Models of Decision Making and Residential Energy Use

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Annu. Rev. Environ. Resour. 2007. 32:169–203

First published online as a Review in Advance on June 26, 2007

The *Annual Review of Environment and Resources* is online at http://environ.annualreviews.org

This article's doi:
10.1146/annurev.energy.32.053006.141137

1543-5938/07/1121-0169$20.00

Key Words

economics, energy demand, psychology, sociology

Abstract

Research traditions across the social sciences have explored the drivers of individual behavior and proposed different models of decision making. Four diverse perspectives are reviewed here: conventional and behavioral economics, technology adoption theory and attitude-based decision making, social and environmental psychology, and sociology. The individual decision models in these traditions differ axiomatically. Some are founded on informed rationality or psychological variables, and others emphasize physical or contextual factors from individual to social scales. Each perspective suggests particular lessons for designing interventions to change behavior. Throughout the review, these lessons are applied to decisions affecting residential energy use. Examples are drawn from both intuitive and reasoning-based types of decision as well as from a range of decision contexts that include capital investments in weatherization and repetitive behaviors such as appliance use. Areas of difference and similarity between various theoretical approaches and their practical implications are highlighted. Conclusions are drawn on how to develop a more integrated approach to both behavioral research and intervention design in a residential energy context.

Contents

1. INTRODUCTION

Understanding how individuals make decisions is important for researchers and intervention designers concerned with the impact of human behavior on energy use and the environment (1). This chapter reviews different models of individual decision making from across the social sciences. In an applied field such as energy and environment, theoretical approaches to decision making have two main roles. The first is to help explain behavior and identify important behavioral drivers for interventions to target. The second is to provide a framework for empirical research on the impact of these interventions (2). The general term "intervention" is used throughout to mean any regulation, policy, program, measure, activity, or event that aims to influence behavior.

Intervention: any regulation, policy, program, measure, activity, or event that aims to influence behavior

The theoretical emphasis of this paper is illustrated where possible by empirical work on residential energy supply, use, and efficiency. This provides a common context for comparing the decision models reviewed and their implications for intervention design. Decisions also vary widely in their speed, effort, level of conscious control, cognition (information processing), and other factors. Intuitive decisions are made on a very different basis than reasoning-based decisions (3). These different types of decisions are considered, and their relevance for interventions in particular contexts is discussed.

The objective of this review is fourfold: first, and most importantly, to review different disciplinary models and theories on individual decision making and the determinants of decisions; second, to extract general lessons for designing interventions to influence those decisions; third, to apply these lessons to residential energy use, particularly energy efficiency; and fourth, to appeal for a more integrated approach to research into residential energy use and other problems of environmental consequence.

Organization

Section 2 sets out the decision context of residential energy use, with reference to the "energy efficiency gap." The body of this review then comprises sections on decision models from different social science traditions, organized along a rough continuum from those with an individual framing of decision making to those with a social framing. Section 3 considers economics and behavioral economics, with a brief reference to consumer psychology and marketing. Section 4 reviews technology adoption theory, focusing on the diffusion of innovations (DoI) tradition, and attitude-based decision models. Section 5 describes decision models that are empirically based in energy-related behavioral research from social and environmental psychology. Section 6 covers sociological questions on the agency of the individual as decision maker and the influence on social context on decision making. Each section ends with some general conclusions on designing interventions for changing individual behavior on the basis of the decision models reviewed.

This organization is not to label different researchers or research traditions but to illustrate the different theoretical approaches to individual decision making. The sections are designed to be read either sequentially or independently according to the reader's preference and prior knowledge. In each section, references to key texts on the relevant decision models and theories are included. Empirical work is drawn upon selectively to illustrate the main theoretical points. Energy-focused research on decision making and behavior varies widely across different research traditions. Social psychologists have extensively explored residential energy behavior; so in Section 5, frequent reference is made to existing empirical reviews (4, 5). In contrast, Section 3 on behavioral economics relies more on general lessons drawn from a theoretical body of research that has not directly explored energy-related decisions.

A concluding Section 7 attempts to draw together and compare the diverse disciplinary findings and develop some more integrated conclusions on intervention design and future behavioral research on decision making and residential energy use. Three themes that emerge repeatedly in the review are discussed: the importance of matching decision models to decision contexts, the scale over which influences on decisions act, and heterogeneity in decision making.

DoI: diffusion of innovations

Attitude: relatively enduring organization of an individual's beliefs that predisposes his or her actions toward an object, person, event or idea

2. THE DECISION CONTEXT: RESIDENTIAL ENERGY USE AND THE ENERGY EFFICIENCY GAP

Energy efficiency provides an interesting empirical context for considering individual decision making and behavior owing to the persistence of a gap between technological and economic potential, and actual market

Heuristics: simple decision rules

Utility: a construct in economics that measures an individual's expressed preferences for different decision alternatives

behavior (6). This energy efficiency gap is repeatedly identified in economic-engineering studies that quantify the potential reduction in energy demand (or greenhouse gas emissions) from the adoption of different technologies (see Reference 7 for a review). Life cycle cost analysis shows short payback periods for the required capital investment in these technologies (8), yet they remain underutilized. Explanations for the energy efficiency gap include a lack of relevant information on available technologies, limited access to capital, misaligned incentives, imperfect markets for energy efficiency, and organizational barriers (9, 10).

Many of these market and nonmarket failures relate to individual decision making and indeed are pervasive facets of human behavior (4). These include (*a*) aversion to risk, uncertainty, and irreversibility; (*b*) use of high short-term discount rates; (*c*) heterogeneity of preferences within a population; (*d*) transaction costs of searching for and processing information; (*e*) sensitivity to changes in the attributes of energy services; and (*f*) the relative unimportance of energy costs as a proportion of total expenditure (9–12). It is widely accepted that interventions to reduce the energy efficiency gap need to address these and other behavioral factors (13). The decision models reviewed in Sections 3–6 offer many suggestions in this regard and help identify reasons for the varying success of interventions to promote energy efficiency (see Reference 14 for a review).

3. UTILITY-BASED DECISION MODELS AND BEHAVIORAL ECONOMICS

This section briefly describes the microeconomic decision model of utility maximization given fixed preferences. Discrete choice applications of this "rational actor" model in a residential energy context are discussed. Utility theory also provides the framework for a more extensive review of behavioral economic findings on the influence of context and heuristics (simple decision rules) on the outcomes of decisions.

Utility Maximization and Rationality

Microeconomic theories of consumer choice are based on the assumption that individuals seek to maximize utility given budget constraints. A decision outcome with higher utility will be consistently preferred to an alternative outcome with lower utility. Utility is a construct that measures the preferences expressed for different outcomes (15), but it is often regarded as a proxy for well-being, personal benefit, or the "betterness" of an outcome (16).

Utility theory is derived from axioms of preference that provide criteria for the rationality of choice (17). Consumers are assumed to behave as rational actors in a normative sense of having preferences that are ordered, known, invariant, and consistent. Utility-based decisions are guided by an individual's evaluation of outcomes and so are essentially instrumental and self-interested (2). However, the rational actor model can incorporate utility from many different sources (other than money), including the perceived fairness of the decision process itself (18).

Utility Theory and Residential Energy Decisions

Utility theory and rational choice provide the building blocks for a broad range of economic theory and practice (19). Two applications with relevance to residential energy use are discrete choice modeling and economic-engineering analyses.

Discrete or qualitative choice models represent individuals' choices between different alternatives characterized by a number of attributes. Choices can be made as stated preferences through survey instruments or as revealed preferences through actual purchasing behavior (see Reference 20). In a residential energy context, discrete choice methods have been used to estimate individuals' discount rates as revealed or implied by their preferences for energy efficient appliances (8, 21). Discount rates measure an individual's willingness to exchange present consumption for future consumption, for example, by spending more up front on an appliance with lower operating (energy) costs. An important finding is that individuals use different discount rates for different types of goods in different contexts (22). In the case of domestic energy technologies, revealed discount rates were found to be clustered in the 5% to 40% range, but higher rates were applied to refrigerators and water heaters than to heating equipment and weatherization measures (21). Other studies have found short-term discount rates as high as 300% for air-conditioning technologies (23). This marked variability suggests that discount rates are influenced by many elements of the decision context, including perceived risk, framing, and social arrangements (22). (See sections below for additional discussion.)

Discrete choice methods have also been used to assess the effectiveness of different types of financial incentive in influencing consumers' preference for high-efficiency appliances (24). Results suggested that loans would have a larger impact than rebates in the case of refrigerators and at a lower unit cost to the energy utility. Other recent examples of discrete choice modeling of energy-related behavior include customers' choice of electricity supplier in deregulated markets (25).

Engineering-economic analyses at an aggregated sectoral or market scale (7) also imply a rational actor whose preferences for different energy technologies are guided by a monetary cost-benefit analysis using a constant discount rate. Nonfinancial costs or benefits can be monetized using contingent valuation or other approaches at an aggregate level (26) and at the level of a residential energy user (27). Additional transaction costs or intangible costs can be included to capture the behavioral factors (described in Section 2) that contribute to the energy efficiency gap (28, 29). However, this monetization of transaction costs can fail to recognize their heterogeneity across both decision makers and decision contexts as well as their dynamic nature (30). The poor characterization of heterogeneous preferences is one reason why macroeconomic models can fail to capture the energy efficiency gap (31).

Econometric models can successfully describe behavior at an aggregate level because, although individual preferences are highly variable, the distribution of preferences across a population is relatively stable (32). Modeling many individuals, in effect, assumes representative decision makers who may not be utility maximizers but who, considered in aggregate, behave as if they were (33).

Irrationality and Behavioral Economics

Behavioral economists seek to integrate a more robust psychological understanding of decision making into microeconomics. As noted above, utility theory and its applications rest on axioms of preference that broadly define rational choice. However, there is a wealth of experimental and field evidence showing that individuals do not make consistently rational decisions (34). Time inconsistency, framing, reference dependence, and bounded rationality are all examples discussed below. In each case, individual choices violate one or more of the axioms of preference on which utility theory is based and so are irrational in normative terms.

