 102486. [[Crossref](#)]
215. Gianluca Trotta. 2020. Assessing energy efficiency improvements and related energy security and climate benefits in Finland: An ex post multi-sectoral decomposition analysis. *Energy Economics* **86**, 104640. [[Crossref](#)]
216. Ibon Galarraga, Steffen Kallbekken, Alessandro Silvestri. 2020. Consumer purchases of energy-efficient cars: How different labelling schemes could affect consumer response to price changes. *Energy Policy* **137**, 111181. [[Crossref](#)]
217. Ibolya Czibere, Imre Kovách, Gergely Boldizsár Megyesi. 2020. Environmental Citizenship and Energy Efficiency in Four European Countries (Italy, The Netherlands, Switzerland and Hungary). *Sustainability* **12**:3, 1154. [[Crossref](#)]
218. Naveed R. Khan, Arsalan Mujahid Ghouri, Irum Gull. Contemporary Dimensions of Econometrics of Green Energy: A Review of Literature 165-188. [[Crossref](#)]
219. Dumindu Soorige, Gayani Karunasena, Hong Xian Li. Energy-Efficient Technologies in the Apparel Industry: Limitations of Existing Energy Research 1-11. [[Crossref](#)]
220. Ian Parry. 2020. Increasing carbon pricing in the EU: Evaluating the options. *European Economic Review* **121**, 103341. [[Crossref](#)]
221. Carolyn Fischer, Michael Hübler, Oliver Schenker. 2020. More Birds Than Stones – A Framework for Second-Best Energy and Climate Policy Adjustments. *SSRN Electronic Journal* **102**. . [[Crossref](#)]
222. Puja Singhal. 2020. Inform Me When It Matters: Cost Salience, Energy Consumption, and Efficiency Investments. *SSRN Electronic Journal* **238**. . [[Crossref](#)]
223. Mohammed Albrahim, Ahmed Al Zahrani, Anvita Arora, Rubal Dua, Bassam Fattouh, Adam Sieminski. 2019. An overview of key evolutions in the light-duty vehicle sector and their impact on oil demand. *Energy Transitions* **3**:1-2, 81-103. [[Crossref](#)]
224. Donald Kennedy, Simon P. Philbin. 2019. Techno-economic analysis of the adoption of electric vehicles. *Frontiers of Engineering Management* **6**:4, 538-550. [[Crossref](#)]
225. Neda Mohammadi, John E. Taylor. 2019. Recurrent Mobility: Urban Conduits for Diffusion of Energy Efficiency. *Scientific Reports* **9**:1. . [[Crossref](#)]

226. Inigo Bonilla-Campos, Nerea Nieto, Luis del Portillo-Valdes, Jaio Manzanedo, Haizea Gaztañaga. 2019. Energy efficiency optimisation in industrial processes: Integral decision support tool. *Energy* 116480. [[Crossref](#)]
227. L.P. Dias, S. Simões, J.P. Gouveia, J. Seixas. 2019. City energy modelling - Optimising local low carbon transitions with household budget constraints. *Energy Strategy Reviews* 26, 100387. [[Crossref](#)]
228. Andrea Chegut, Piet Eichholtz, Nils Kok. 2019. The price of innovation: An analysis of the marginal cost of green buildings. *Journal of Environmental Economics and Management* 98, 102248. [[Crossref](#)]
229. Roland Kube, Kathrine von Graevenitz, Andreas Löschel, Philipp Massier. 2019. Do voluntary environmental programs reduce emissions? EMAS in the German manufacturing sector. *Energy Economics* 84, 104558. [[Crossref](#)]
230. Timo Goeschl. 2019. Cold Case: The forensic economics of energy efficiency labels for domestic refrigeration appliances. *Energy Economics* 84, 104468. [[Crossref](#)]
231. Joshua A. Blonz. 2019. The Welfare Costs of Misaligned Incentives: Energy Inefficiency and the Principal-Agent Problem. *Finance and Economics Discussion Series* 2019:071, 1-39. [[Crossref](#)]
232. Athar Kamal, Sami G. Al-Ghamdi, Muammer Koc. 2019. Revaluating the costs and benefits of energy efficiency: A systematic review. *Energy Research & Social Science* 54, 68-84. [[Crossref](#)]
233. Olivier De Groot, Frank Verboven. 2019. Subsidies and Time Discounting in New Technology Adoption: Evidence from Solar Photovoltaic Systems. *American Economic Review* 109:6, 2137-2172. [[Abstract](#)] [[View PDF article](#)] [[PDF with links](#)]