Time Inconsistency

Having time-consistent preferences means that a decision taken to maximize utility from a stream of both current and future values will remain optimal in the future (35). Time consistency is ensured by trading off present for future consumption at a constant discount rate (36). Consumers' purchasing behavior of energy efficient appliances is used to reveal these discount rates (see above). From a behavioral perspective, however, this methodology is highly problematic (37). Extensive empirical and experimental evidence reveals that individuals do not make decisions in a time-consistent manner using a constant discount rate (22). An immediacy effect gives rise to high short-term discount rates when otherwise immediate consumption is delayed, but this is accompanied by a decline in discount rates over the longer term (36). The implication is that when all costs and benefits are in the future, individuals are farsighted in their advance planning, but when some costs or benefits are immediate, decisions will be very shortsighted (34). Consumers can also be aware that their impulse to consume now impacts negatively on their long-term self-interest (23).

Hyperbolic or proportional discount functions have been proposed as more accurate representations of how individuals value costs and benefits over time (23, 38). Yet nonconstant discount rates are rarely incorporated into utility-based decision models. One reason is that time inconsistency makes equilibrium models intractable, as do other violations of utility theory's axioms of preference (39).

Framing and Reference Dependence

Framing effects show that individual preferences are not fixed or invariant. A decision frame refers to all the different elements that comprise a decision: alternatives, attributes, outcomes, and probabilities (40). The way these elements are presented to the decision maker can influence the decision outcome. Simply by framing one decision as a choice between losses and another as a choice between gains, preferences can be reversed even though the outcomes and their expected values are identical in both decision contexts (17). This is because individuals are generally averse to losses.

When making a decision, individuals also tend to "anchor" on certain types of information, rather than search for and process all relevant information (41, 42). Depending on how information is presented or otherwise available, preferences can be biased toward the initial anchor point. More generally, the status quo or default option of a decision tends to be favored (43).

Loss aversion, anchoring, and status quo bias all illustrate the importance of framing and context on decision making. There are two key implications for the microeconomic decision model: (*a*) utility is dependent on a reference point; and (*b*) utility is carried by gains and losses relative to this reference point, not final outcomes (44). Reference dependence also explains why expectations about decision outcomes are important (18). If expectations set a high reference point, certain outcomes may be perceived as losses or as unfair, reducing the utility associated with consumption (45, 46).

At the household level, framing and reference dependence mean that income and budgeting decisions may be assigned to different "mental accounts" (47, 48). As an example, an individual's willingness to spend earned income, windfall income, and saved income is rarely the same even though the money in each case is fully interchangeable (49). Consumption that is apparently suboptimal according to utility theory can be explained by differences in the decision criteria used in different mental accounts (50).

Bounded Rationality and Decision Heuristics

To maximize utility within budget constraints requires rational actors to acquire, analyze, and trade off information about all possible alternatives before making a decision. Early research found that the way information is structured in different decision contexts can influence choices (51). In other words, preferences are influenced by the cognitive burden of information gathering and processing. Individuals' rationality (in a normative sense) is bounded by these psychological and environmental constraints (33).

Rather than always seeking to maximize utility, decision makers use a wide range of rules or heuristics to help reduce cognitive or computational requirements (52). The "satisficing heuristic," for example, means sequentially searching for information about alternatives until a utility threshold or aspirational target is reached (53). "Recognition heuristics" favor recognized or familiar elements of a decision (e.g., choose the alternative that was chosen last time). "Elimination heuristics" narrow down the range of alternatives by immediately rejecting those with the worst score on a particular attribute (e.g., ignore the two most expensive alternatives) (54, 55).

Another class of heuristics explains how decision makers retrieve information (both internally and from external sources) to help characterize decision alternatives. The "availability heuristic" means that this retrieval process can be biased in favor of information that is readily available (e.g., very personal, recent, or repeated) or particularly salient (e.g., vivid, atypical, or otherwise memorable). Although more easily recalled, such information may not represent typical conditions and, when combined with anchoring (see above), can bias decisions. Emotions are also an important heuristic, particularly when assessing risk (56). As an example, an emotional reaction to an alternative can substitute for other attributes that do not come readily to mind (3).

Heuristics allow cognitive effort to be matched to the particular structure of a decision (55). Given their potential influence over decision outcomes, how and why particular heuristics are selected in different decision contexts are important research questions. Detectable analogies, past cases, or exemplars with a high degree of correspondence commonly influence heuristic selection (32, 57). As yet, however, there is no generalized theory, so empirical evidence is the best guide (3).

Lessons for Interventions

The central implications of the rational actor model for interventions are to improve the instrumental outcomes (i.e., net benefits) of the desirable alternative and to ensure sufficient information is available for reasoning-based decisions. Behavioral economic findings, however, challenge utility theory's normative assumptions, which underpin the rational actor model. In particular, individual preferences are found not to be well defined, fixed, or consistent, and decision making cannot be assumed to be deliberative or even optimal.

Although much behavioral economic research is conducted through controlled lab-based experiments (see Section 7), key findings have been replicated in real-world conditions (58) and are widely applied in consumer psychology and marketing. Marketers routinely exploit information gathering and retrieval heuristics such as anchoring (59). A common example is for manufacturers to add inferior options to a product range to increase consumer's preference for the superior (and more expensive) alternative (60). By setting appropriate reference points, marketers also look to influence decision makers' expectations. Where expectations are embedded in routines (see Section 6), interventions to change behavior must be framed appropriately to avoid loss aversion (which is why energy efficiency is a preferred framing over curtailment). Much consumption results not from rational deliberation but from automated cognitive or affective responses to stimuli (61), so the establishment and consolidation of habits, routines, mental associations, and emotional reactions are key for influencing the selection of decision heuristics (62). Emphasizing one particularly salient or emotional attribute may influence a decision more than providing information on all attributes. Selling comfort and fulfilled desires can motivate homeowners to renovate their home better than the prospect of energy efficiency (63).

Behavioral decision researchers combine the normative analysis of utility theory with the psychological insights of behavioral economics to support better decision making (64). (See the Behavioral Decision Research sidebar for additional discussion.) Decision-structuring tools are used to clarify information, mitigate biases, and help an individual understand his or her own interests and values

BEHAVIORAL DECISION RESEARCH

Most of the theoretical models and empirical studies reviewed in this chapter assume decision makers respond to stimuli or external conditions through psychological mechanisms that can be unearthed through careful research (192). As a result, the lessons used for intervention design draw on an understanding of these mechanisms to persuade or otherwise influence individuals to make decisions commensurate with public policy objectives.

Behavioral decision research provides an alternative tradition within cognitive psychology to this psychophysical approach (192). Testing the normative assumptions of utility theory in real-world decision making reveals mechanisms that are contingent, context dependent, time sensitive, reactive, and iterative. Preferences based on an individual's values are often constructed as they are being elicited (193). As values (and beliefs, attitudes, or norms) are difficult to measure without asking, specifying psychological decision models is more an architectural process than an archaeological one (194). Decision researchers in this tradition emphasize the preference elicitation process, prior knowledge or mental models, biases and cognitive limitations, as well as the need for a normative analysis from the decision maker's perspective. Structured methods can then be used by decision analysts to help individuals make better decisions (15, 40). Lessons for interventions are similarly prescriptive but are focused on the decision process. By comparison, the lessons for interventions considered in this review concentrate on (socially desirable) decision outcomes.

(15, 40). However, these types of intervention are focused on the decision-making process and tend to remain neutral as to the decision outcome.

Outside marketing therefore, behavioral economic findings are not typically used to design interventions for changing behavior. An exception is found in the case made in legal journals for paternalistic regulations to help consumers avoid suboptimal choices that do not serve their own interests insofar as they would be made differently with complete information, coherent and ordered preferences, and unlimited cognitive resources (65, 66). In this vein, one study of refrigerator purchases demonstrated that efficiency standards had utility benefits to individual consumers despite reducing the range of choice as they removed inferior (in utility terms) models from among the alternatives (67). More generally, as the number of choices for a decision increases, so too can sensitivity to regret, unrealistic expectations, and the opportunity costs of choosing one alternative (45). Utility can be negatively affected if consumers avoid choosing as a result (due to status quo bias). This has been demonstrated for households' choice of electricity supplier in deregulated retail markets (68). Interventions to emphasize habitual behavior and remove the risk of switching supplier might encourage households to make better nondefault choices (69). Alternatively, default choices (or behaviors) can be defined in the public interest as is common in other public policy domains, e.g., health and crime (70). For example, removing default temperature settings from washing machines was found to reduce energy usage by 24% as users set lower washing temperatures using the new implicit anchor point of zero (71). Appropriate anchor points on Energy Star or other energy efficiency product labels might also be influential.

Mental accounting provides an alternative framework for assessing energy efficient renovations or weatherization. In conventional economic analyses, payback periods for capital investments are calculated from energy savings. In making decisions, however, individuals may partition monetary/nonmonetary, energy/nonenergy, positive/negative elements into different mental accounts and assess them separately. Where minimally satisfactory outcomes in each account cannot be achieved, individuals might search for new alternatives (53). Interventions cannot therefore simply rely on short-term monetary paybacks if there are perceived losses in comfort or service quality. Net benefits may be needed in each mental account, not just overall, particularly if there are salient opportunity costs to investment (e.g., if renovate and go on holiday are alternatives for expenditure in the saved income account).

Norm: an expected pattern of behavior, either social or personal

4. TECHNOLOGY ADOPTION AND ATTITUDE-BASED DECISION MODELS

This section describes the dominant model of individual decision making used in studies of technology diffusion in which social networks and technological attributes are key influences. This innovation decision process is related to other attitude-based theories of behavior.

Diffusion of Innovations

Technology adoption and diffusion theories seek to explain how and why innovations come about, enter into use, and become widespread (or not, as the case may be). Innovations are defined broadly as an idea, practice or technology perceived as new (72). The dominant model, DoI, has a broad empirical basis that evidences impressive universality (Reference 73 is the key text for this section). DoI describes a social communication process via both person-to-person and media channels that influences individual technology adoption decisions. There are various key assumptions to this innovation decision process (see **Figure 1**). First, decisions are a process with identifiable stages moving from a change in knowledge to a change in behavior. Second, the decision process is initiated by prior conditions (e.g., perceived needs, social norms). Third, adopter characteristics and an innovation's attributes influence how knowledge is formed into object-specific attitudes. Fourth, feedbacks from the later stages of the decision process to the initial stages (see dotted arrows in **Figure 1**) are both internal or psychological and external or communicative (the empirical focus of many diffusion studies) (73).

Five perceived attributes of an innovation explain the majority of the variance in adoption rates (see Reference 73 for a review). Different studies have shown each of these attributes to be relevant for residential energy use (see **Table 1**). In specific contexts, other attributes have been found to correlate with adoption—including image or status conferral, and voluntariness (74, 75).

From Knowledge to Action: Cognitive Dissonance

Technologies and behaviors are not adopted simply through awareness and favorable attitudes (82, 83). The principal weakness of the innovation decision process is its linear representation of knowledge, awareness, intention, behavior. DoI has weakest explanatory power when adoption is constrained by situational factors, such as lack of resources or access to technologies (84). DoI also suggests that adoption barriers are the inverse of adoption drivers, but this cannot be assumed (85). The energy efficiency gap provides a good example of these points. A homeowner may have well-informed and positive attitudes to low-cost weatherization measures as well as the necessary resources but may not translate these into action even though the outcomes are clearly beneficial and fulfill a perceived need.

Other behavioral models that have been linked to DoI provide some insights as to how cognition links to action. According to the theory of cognitive dissonance, individuals strive for internal consistency between their knowledge, attitudes, and actions as inconsistency or dissonance produces discomfort (86, 87). Individuals will actively make decisions or behave so as to reduce cognitive dissonance. In a residential energy context, potential technology adopters who have made public commitments to conserve energy may act in order to be consistent with their stated attitudes (76, 88). The internal feedback dotted arrows above the decision process in **Figure 1** show this resolution of potential dissonance. But the converse is also possible: Adopters who doubt their own self-efficacy owing to lack of resources, for example, may reject or question information that supports efficiency and so avoid creating dissonance between their knowledge and their lack of action (see selected exposure arrow in the bottom left of **Figure 1**).

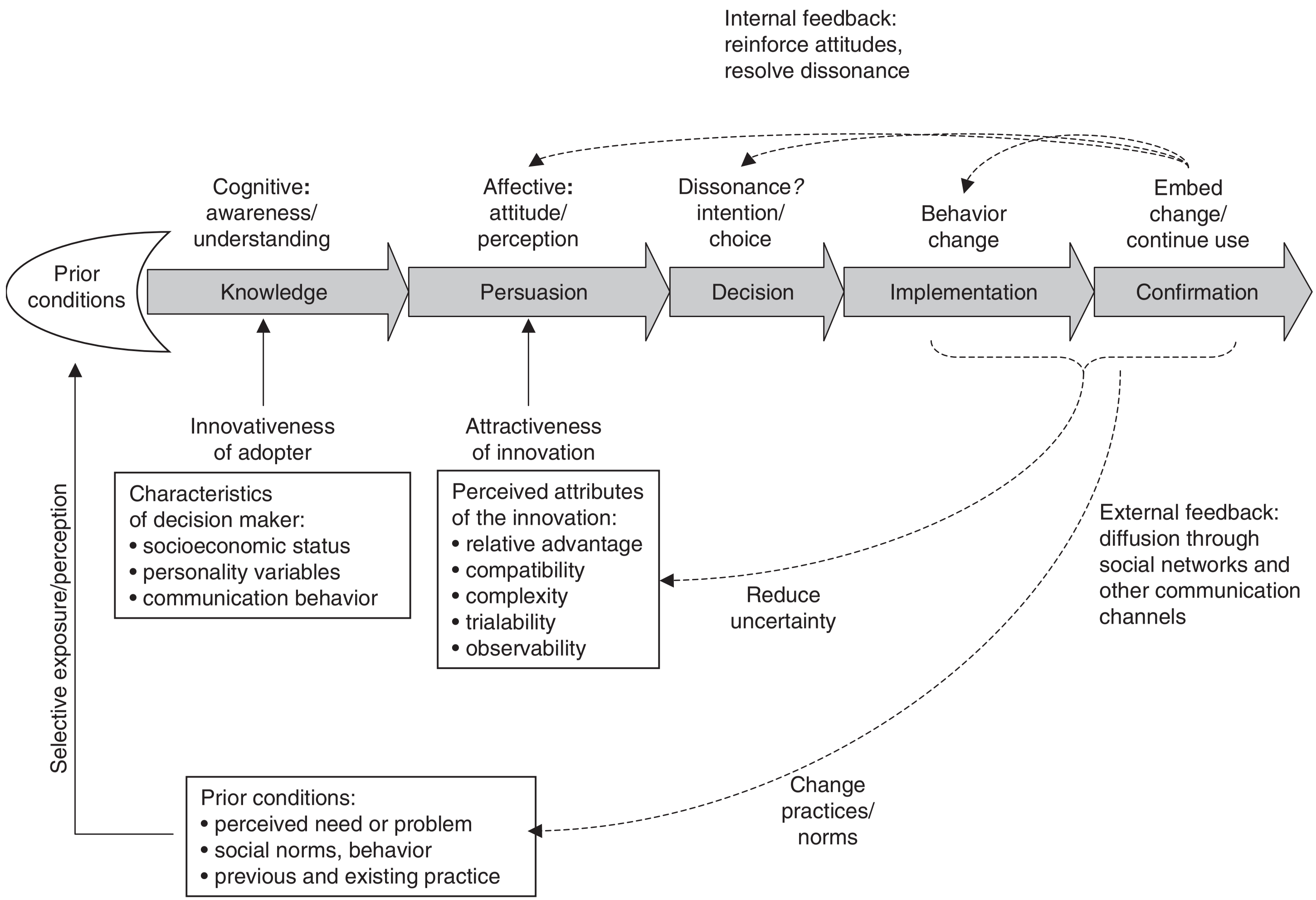

Figure 1

The innovation decision process. Adapted with the permission of The Free Press from *Diffusion of Innovations*, fifth edition, by Everett M. Rogers, copyright © 2003 (73).

Table 1 Attributes of innovations that support adoption decisions, with examples from studies of residential energy use

Attribute (from DoI) and its description (73)	Example of attribute in a residential energy context
Relative advantage over the incumbent technology or practice (e.g., more convenient, flexible, cheap)	Cost savings, personal comfort, and family health from weatherization measures (76, 77)
Compatibility with existing needs or problems, prevailing social norms, and behavior	Energy efficiency is unattractive if framed as a major deviation from behavioral norms (78)
Complexity, i.e., the skills, capacity, and effort required to adopt an innovation	A perceived barrier to solar photovoltaic adoption (79)
Trialability, e.g., whether innovations can be tested prior to adoption	Peer experience or social feedback is important to reduce uncertainty about irreversible weatherization measures (76); conversely, clock thermostats can be tested in situ (80)
Observability, e.g., whether innovations are highly visible (to potential adopters)	Solar technologies have greater normative appeal than less visible measures such as home insulation (81)

From Knowledge to Action: The Theory of Planned Behavior

DoI's decision model centers on the influence of an innovation's attributes on attitude formation. By implication, technology adoption decisions are instrumental and based on expected outcomes (as in the rational actor model but without the axioms of preference). This emphasis on attitudes and outcomes links DoI to the theory of planned behavior (TPB). TPB is an extension of an earlier theory of reasoned action in which attitudes and perceived social norms explain behavior (89). According to TPB, attitudes are formed from an individual's beliefs about a behavior as well as an evaluation of its outcomes (90). Together with normative beliefs about what valued peers might think of the behavior, these attitudes lead to an intention to act, which in turn predicts behavior. To address decision contexts in which action is constrained or individuals do not otherwise have full control over volition, perceived behavioral control was incorporated as a third precursor of intention to act as well as a direct precursor of behavior (90, 91). A meta-analysis of studies using TPB found it explained 27% and 39% of the variance in behavior and intention, respectively, with perceived behavioral control the most significant antecedent (92). The 185 independent studies reviewed were from a wide range of behavioral contexts from transport choices, recycling, and green consumerism to public health concerns, such as condom use and smoking cessation, although no studies relating directly to residential energy use were considered.

TPB: theory of planned behavior

Empirical studies of TPB and other attitude- or belief-based models rely on the elicitation of psychological constructs (typically through surveys/questionnaires). The more specifically these constructs correspond with the behavior in question (particularly where it is self-reported), the greater the predictive power of the models (93). However, the models also become less informative and capture underlying psychological processes only indirectly through correlated variables (64) (see Section 7 for additional discussion).

Self-Efficacy, Feedback, and Reinforcement

Perceived behavioral control in TPB is a subjective assessment of how contextual factors influence behavior. This is explored further in social cognitive theories on self-efficacy, individuals' own perceptions of how well they can act to deal with a prospective situation (94, 95). Self-efficacy may determine whether an individual attempts and persists with a given task and is influenced by past experience, the example of others, and perceived skills. Reinforcing self-efficacy by setting achievable goals and providing feedback demonstrably supports energy conservation, for example, by changing how appliances are used (71, 96).

Other behavioral models linked to DoI shift the focus from psychological processes to social communication and feedback. The hierarchy of effects model examines how different communication channels (e.g., mass media, or person to person) influence decision making at each layer of a hierarchy from information, knowledge, attitude, and intention through to behavior (97). For example, mass media channels were found to influence general energy awareness but have little impact on specific residential conservation behaviors (98). The stages of change model, developed from studies of addictions, emphasizes the gradual and iterative reinforcement of an individual's readiness to act (99). As individuals move through the stages of the decision process, their evaluation of the outcomes of action improves, as does their perceived ability to act. Intervention design should target the particular processes that influence change at each stage (100). Taking thermostat-setting behavior as an example, raising awareness is more relevant for early stage decision makers, and reinforcing choices through feedback is more appropriate during later stages. The precede-proceed model, also from public health, similarly emphasizes the importance of reinforcing factors, e.g., advice, subsidies, and feedback, to sustain behavior that may have initially been prompted by predisposing factors such as awareness, norms, and attitudes (101).

Lessons for Interventions

As with the rational actor model, the insights generated by DoI, TPB, and related models are limited by their implicit assumptions of deliberative and instrumental decision making. Nevertheless, there are many lessons for intervention design relevant for technology adoption in a residential energy use context.

First, the attributes of innovations in **Table 1** should orient both product development and marketing of energy efficient technologies and behaviors. Energy efficiency (noncomplex, clear relative advantage) and solar photovoltaics (observable, trialable/reversible) have complementary attributes that may aid adoption if packaged together as a "zero-emission home" or its equivalent. Second, barriers to adoption should be positively identified (rather than assumed to be the inverse of drivers of adoption), and interventions should be designed to overcome them (85). Third, DoI clearly distinguishes between the different types of adopter (see the characteristics of decision maker box in **Figure 1**) and recognizes heterogeneity in a population (see Section 7). Market segmentation studies for new technologies aim to identify and then target the innovators and early adopters. This approach has been used in the United States to size the demand for residential solar photovoltaic technologies (79). A U.K. study found a chasm in attitudes between the early adopters and the subsequent majority market, which also needs to be targeted by interventions if solar technology is to expand beyond a niche (102, 103). The same arguments apply to energy efficiency. Interventions designed to reduce residential energy use often fail to recognize heterogeneity in target samples. Specific types of energy efficiency intervention correspond more effectively with early adopter characteristics (e.g., demonstration projects) and vice versa for the mainstream market (e.g., stimulating communication from innovators) (104).