234. Cristina Cattaneo. 2019. Internal and external barriers to energy efficiency: which role for policy interventions?. *Energy Efficiency* 12:5, 1293-1311. [[Crossref](#)]
235. Heather Klemick, Elizabeth Kopits, Ann Wolverton. 2019. How do data centers make energy efficiency investment decisions? Qualitative evidence from focus groups and interviews. *Energy Efficiency* 12:5, 1359-1377. [[Crossref](#)]
236. Jacob Adenbaum, Adam Copeland, John Stevens. 2019. Do long-haul truckers undervalue future fuel savings?. *Energy Economics* 81, 1148-1166. [[Crossref](#)]
237. Arthur G. Fraas, Randall W. Lutter, Derek C. Wietelman. 2019. The energy paradox in seemingly competitive industries: The use of energy-efficient equipment on heavy-duty tractor trailers. *Energy Policy* 129, 467-480. [[Crossref](#)]
238. Anita Thonipara, Petrik Runst, Christian Ochsner, Kilian Bizer. 2019. Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns. *Energy Policy* 129, 1156-1167. [[Crossref](#)]
239. Joachim Schleich, Xavier Gassmann, Thomas Meissner, Corinne Faure. 2019. A large-scale test of the effects of time discounting, risk aversion, loss aversion, and present bias on household adoption of energy-efficient technologies. *Energy Economics* 80, 377-393. [[Crossref](#)]
240. Shuanglian Chen, Gaoke Liao, Benjamin M. Drakeford, Pierre Failler. 2019. The Non-Linear Effect of Financial Support on Energy Efficiency: Evidence from China. *Sustainability* 11:7, 1959. [[Crossref](#)]
241. Wadim Strielkowski, Elena Volkova, Luidmila Pushkareva, Dalia Streimikiene. 2019. Innovative Policies for Energy Efficiency and the Use of Renewables in Households. *Energies* 12:7, 1392. [[Crossref](#)]
242. Paulína Šujanová, Monika Rychtáriková, Tiago Sotto Mayor, Affan Hyder. 2019. A Healthy, Energy-Efficient and Comfortable Indoor Environment, a Review. *Energies* 12:8, 1414. [[Crossref](#)]

243. Dalia Streimikiene, Tomas Balezentis, Ilona Alisauskaite-Seskiene, Gintare Stankuniene, Zaneta Simanaviciene. 2019. A Review of Willingness to Pay Studies for Climate Change Mitigation in the Energy Sector. *Energies* **12**:8, 1481. [[Crossref](#)]
244. Phu Nguyen-van, Thi Kim Cuong Pham. Environmental Incentives Over Time: From the First Forms of Regulation to the Recognition of Cognitive Biases 25-46. [[Crossref](#)]
245. Laura Abrardi. 2019. Behavioral barriers and the energy efficiency gap: a survey of the literature. *Journal of Industrial and Business Economics* **46**:1, 25-43. [[Crossref](#)]
246. Anton Orlov, Steffen Kallbekken. 2019. The impact of consumer attitudes towards energy efficiency on car choice: Survey results from Norway. *Journal of Cleaner Production* **214**, 816-822. [[Crossref](#)]
247. Jonas Sonnenschein, Robert Van Buskirk, Jessika Luth Richter, Carl Dalhammar. 2019. Minimum energy performance standards for the 1.5 °C target: an effective complement to carbon pricing. *Energy Efficiency* **12**:2, 387-402. [[Crossref](#)]
248. Jing Liang, Yueming Qiu, Ming Hu. 2019. Mind the energy performance gap: Evidence from green commercial buildings. *Resources, Conservation and Recycling* **141**, 364-377. [[Crossref](#)]
249. Subhes C. Bhattacharyya. Energy Demand Management and Demand Response 571-603. [[Crossref](#)]
250. Peter Heindl, Anna Wolff, Ines Weber, Christiane Reif, Bernhard Gill. The Relevance of Consumer Preferences and Behaviour for Climate Policy Design: Evidence from Germany 335-350. [[Crossref](#)]
251. Victoria R. Nalule. Regional Cooperation in Renewable Energy and Fossil Fuel Development 91-141. [[Crossref](#)]
252. Iñigo Aranburu, Bakartxo Egilegor, Iñigo Bonilla, Jaio Manzanedo, Haizea Gaztañaga. 2019. Modelica model of industrial gas furnaces. *E3S Web of Conferences* **116**, 00003. [[Crossref](#)]