Fourth, the importance of control beliefs in TPB and social cognitive theories support interventions that enhance individuals' perceptions of empowerment, leadership, and self-efficacy through access to skills, resources, and training. This relates to a fifth lesson: harness social feedback. The use of change agents in disseminating information and experience about technologies is widely employed in agriculture and public health (73) and also helps promote social learning on residential energy efficiency (105). Providing opportunities for homeowners or utility managers to learn from early adopters' experience of solar photovoltaics supported diffusion more effectively than detailed technical information (106, 107). Homeowners of zero-emission homes in a California residential development communicated the energy cost savings to neighbors in standard efficiency homes (108). This type of social feedback on outcomes is important in supporting positive attitude formation (see **Figure 1**) and in complementing normative beliefs (84). Social marketing approaches aim to embed behavior change in a social context through public commitments monitored by the participating community (109). Establishing social norms works most effectively for technologies or behaviors that are observable by potential adopters (110), favoring solar photovoltaics over insulation for example. Interventions at the community level are particularly relevant where social norms at the household level might actually be barriers to adoption as in some cases with photovoltaics (79). Social feedback, communication, and reinforcement approaches (see the hierarchy of effects and precede-proceed models) are used in other domains but should undergo additional testing in a residential energy use context.

5. DECISION MODELS IN SOCIAL AND ENVIRONMENTAL PSYCHOLOGY

Social and environmental psychologists have focused extensively on residential energy efficiency. Early research from the 1970s explored the influence of information and incentives on residential energy use behavior (111). As energy prices and the associated incentives to conserve ebbed through the 1980s, attention shifted from deficient information as a source of market failure to the role of psychological constructs (values, attitudes, norms) framed by environmental concerns.

Information and Incentives

Social psychologists demonstrated the shortcomings of the rational actor model's undifferentiated focus on information and net monetary benefits as determinants of decisions (78). Residential energy users were found to be consumers of intangibles, members of social groups, committed individuals, and problem avoiders as well as informed economic rationalists (112). Although monetary incentives certainly have a calculable effect on monetary cost-benefit ratios, their impact on decisions are more contingent. For example, the attractiveness of incentives varies across different target groups. Administrative effort, eligibility criteria, cash-flow timing, the relevance of immediacy (see Section 3 on discount rates), and the requirement to take on debt are all attributes of an incentive, which may affect its uptake and bring social and psychological factors into play (113). Similar findings on the effectiveness of incentives apply to other types of proenvironmental behavior (114).

Proenvironmental behavior: intentional behavior with a reduced environmental impact relative to comparable behaviors

Providing information to raise awareness, substantiate beliefs, and influence behavior was also not found to be universally effective (see Reference 5 for a detailed review). Whereas diffusion studies explored the influence of different channels of communication, social psychologists focused more on the form and content of information. A key set of findings was that the most effective information in promoting residential energy efficiency was simple, salient, personally relevant, and easily comparable rather than technical, detailed, factual, and comprehensive (115, 116). The perceived trustworthiness and credibility of the information and/or service provider was also important (117, 118).

As in DoI (see Section 4), social psychologists emphasized the importance of information as feedback (119, 120). To conserve energy, home occupants must know how behavior and energy use interrelate and must be motivated to conserve (121). In this simplified model, information provides the former, incentives provide the latter, but only feedback provides both. Periodic and undifferentiated utility bills hinder direct feedback on energy efficient behavior (122). Alternative mechanisms for confirming cost savings include visible consumption meters, differentiated billing, and smoke sticks (which indicate

VBN: value-belief-norm (theory)

leaky building envelopes) (96, 123). Targeted, personalized, or otherwise tailored information is also important (124). Web-based tools can now combine large sample sizes with tailored information (125). Electricity market deregulation has enabled further experimentation with time-of-use or real-time pricing to support feedback (see Reference 126 for a recent review). As a recent example, load reductions of 25% and 13% for California households with and without automated response thermostats, respectively, were achieved during critical peak pricing periods (127).

Correlates of Proenvironmental and Residential Energy Behavior

Another ongoing theme of social psychology research has been the testing of socioeconomic and psychological correlates of residential energy use, and more broadly, proenvironmental behavior (128, 129). Somewhat inconsistent support for predictors of (self-reported) proenvironmental behavior has been found for income, education, and household composition (e.g., absence of young children, people in ill health, or elderly people), with weaker and more ambiguous correlations for gender (female) and age (youth) (130, 131). Values, knowledge, and attitudes toward proenvironmental behavior also failed to show strong correlations, particularly where the psychological constructs tested were of a more general nature (132, 133). (See the earlier discussion in Section 4 on the theory of planned behavior.)

A major lesson from these studies was that behaviors need to be distinguished by their psychosocial characteristics, including frequency (or repetitiveness), cost, and associated amenity losses (111). Residential energy efficiency, for example, encompasses a wide range of behaviors: capital investments, low-cost efficiency improvements, ambient temperature setting, and minor curtailments. Although home ownership influences efficient capital investment decisions, favorable attitudes are more influential for repeatedly reinforcing curtailment behaviors, such as thermostat setting (134). Household characteristics (age, size, state of repair), composition, and occupancy are also important for heating and comfort-related measures (5, 132). A review of more than 40 U.S.-based studies of residential energy use found that while attitudes correlate with intentions to change behavior, house characteristics better predict actual actions like weatherization (135).

Values, Attitudes, and Norms

Failure to find strong correlates of behavior highlighted the need for robust mechanisms to map deeper influences of social demographics and values down onto specific attitudes and behaviors (136). Value-belief-norm (VBN) theory proposed a causal chain from the stable essentials of personality (values, worldviews) to specific beliefs about the consequences and responsibilities of particular actions, and on to attitudes and norms (137). The basis for VBN was activated norm theory, which stemmed from earlier work on the elicitation and characterization of values (138). In VBN, activated norms directly influence behavior, and other psychological constructs act indirectly through activated norms (see left side of **Figure 2**). Activated norms are personal obligations to act in a way that reduces adverse consequences to things of value (139); this is stated simply as, "I ought to do X to prevent Y from adversely impacting Z, because I value Z." This creates a predisposition for behavior change and is linked to self-expectations (140). VBN theory modified the norm activation pathway to include altruistic values toward both humans and the biosphere. Both types of altruism in addition to self-enhancement values (e.g., for status) and egotism (e.g., for financial returns) have been shown empirically to predict different types of proenvironmental behavior, including residential energy conservation (98, 133, 134, 137). The characteristics and context of the behavior in question influences the role

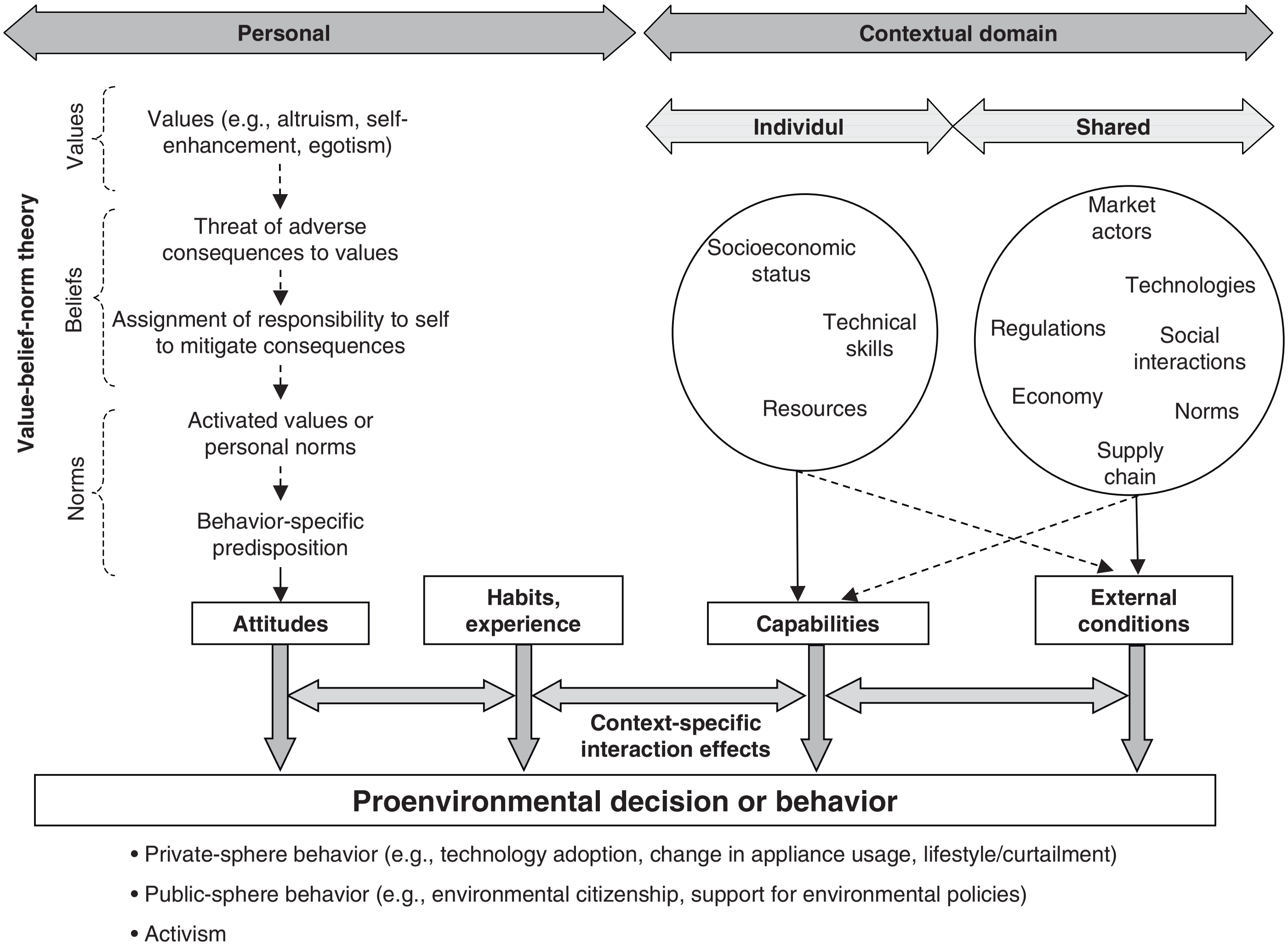

Figure 2

An integrated model of proenvironmental behavior. Adapted from Reference 150 (PC Stern, "Towards a Coherent Theory of Environmentally Significant Behavior," *Journal of Social Issues*, with permission from Blackwell Publishing).

ABC: attitude-behavior-external conditions (model)

played by values (141). As examples, altruistic values may not be relevant in contexts where individuals lack perceived self-efficacy (124) or where action is associated with self-sacrifice or a sense of helplessness (142). The relationship between values and proenvironmental behavior is discussed further in a recent review (143).

The Importance of External Conditions

The psychological antecedents of behavior vary because of external conditions that either support or hinder behavior change. External conditions include physical, financial, legal, or social influences upon a decision. In linear decision models, e.g., TPB, these are mediated by other precursors of behavior, such as perceived behavioral control (142). More generally, instrumental decision making implies a strongly internal locus of control or perceived ability to bring about change through behavior (144). Decision models that do not explicitly include external conditions are weakest when behavior change involves high-effort, high-cost, and high-involvement decisions (145).

The importance of external conditions was articulated in an ABC (attitude-behavior-external conditions) model in which attitudes lead to behavior change only if contextual variables provide either weak incentives or disincentives (146). In other words, there are boundary conditions, determined by context, on the ability of attitudes to predict behavior (discussed further in Section 7). This is evidenced in studies of residential energy conservation that show threshold effects when a given level of support from external conditions (e.g., through incentives) is reached and psychological variables then emerge as the main barriers to action (113). An early study of real-time pricing showed a similar threshold effect in which an increase from 2:1 to 8:1 in the peak:off-peak electricity price differential explained only 2% of the variance in behavior compared to 11% explained by attitudinal measures (147). External conditions influence behavior both directly by defining available choices and their relative attractiveness (see Section 6) and indirectly through attitude formation (134). In a study of curbside recycling, individuals' perceptions of costs in terms of time, effort, and inconvenience were not found to impact behavior directly but acted to reduce the strength of supporting attitudes (146). Some studies have suggested that external conditions drive behavior change, which then changes attitudes to reduce cognitive dissonance (134, 148). This has an interesting implication for the DoI framework (see **Figure 1**) because it suggests preadoption and postadoption drivers of behavior may differ, although it is the postadoption drivers that form the basis of social feedback.

Integrating Sociopsychological Findings

The ABC model explicitly drew together attitude-based decision models and findings on the influence of external conditions, including incentives and information, on behavior. Drawing on both the ABC model and VBN theory, as well as other social psychological research (summarized in Reference 85), an integrated model of proenvironmental behavior was proposed and is shown schematically in **Figure 2** (149, 150).

The model distinguishes personal and contextual domains (see the left and right sides, respectively, of **Figure 2**) while recognizing interactions between them (85). The personal domain comprises habits, current practice, and past experience as well as attitudes. The VBN chain allows for values to be mapped onto activated norms for particular behaviors. By incorporating values, the integrated model rejects the instrumental utility calculus of the rational actor model and, implicitly, of DoI and TPB (149). The contextual domain comprises variables specific to the individual (e.g., acquired technical skills and know-how) and variables that are shared by many individuals (e.g., social norms and expectations). The model emphasizes interaction effects between these different personal and contextual variables (150), as well as behavior-specific characteristics (e.g., the degree of involvement, effort, cost, time, skill requirement, financial resources, convenience, repetition, contextual support, normative compliance) (136, 137). Multivariate analysis of the causal pathways by which both personal and contextual variables act on individual decisions is needed to apply the model to different behaviors, and so generate further insights (1, 82, 151).

Lessons for Interventions

The social psychology research reviewed concerns individual decisions with consequences on either residential energy use or, more broadly, the environment. Independent variables that explain those decisions are specific to both context and the behavior in question (see Section 7). The influence of psychological variables is constrained by external conditions. As with the expected utility and attitude-based models reviewed in Sections 3 and 4, systemic influences are treated as exogenous so the timescale over which decisions are considered is short (e.g., weeks). The integrated model shown in **Figure 2** offers a framework for exploring both personal and contextual variables as well as their interactions. Lessons for designing interventions follow from these basic insights.

Both behaviors and interventions must be distinguished, as well as the linkages between them. One suggested typology identifies the following linkages at a general level (85):

- Moral suasion/education (change beliefs/attitudes or activate norms) (153)
- Policy/regulation (change external conditions/incentive structure)
- Supply chain (changes decision alternatives or their relative attractiveness)
- Community management (changes social norms) (109)

Any given behavior will typically have many constraints across both personal and contextual domains (see **Figure 2**). Interventions seeking to change behavior need to identify and target the relevant constraints in that particular context (154). Because a single intervention might only influence some of these constraints (104), multiple interventions are often required to act in concert (85, 155).

Interaction effects between personal and contextual variables may mean that addressing one constraint causes another to emerge. Once an incentive creates unambiguous personal benefits, interventions should target personal variables such as the attitudes and norms that predispose an individual to act rather than further increase the incentives (113). Interventions themselves can also have overlapping or reinforcing interaction effects. A study of measures (energy tax, investment subsidies, gas use regulation) promoting residential energy efficiency in the Netherlands found that their combined effect on energy use was up to 30% less than the sum of their individual effects (156). More generally, research should be oriented toward interventions with the greatest potential environmental impact rather than those of the greatest theoretical or experimental interest (150).

Different drivers of decisions change over varied timescales (149). Interventions designed to address contextual variables (e.g., price incentives) or personal variables (e.g., information to reinforce favorable attitudes) may aim for short-term change. When behavior is strongly limited by external conditions, interventions aimed at personal variables may have a weak direct impact on behavior but may be important in the longer term to build political support for policy change and social support for norm change. The decision models reviewed in Sections 3–5 concern behavior change over shorter time frames, but the sociological models considered in Section 6 provide more insight into longer-term dynamics. For ongoing or repetitive behaviors (e.g., thermostat setting), the variables that influence behavior will change over time as knowledge replaces preconception, benefits and costs become clearly defined, habits and routines are established, and social norms cede to personal norms (148).

Finally, information can support positive attitude formation and can potentially reinforce or influence beliefs that activate values and so create personal norms (as recognized by marketers). Information and education-based interventions from multiple sources or channels should be targeted, personalized, timed to take advantage of windows of opportunity, and combined with other interventions particularly where external conditions are strongly limiting (82).

6. THE SOCIAL CONSTRUCTION OF DECISION MAKING

The literature reviewed in this section considers the broader social and technological context in which residential energy use decisions are embedded. This sociological orientation questions the relevance of individual decision models and shifts the emphasis from energy using behavior to the role of, and demand for, energy services.

Energy Demand as a Social Construct

Although the preceding sections in this review have considered individual behavior from different perspectives, they have shared the basic assumption that the individual is an autonomous decision maker, albeit subject to external influences. Consequently, the subjects of decision models are individuals. This assumption is contested by researchers who argue that individual decisions are instead "constructed" or determined by social and technological systems. Needs, attitudes, and expectations are not individual in nature but are part of a complex relationship between social norms and relations, technologies, infrastructures, and institutions (157).

From this "sociotechnical" perspective, individuals do not make decisions to consume energy or the resources that provide energy. Rather, energy provides useful services that enable normal and socially acceptable activities to be carried out as part of routine domestic life (158). The demand for energy is therefore indirect, created by services such as comfort and cleanliness, which are in turn provided by devices (e.g., light fixtures, washing machines) and by infrastructures (e.g., transmission grids) (159). Demand is not a consequence of individual decisions or beliefs manifest over short time frames but is something that is "systematically configured" over the long term (160). Accordingly, it is unsurprising that individual decision models centered on psychological variables can only weakly explain energy use (161). The broad empirical support for models such as DoI (see **Figure 1**) relies not on the explanatory power of its underlying individual decision model but on uniformity in the social and technological context for diffusion (162).

Revisiting the Energy Efficiency Gap: Embedded Energy Use

The conventional framing of the energy efficiency gap (see Section 2) allows the problem to be defined technically and resolved by targeting individuals with universally applicable technologies, practices, and standards (162). The sociotechnical perspective, however, contends that household uses of energy technologies are adaptive responses to particular local conditions and norms and thus are highly heterogeneous (159, 163). The social dimension of residential energy use is needed to understand the energy efficiency gap. Four key characteristics (161) are

- Embeddedness (home life is inherently energetic; habitual activities such as cooking, cleanliness, child care, mobility, and entertaining all embed energy consumption into daily routine);
- Constraints on choice (the supply-chain of technologies, an individual's skills and knowledge, and the disposition of tradesmen and contractors, all constrain individual choice);

- Counter marketing (the dominant message to which households are exposed is not conservation but consumption); and
- Impetus (because oil shock-driven energy prices have receded in memory, energy efficiency as an issue has lacked a systematic driving force).

Some of these points are incorporated in the individual decision models reviewed in earlier sections. Impetus relates to the issue of salience (Section 3) and to the importance of both the form and content of information provided to households on energy efficiency (Section 5). Constraints on choice are (or can be) represented through the choice sets available to individuals in different decision contexts (Section 3), through perceived behavioral control or self-efficacy variables (Section 4), and through capabilities (Section 5).

The real wedge between individual decision models and this social dimension of energy use is embeddedness (159). The use of space conditioning technologies to make homes comfortable is a good example. Households' needs and expectations for thermal comfort have evolved over time. So too have the design of houses (e.g., room sizes, window area), energy technologies (e.g., furnaces, thermostats), supporting infrastructure and institutions (e.g., electricity grids, utility tariffs, and services), as well as social norms (e.g., indoor temperatures, room occupancy profiles) (158). These changes in norms and technologies affect one another and drive further change. In the three decades from 1962 to 1992, use of air-conditioning (AC) spread from 12% to 64% of American homes (164) and by 2001 had risen to 75% (165). The availability and adoption of AC technologies led to changes in the way homes were designed: Verandas, eaves, thermal mass, and other means of passive cooling ceased to be integral features. But these changes in design had a ratchet effect on the perceived need for AC (see Reference 159 for a full discussion). This changing sociotechnical regime for AC was part of a broader normalization of the ability to control and customize the indoor thermal environment. Space conditioning (heating and cooling) now accounts for around 50% of U.S. household energy use (166).