253. Catherine Hausman, Lucija Muehlenbachs. 2019. Price Regulation and Environmental Externalities: Evidence from Methane Leaks. *Journal of the Association of Environmental and Resource Economists* **6**:1, 73-109. [[Crossref](#)]
254. Vladyslav V. Pavlyk. 2019. Energy Gap: Bibliometric Analysis. *Mechanism of an Economic Regulation* :4, 16-23. [[Crossref](#)]
255. Achim Voß. 2019. Energy-Efficiency Policy and its Effects at the Intensive and at the Extensive Investment Margins with Heterogenous Households. *SSRN Electronic Journal* . [[Crossref](#)]
256. Sorabh Tomar. 2019. CSR Disclosure and Benchmarking-Learning: Emissions Responses to Mandatory Greenhouse Gas Disclosure. *SSRN Electronic Journal* **129** . [[Crossref](#)]
257. Gaoke Liao, Benjamin M. Drakeford. 2019. An analysis of financial support, technological progress and energy efficiency#evidence from China. *Green Finance* **1**:2, 174-187. [[Crossref](#)]
258. Jason Nguyen, Karen Donohue, Mili Mehrotra. 2019. Closing a Supplier's Energy Efficiency Gap Through Assessment Assistance and Procurement Commitment. *Management Science* **65**:1, 122-138. [[Crossref](#)]
259. Franz Wirl. 2019. Incentivizing Energy Efficiency under Private Information: The Social Optimum. *The Energy Journal* **40**:6, 1-22. [[Crossref](#)]
260. Gianluca Trotta, Joachim Spangenberg, Sylvia Lorek. 2018. Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries. *Energy Efficiency* **11**:8, 2111-2135. [[Crossref](#)]

261. Nevenka Hrovatin, Jelena Zorić. 2018. Determinants of energy-efficient home retrofits in Slovenia: The role of information sources. *Energy and Buildings* **180**, 42-50. [[Crossref](#)]
262. Kenneth Gillingham, James H. Stock. 2018. The Cost of Reducing Greenhouse Gas Emissions. *Journal of Economic Perspectives* **32**:4, 53-72. [[Abstract](#)] [[View PDF article](#)] [[PDF with links](#)]
263. Kenneth Gillingham, Amelia Keyes, Karen Palmer. 2018. Advances in Evaluating Energy Efficiency Policies and Programs. *Annual Review of Resource Economics* **10**:1, 511-532. [[Crossref](#)]
264. Erik Haites. 2018. Carbon taxes and greenhouse gas emissions trading systems: what have we learned?. *Climate Policy* **18**:8, 955-966. [[Crossref](#)]
265. Kevin Novan, Aaron Smith. 2018. The Incentive to Overinvest in Energy Efficiency: Evidence from Hourly Smart-Meter Data. *Journal of the Association of Environmental and Resource Economists* **5**:3, 577-605. [[Crossref](#)]
266. Albert Roger. Outlook: Can Environmental Product Standards Enable Eco-Innovation? 95-122. [[Crossref](#)]
267. Thomas J. Kniesner, Galib Rustamov. 2018. Differential and Distributional Effects of Energy Efficiency Surveys: Evidence from Electricity Consumption. *Journal of Benefit-Cost Analysis* **9**:3, 375-406. [[Crossref](#)]
268. Liudmila Sakhno, Olga Sakhno, Vitaliy Boronin, Elena Kochetkova, Chen Hao. 2018. Reduction of power consumption during arc welding operation. *MATEC Web of Conferences* **245**, 05001. [[Crossref](#)]
269. Erik Haites, Duan Maosheng, Kelly Sims Gallagher, Sharon Mascher, Easwaran Narassimhan, Kenneth R. Richards, Masayo Wakabayashi. 2018. Experience with Carbon Taxes and Greenhouse Gas Emissions Trading Systems. *SSRN Electronic Journal* . [[Crossref](#)]
270. Graeme Guthrie. 2018. Rate-of-Return Regulation and the Scale and Timing of Investment. *SSRN Electronic Journal* . [[Crossref](#)]
271. Andreas LLSchel, Benjamin Johannes Lutz, Philipp Massier. 2017. Credit Constraints, Energy Management Practices, and Investments in Energy Saving Technologies: German Manufacturing in Close-Up. *SSRN Electronic Journal* . [[Crossref](#)]
272. Adriaan R. Soetevent, Gert-Jan Romensen. 2017. Tailored Feedback and Worker Green Behavior: Field Evidence from Bus Drivers. *SSRN Electronic Journal* **104**. . [[Crossref](#)]
273. Eric Webb, Owen Q. Wu, Kyle Cattani. 2016. Mind the Gap: Coordinating Energy Efficiency and Demand Response. *SSRN Electronic Journal* . [[Crossref](#)]