The embeddedness of energy use in domestic routines is reinforced by the counter marketing of newly available and desirable energy devices and the services they provide (e.g., under-floor heating to warm cold tile floors in air-conditioned homes). The marketing strategies used to sell these services indicate the myriad social roles played by energy technologies: display, status, self-expression, conventionality, convenience, security, independence, and flexibility (167, 168).

Sociotechnical regime: the structured web of interrelationships between social norms, human behavior, and technological systems

Analyzing the Social Organization of Residential Energy Use

The embedded social dimension of energy use is organized at different levels or scales. Analysis at the household (rather than individual) level captures normative and routine behavior and recognizes the specialization of domestic roles (169). The number, age, gender, and income of household occupants can be used to create meaningful sociocultural units: Two wealthy retirees have energy needs that differ from a low-income family with three young children (170). The household as a unit of analysis also allows for more anthropological considerations of the role of family relations, kinship, gender, and ethnicity on energy use (168, 171).

Controlling for differences in building design and technologies, social interactions within households give rise to fairly stable patterns of energy use over time and also explain the substantial variability between households (see Section 5 for a review of empirical studies). These patterns are also evident at the level of specific energy services, such as space conditioning, washing, and bathing. The energy demand from these habitual domestic practices has been termed the social base load as a sociological analogy to the load analyses used in energy system management (167). Just as energy supply systems are scaled to meet peak demand, so too do extraordinary social events and activities (e.g., having dinner parties or sick children) create social peak loads, which determine the need for, and size of, service-providing technologies (e.g., large ovens and refrigerators or heated bedrooms).

Patterned differences in household energy demand are further explored by lifestyle studies. These take an approach similar to the market segmentation analyses used widely in marketing and DoI-based studies to address heterogeneity (see Sections 3 and 4). Lifestyle studies extend beyond demographic variables to find linkages between energy use and proxies of broader cultural and social identities (172). Borrowing from life cycle analysis methods, indirect or embodied energy can be included as well as direct energy use (173, 174). Lifestyle is represented by, for example, patterns of time and money allocation (175). Early lifestyle studies looked at both inter- and intranational linkages between lifestyle, well-being, and energy use in the context of the curtailment and conservation response to the oil shocks in the 1970s (176, 177). Later studies had a more explicit sociotechnical perspective by assessing how changes in the structural determinants of energy use, such as employment and housing stock, gave rise to large-scale energy use trends (178). However, as with market segmentation analysis, the underlying assumption was that of an individual energy user making decisions on the basis of external conditions (163). More fundamental questions of how and why structural changes took place in the first place, and how they embedded demand for energy, remained unasked (5).

Lessons for Interventions

Energy demand is deeply embedded in inconspicuous norms of comfort, cleanliness, and convenience (159) as well as throughout the whole supply chain for energy services (160). This has profound implications for the ability of interventions to impact residential energy use by changing behavior. Individuals' decisions about energy services are highly constrained, and individual behavior is not readily influenced. Targeting psychological variables (e.g., information/education campaigns to influence attitudes) or contextual variables (e.g., monetary incentives to improve cost-benefit ratios) can only achieve limited success in effecting behavioral change in the short term (161).

Although contextual variables are recognized by social psychologists and diffusion researchers as important drivers of behavior (see Sections 4 and 5), they are also seen as malleable and legitimate targets for interventions. Sociologists, by contrast, argue that contextual variables are elements of highly structured systems that shape, stabilize, and constrain behavior and that in many cases have evolved alongside technologies over long time periods (159). Barriers to energy efficiency may have normative and social functions that cannot simply be removed (158). Substantial reductions in residential energy use can only be achieved by developing appropriate sociotechnical regimes. But these regimes are strongly path dependent, i.e., defined by their historical development (179). To overcome this inertia, intervention designers need to recognize critical moments when sociotechnical regimes are openly changing and can be most easily influenced (163). In the case of energy utilities, for example, changing regulation and market structure have led to service differentiation and opportunities for decentralized production (160). New relationships between consumer and producer are emerging, with consequences for energy demand. As an example, interruptible loads challenge the established norm that a utility company's role is to provide electricity to meet demand. The use of infrastructure is proving similarly flexible with the centralized hub-and-spoke electricity network giving way to more varied and coexisting configurations (180). For electricity, these critical moments for sociotechnical regime change are apparent.

Potential targets for interventions are far broader than either the individual or the energy supply chain. A range of social and technological systems construct energy demand. These include urban planning, food production, fashion, and advertising (163). Interventions should facilitate interactions between households, utilities, and all the other institutions that play some role in structuring everyday life and routine (160, 168). Rather than prescribing individual behavior, the objective of these interactions should be to sketch out future sociotechnical conditions necessary for reducing demand or to influence expectations and norms (163). Integrated assessment and scenario analysis are useful decision support tools for such endeavors (181).

Interventions should also shift in focus from energy efficient technologies to energy service provision (159). Marketing strategies recognize this distinction: It is not energy efficiency investments that sell weatherization but comfort, health, and noise reduction (182). The social and cultural nature of energy demand may mean effective interventions are specific to a time and a place and not universally applicable (see the discussion on context in Section 7).

Compared to other disciplines, these sociological lessons for intervention design are less generic, less prescriptive, more complex, more diffuse, more gradual, far-reaching, and so, in all senses, less palatable to intervention designers interested in verifiable impacts over short-time periods. As such, they have not been as widely implemented and tested as have many of the interventions suggested by other disciplines (see Sections 3–5). This is compounded by the lack of specific and purposive recommendations made by researchers, even in studies of sociotechnical regimes in transition (e.g., deregulating electricity markets) where opportunities to restructure demand are more evident (160).

7. CONCLUSIONS

In this final section, a brief comparison is made of the disciplinary approaches and decision models reviewed in Sections 3–6. Key lessons for designing interventions to influence residential energy use are restated and further developed. Directions for future research are also considered.

Comparison of Disciplinary Approaches to Individual Decision Making

It is worth re-emphasizing that this review is far from an exhaustive review of all decision models. The intent is to represent the range of approaches to individual decision making and behavior from across the social sciences. A more comprehensive treatment can be found in (2). The sidebar in this review discusses the related field of behavioral decision research. **Table 2** synthesizes and compares some of the main features of the decision models reviewed above.

Integrating Disciplinary Findings

"An overarching model that can simultaneously capture group dynamics, body use, cognitive processes, and human-machine interactions is needed. To date, progress towards such a model has been limited by the theoretical preferences of the various disciplines involved in energy research" (5, p. 267).

One of the objectives of this review is to broaden understanding of the "theoretical preferences of the various disciplines" and, in so doing, make a small contribution toward integration. It is important to recognize, however, that decision models are useful both for researching and understanding behavior as well as for designing and evaluating interventions (2). These distinct functions pull in different directions: (*a*) completeness and complexity for representing behavior and (*b*) parsimony and simplicity for testing interventions. Integrative models pursuant to one role (e.g., research, intervention design) may not be readily applicable to the other (intervention evaluation). A more general trade-off between theory and practice is seen in the detailed characterizations of decision models that may capture context-specific

Table 2 Comparison of disciplinary approaches to decision making in the context of residential energy use

Main features	Conventional economics	Behavioral economics	Technology diffusion	Social psychology	Sociology
	Section 3		Section 4	Section 5	Section 6
Decision model	Utility-maximization based on fixed and consistent preferences	Widely varying decision heuristics and context-dependent preferences	Attitude-based evaluation of technologies and the consequences of adoption	Interacting psychological and contextual variables	Sociotechnical construction of demand
Decision scale	Individual	Individual	Individual/social	Individual/social	Social
Main research methods	Quantitative (observed behavior)	Quantitative (controlled experiments)	Quantitative and qualitative (surveys, interviews, observed behavior)	Quantitative and qualitative (surveys, observed behavior)	Qualitative (interviews, observation)
Main dependent variables	Preferences between decision outcomes	Preferences between decision outcomes	Rate of diffusion	Self-reports of behavior and/or energy use	Observed or self-reported behavior
Main independent variables	Costs and benefits of outcomes and their respective weightings	Aspects of the decision frame, context, and elicitation method, as well as outcomes	Adopter role in social networks, communication channels, technology attributes, and leadership of adopter	Values, attitudes, norms, sociodemographics, economic incentives, skills, capabilities, and resources	Social, cultural and technical determinants of energy demand embedded in routine behavior
Empirical basis in energy use	Extensive	Very little	Some	Extensive	Some
Implications for interventions to reduce residential energy use	Provide information about benefits and incentives to improve cost-benefit ratio and improve cognitive capacity to assess net benefits/utility	Pay attention to framing and reference points for decisions, influence heuristic selection by emphasizing associations or emotive attributes, control choice sets and default options	Segment target population, exploit communication channels through social networks and use change agents, identify stage of decision process in target groups and use appropriate change mechanisms, ensure desired technology or behavior has key attributes	Influence attitudes only if external conditions are weak, use multiple interventions with due attention to interaction effects, identify and target barriers, design salient and personally relevant information, values provide a disposition for long-term change	Work toward long-term sociotechnical regime change, exploit opportunities of transition, recognize the social role of routine or habitual behavior, manage expectations
Timescales for interventions	Short term	Short term	Short to medium term	Short to medium term	Long term

psychological processes but may fail to demonstrate real-world effect sizes.

Although they have different emphases, utility theory, behavioral economics, technology diffusion, attitude-based behavior, and social psychology all share the assumption that the individual can be the subject of an integrated decision model comprising distinct explanatory variables. The main integrative challenge is to resolve this assumption of individual agency with sociological findings on the structuring of behavior by sociotechnical systems. This means bridging widely different basic assumptions, analytical techniques, data use, and implications for intervention designers (see **Table 2**).

Integrating economic and sociological perspectives—at the two extremes—is particularly imperative for sociologists seeking to overcome the entrenched influence of technical and economic analysis on energy efficiency policy (183). Sociological constraints on behavioral elasticity (see Section 6) may support those economists whose findings question the cost-effectiveness of demand-side management programs (184, 185), but such cross-disciplinary links remain largely untapped. Although social and behavioral researchers concerned with the human dimension of energy use certainly do provide policy input, it is from a distinct domain that is rarely treated as an inseparable constituent of energy demand and technology use (163).

Various research approaches have tackled this challenge of cross-disciplinary integration. Work on the linkages between lifestyle and energy use and, more broadly, on the macropatterning of energy demand (5) best proxies the largely qualitative analyses of sociotechnical regime change. A recent review of several other proposals for integrated energy research proposed an agent-based modeling framework to link different scales in the energy supply chain (186). By incorporating both personal and contextual variables, the integrated model of environmental behavior described in **Figure 2** can also be used to test interventions across different decision contexts (150). Expectations could act as another bridge between disciplines because they play a key role in both economic studies of decision behavior (see fairness and reference points in Section 3) and in sociological studies of normative and routine behavior (see Section 6). Nevertheless, appealing for integration between models of individual behavior and models built around social and technical systems may be a quixotic simplification, idealized and with merit perhaps, but quite mad given its scant chance of success.

Suggestions for Integrated Research and Intervention Design

Three themes arise repeatedly throughout Sections 3–6: context, scale, and heterogeneity. These suggest potential directions for integrated decision making and behavioral research, as well as interventions for reducing residential energy use.

Matching decision models to decision types and contexts. Decisions range from highly deliberative, informed, and conscious choices to habitual, instinctive, and subconscious “nondecisions” (3). Decision models are not universally applicable but have particular behavioral niches. Psychologically driven models may have weak explanatory power in strongly constrained decision contexts, and instrumental utility-based models may poorly represent choices motivated by values. Heuristic decision models may not apply in novel and challenging situations where individuals make deliberative choices but may capture the decision process behind instinctive acts of consumption. Research and interventions alike should be based on decision models that match the type and context of behavior in question by asking the following questions: Is it habitual? Does it involve money? Is it salient? Is it part of social interaction? Is the choice set constrained? Is it socially normative? Is it technically difficult? Is it novel? Is it repetitive? Is it a function of infrastructure?

More broadly, it is essential to understand the context for the decision. A common bias is to emphasize psychological variables over contextual variables (70). As emphasized by the ABC model (Section 5), identifying the strength of influence of external conditions—regulations, economics, social norms, available technologies, and supply chains—is the most important determinant of the type of decision being made and so the type of decision model to employ. Each of the decision models reviewed includes the influence of contextual factors on behavior in some way: choice sets, reference points, and framing in behavioral economics (Section 3); perceived behavioral control in TPB (Section 4); capabilities, regulations, economic incentives, and technologies in the integrated social psychology model (Section 5); and sociotechnical regimes and the construction of demand in sociology (Section 6). In general terms, the larger the scale and/or stronger the influence of external conditions on the decision maker, the more the appropriate decision model moves through this same sequence (Sections 3–6).

Decision models also range in their function. Utility-based models seek to describe choices made and so preferences revealed. Psychological models seek explanations for these choices at an individual or social network level. Sociological models extend these explanations to the level of sociotechnical regimes, which subsume individual choices. Distinguishing descriptive from explanatory functions is also important when selecting and using different decision models, particularly when the subject of analysis is similar. As an example, long-term elasticities of demand in econometric models (Section 3) and the sociotechnical structuring of demand in sociological models (Section 6) may be analogous but answer how and why questions, respectively.

In short, critical questions for intervention designers to ask are where on the individual-to-social, instinctive-to-deliberative, psychological-to-contextual, and short-to-long-term decision continua their interventions are targeted and which of the determinants of decisions they are aiming to influence. The answers to these questions make it possible to select an appropriate decision model and allow a realistic determination of the level of behavioral response that can be expected from any given intervention.

Scales and nested decision models. The research traditions reviewed address different temporal and spatial scales of decision making. This accounts for differences in both theoretical preferences and empirical findings. Moving from left to right through **Table 2** (and sequentially through Sections 3–6), the behavioral focus moves from the short term to the long term and from the individual to the social. These scales can be nested within one another like Russian dolls. Behavioral economic findings on the framing of decisions can be nested within attitudinal models of technology adoption. These in turn can be nested within integrated social psychology models that incorporate a broader range of psychological variables, including personal norms as well as contextual variables such as social norms. The individuals that these nested models describe can themselves be nested within networks of social interactions and within sociotechnical regimes that provide both context and constraint. Each scale of nesting sets boundary conditions for the explanatory power of the decision model in the scale below.

A similar argument has been made within economics by distinguishing preferences used in the short run to make decisions from "constitutional" preferences (precommitments or self-imposed rules) that constrain these decisions but are ultimately changeable in the long run (187). Although the potential for changing behavior increases with the nesting of more scales, the interventions required become more systemic and long term (see Reference 188 for an analogous point regarding institutional decision making).

Recognizing heterogeneity. Empirically, individual and household energy use varies widely even when differences in contextual variables are controlled (5). More generally, behavioral patterns and responses will be heterogeneous over the target population for an intervention. In moving from individual up to socially framed decision models, it is essential to take heterogeneity into account. Marketing and DoI studies segment the population along psychosocial dimensions (see Sections 3 and 4) and lifestyle studies along dimensions of material or cultural identity (see Section 6). More work is needed on segmentation methods that allow decision making to be understood at different scales.

Nested decision models readily incorporate heterogeneity because each scale suggests a source of difference, for example, in decision heuristics (behavioral economics), in attitudes or communication behavior (DoI), in values or capabilities (social psychology), and in routines or norms (sociology). Controlling for heterogeneity at one scale may help characterize better the impact of heterogeneity at another scale. Heterogeneity also raises important questions about equity and the distributional impact of interventions (189, 190). Aggregate analyses (of the potential for, or results of, an intervention) will conceal much of the detail of individual behavioral change. This can lead to the misspecification of decision models at the individual scale (see Section 3).

Finally, heterogeneity within populations emphasizes the benefits of natural experiments in an adaptive management tradition (191). Variability in the demand-side management programs implemented in the 1970s and 1980s helped researchers isolate the effects of information and incentives on energy use (113) and on the unit costs of reduced demand (185). To learn more about decision making and behavioral responses to interventions, a diversity of approaches should be embraced in lieu of a hunt for universally applicable solutions. Interventions should be designed specifically to test the applicability of different decision models to a given decision context.

A Final Appeal for Integration

Resurgent interest in demand-side management programs, framed by climate change and energy security concerns, feeds a concrete need for applied research on energy efficiency intervention design and evaluation. A vast amount has been learned over the last three decades on human behavior and energy use. As well as reaffirming this body of knowledge, this review aims to highlight the benefits of renewed and sustained collaboration between disciplinary approaches to energy efficiency. Among other things, this requires greater openness on the part of the dominant economic-engineering tradition and a more applied focus on the part of behavioral scientists. The shared goal should be to entrench the social and behavioral determinants of energy use as a wholly integrated part of energy efficiency research.

SUMMARY POINTS

1. There are many different models of decision making and behavior within the social sciences. These models vary widely in their basic assumptions, independent variables, structure, and scale.
2. The determinants of decisions can be broadly grouped into psychological and contextual domains. Psychological determinants include values, attitudes, and personal norms. Contextual determinants include available choices, economic incentives, social norms, technologies, and infrastructures.

3. Most research traditions, including economics, behavioral and social psychology, and technology diffusion, center on the individual as decision maker. In contrast, sociologists question the relevance of individually framed decision models and emphasize the social and technological construction of behavior.
4. Decision models can inform the design of interventions to change behavior by identifying the key influences on decision making. Each of the research traditions offers specific lessons for intervention design.
5. When applying behavioral theories to the design or evaluation of an intervention, an appropriate decision model must be selected to match the particular decision characteristics and context that the intervention seeks to influence.
6. There is an unexplored potential to reconcile the theoretical preferences of different research traditions, although different integrative approaches have been proposed. The most significant challenge is to combine the economic and sociological bases for behavior.
7. Residential energy use is characterized by a wide range of decision types and contexts, as well as psychological and contextual influences on behavior. Decision models from different research traditions are all relevant to some aspect of residential energy use.

FUTURE ISSUES

1. Various integrated approaches to decision making have been proposed, but these approaches should be developed further and tested in different decision contexts.
2. Researchers should develop general rules or guidelines to help intervention designers select decision models that are appropriate for understanding how to influence particular behaviors.
3. New frameworks and methods are needed to reconcile individual scale (and predominantly quantitative) decision models with social scale (and predominantly qualitative) representations of behavior.
4. Better methods for characterizing heterogeneity in decision making and behavior across the target population for an intervention are needed.

DISCLOSURE STATEMENT

The authors are not aware of any biases that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

We are very grateful to Baruch Fischhoff, Paul Stern, and Ashok Gadgil for helpful advice and comments. This review was supported by the Climate Decision Making Center created through a cooperative agreement between the National Science Foundation (SES-0345798) and Carnegie Mellon University.

LITERATURE CITED

1. Brewer G, Stern PC. 2005. *Decision-making for the Environment: Social and Behavioral Science Research Priorities*. Washington, DC: Natl. Acad.
2. Jackson T. 2005. Motivating sustainable consumption: A review of evidence on consumer behaviour and behavioural change. *Rep. to Sustain. Dev. Res. Netw.*, Univ. Surrey, Guildford, UK
3. Kahneman D. 2003. Maps of bounded rationality: psychology for behavioral economics. *Am. Econ. Rev.* 93:1449–75
4. Stern PC. 1992. What psychology knows about energy conservation. *Am. Psychol.* 47:1224–32
5. Lutzenhiser L. 1993. Social and behavioral aspects of energy use. *Annu. Rev. Energy Environ.* 18:247–89
6. Jaffe AB, Stavins RN. 1994. The energy efficiency gap: What does it mean? *Energy Policy* 22:804–10
7. Brown MA, Levine MD, Romm JP, Rosenfeld AH, Koomey JG. 1998. Engineering-economic studies of energy technologies to reduce greenhouse gas emissions: opportunities and challenges. *Annu. Rev. Energy Environ.* 23:287–385
8. Ruderman H, Levine MD, McMahon JE. 1987. The behavior of the market for energy efficiency in residential appliances including heating and cooling equipment. *Energy J.* 8:101–24
9. Brown MA. 2001. Market failures and barriers as a basis for clean energy policies. *Energy Policy* 29:1197–207
10. Levine MD, Koomey JG, McMahon JE, Sanstad AH, Hirst E. 1995. Energy efficiency policy and market failures. *Annu. Rev. Energy Environ.* 20:535–55
11. Jaffe AB, Stavins RN. 1994. Energy efficiency investments and public policy. *Energy J.* 15:43–65
12. Sutherland RJ. 1991. Market barriers to energy efficiency investments. *Energy J.* 12:15–34
13. Intergov. Panel Clim. Change (IPCC). 2001. *Climate Change 2001: Mitigation.* Cambridge, UK: Cambridge Univ. Press
14. Gillingham K, Newell R, Palmer K. 2006. Energy efficiency policies: a retrospective examination. *Annu. Rev. Environ. Resour.* 31:161–92
15. Clemen RT, Reilly T. 2001. *Making Hard Decisions*. Pacific Grove, CA: Duxbury
16. Kahneman D, Diener E, Schwartz N. 1999. *Well-being: The Foundations of Hedonic Psychology*. New York: Russell Sage
17. Tversky A, Kahneman D. 1981. The framing of decisions and the psychology of choice. *Science* 211:453–58
18. Thaler R. 1985. Mental accounting and consumer choice. *Mark. Sci.* 4:199–214
19. Starmer C. 2000. Developments in nonexpected utility theory: the hunt for a descriptive theory of choice under risk. *J. Econ. Lit.* 38:332–82
20. Louviere JJ, Hensher DA, Swait JD. 2000. *Stated Choice Methods: Analysis and Application*. Cambridge, UK: Cambridge Univ. Press
21. Train K. 1985. Discount rates in consumers' energy-related decisions: a review of the literature. *Energy* 10:1243–53
22. Frederick S, Loewenstein G, O'Donoghue T. 2002. Time discounting and time preference: a critical review. *J. Econ. Lit.* 40:351–401

23. Loewenstein G, Prelec D. 1992. Anomalies in intertemporal choice: evidence and an interpretation. *Q. J. Econ.* 107:573–97
24. Revelt D, Train KE. 1998. Mixed logit with repeated choices: households' choices of appliance efficiency level. *Rev. Econ. Stat.* 80:647–57
25. Goett AA, Hudson K, Train KE. 2000. Customers' choice among retail electricity suppliers: The willingness-to-pay for service attributes. *Energy J.* 21:1–28
26. Mitchell R, Carson R. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, DC: Resour. Future
27. Amann JT. 2006. Valuation of nonenergy benefits to determine cost-effectiveness of whole-house retrofit programs: a literature review. *Rep. AO61*, Am. Counc. Energy-Effic. Econ., Washington, DC
28. Jaccard M, Nyboer J, Bataille C, Sadownik B. 2003. Modeling the cost of climate policy: distinguishing between alternative cost definitions and long-run cost dynamics. *Energy J.* 24:49–73
29. Wirl F, Orasch W. 1998. Analysis of United States' utility conservation programs. *Rev. Ind. Organ.* 13:467–86
30. Ramesohl S. 2000. Social interactions and conditions for change in energy-related decision-making in SMCs: an empirical socio-economic analysis. See Ref. 195, pp. 207–26
31. Laitner JAS, DeCanio SJ, Peters I. 2000. Incorporating behavioural, social, and organizational phenomena in the assessment of climate change mitigation options. See Ref. 195, pp.1–64
32. McFadden D. 1999. Rationality for economists? *J. Risk Uncertain.* 19:73–105
33. Conlisk J. 1996. Why bounded rationality? *J. Econ. Lit.* 34:669–700
34. Camerer C, Loewenstein G. 2004. Behavioral economics: past, present, future. See Ref. 196, pp. 3–51
35. O'Donoghue T, Rabin M. 1999. Doing it now or later. *Am. Econ. Rev.* 89:103–24
36. Gintis H. 2000. Beyond homo economicus: evidence from experimental economics. *Ecol. Econ.* 35:311–22
37. Stern PC. 1986. Blind spots in policy analysis: What economics doesn't say about energy use. *J. Policy Anal. Manag.* 5:200–27
38. Harvey CM. 1994. The reasonableness of non-constant discounting. *J. Public Econ.* 53:31–51
39. Tversky A, Kahneman D. 1992. Advances in prospect theory: cumulative representation of uncertainty. *J. Risk Uncertain.* 5:297–323
40. Keeney RL. 1992. *Value-Focused Thinking: A Path to Creative Decision-making*. Cambridge, MA: Harvard Univ. Press. 416 pp.
41. Tversky A, Kahneman D. 1974. Judgment under uncertainty: heuristics and biases. *Science* 185:1124–31
42. Ariely D, Loewenstein G, Prelec D. 2003. Coherent arbitrariness: stable demand curves without stable preferences. *Q. J. Econ.* 118:73–106
43. Baron J. 2004. *Thinking and Deciding*. Cambridge, UK: Cambridge Univ. Press
44. Kahneman D, Tversky A. 1979. Prospect theory: an analysis of decision under risk. *Econometrica* 47:263–92
45. Schwartz B. 2004. *The Paradox of Choice: Why More Is Less*. New York: HarperCollins.
46. Frey BS, Benz M, Stutzer A. 2004. Introducing procedural utility: not only what, but also how matters. *J. Inst. Theor. Econ.* 160:377–401
47. Thaler R. 1990. Anomalies: saving, fungibility and mental accounts. *J. Econ. Perspect.* 4:193–205

48. Shefrin HM, Thaler R. 2004. Mental accounting, saving, and self-control. See Ref. 196, pp. 395–428
49. Thaler R. 1999. Mental accounting matters. *J. Behav. Decis. Making* 12:183–206
50. Heath C, Soll JB. 1996. Mental budgeting and consumer decisions. *J. Consum. Res.* 23:40–52
51. Simon HA. 1956. Rational choice and the structure of environments. *Psychol. Rev.* 63:129–38
52. Gigerenzer G, Todd P. 1999. *Simple Heuristics that Make Us Smart*. Oxford: Oxford Univ. Press
53. Simon HA. 1997. *Empirically Grounded Economic Reason*. Cambridge, MA: MIT Press
54. Todd PM, Gigerenzer G. 2003. Bounding rationality to the world. *J. Econ. Psychol.* 24:143–65
55. Payne JW, Bettman JR, Johnson EJ. 1993. *The Adaptive Decision Maker*. Cambridge, UK: Cambridge Univ. Press
56. Finucane ML, Alhakami A, Slovic P, Johnson SM. 2000. The affect heuristic in judgments of risks and benefits. *J. Behav. Decis. Making* 13:1–17
57. Gilboa I, Schmeidler D. 1995. Case-based decision theory. *Q. J. Econ.* 110:605–39
58. Camerer C. 2004. Prospect theory in the wild: evidence from the field. See Ref. 196, pp. 148–61
59. Hoyer WD, MacInnis DJ. 2004. *Consumer Behavior*. New York: Houghton Mifflin
60. Simonson I. 1993. Get closer to your customers by understanding how they make choices. *Calif. Manag. Rev.* 35:68–84
61. Paul Peter J, Olsen JC. 2005. *Consumer Behavior and Marketing Strategy*. New York: McGraw-Hill
62. Hawkins DL, Best RJ, Coney EA. 2004. *Consumer Behavior: Building Marketing Strategy.* New York: McGraw-Hill
63. Knight RL, Lutzenhiser L, Lutzenhiser S. 2006. *Why comprehensive residential energy efficiency retrofits are undervalued*. Presented at ACEEE Summer Study Energy Effic. Build., Asilomar, CA
64. Fischhoff B. 2005. Decision research strategies. *Health Psychol.* 24:S9–16
65. Sunstein CR, Thaler R. 2003. *Libertarian paternalism is not an oxymoron.* Work. Pap. 03-2, AEI-Brookings Jt. Cent. Regul. Stud., Washington, DC
66. Camerer C, Issacharoff S, Loewenstein G, O'Donoghue T, Rabin M. 2003. Regulation for conservatives and the case for "asymmetric paternalism"? *Univ. Pennsylvania Law Rev.* 151:1211–54
67. Moxnes E. 2004. Estimating customer utility of energy efficiency standards for refrigerators. *J. Econ. Psychol.* 25:707–24
68. Brennan TJ. 2007. Consumer preference not to choose: methodological and policy implications. *Energy Policy* 35:1616–27
69. Dawnay E, Shah H. 2005. *Behavioural economics: seven principles for policy-makers*, New Econ. Found., London, UK. **http://www.neweconomics.org/gen/uploads/tfi0ypn1141p45zoi0mrrgf222092005201739.pdf**
70. Halpern D, Bates C, Mulgan G, Aldridge S. 2004. *Personal responsibility and changing behaviour: the state of knowledge and its implications for public policy*, Prime Minister's Strategy Unit Cabinet Off., London, UK
71. McCalley LT. 2006. From motivation and cognition theories to everyday applications and back again: the case of product-integrated information and feedback. *Energy Policy* 34:129–37

72. Rogers EM. 2004. A prospective and retrospective look at the diffusion model. *J. Health Commun.* 9:13–19
73. Rogers EM. 2003. *Diffusion of Innovations*. New York: Free
74. Tornatzky LG, Klein KJ. 1982. Innovation characteristics and adoption-implementation: a meta-analysis of findings. *IEEE Trans. Eng. Manag.* 29:28–45
75. Moore GC, Benbast I. 1991. Development of an instrument to measure the perceptions of adopting an information technology innovation. *Inf. Syst. Res.* 2:192–220
76. Darley JM, Beniger JR. 1981. Diffusion of energy-conserving innovations. *J. Soc. Issues* 37:150–71
77. Brown MA. 1984. Change mechanisms in the diffusion of residential energy conservation practices: an empirical study. *Technol. Forecast. Soc. Change* 25:123–38
78. Dennis M, Soderstron EJ, Koncinski WS, Cavanaugh B. 1990. Effective dissemination of energy-related information: applying social psychology and evaluation research. *Am. Psychol.* 45:1109–17
79. Farhar BC, Coburn TC. 2000. A market assessment of residential grid-tied PV systems in Colorado. *Rep. NREL/TP-550-28872*, Natl. Renew. Energy Lab., Golden, CO
80. Becker LJ, Seligman C, Fazio RH, Darley JM. 1981. Relating attitudes to residential energy use. *Environ. Behav.* 13:590–609
81. Archer D, Pettigrew T, Constanzo M, Iritani B, Walker I, White L. 1987. Energy conservation and public policy: the mediation of individual behavior. In *Energy Efficiency: Perspectives on Individual Behavior*, ed. W Kempton, M Neiman, pp. 69–92. Washington, DC: Am. Counc. Energy-Effic. Econ.
82. Dietz T, Stern PC. 2002. *New Tools for Environmental Protection: Education, Information and Voluntary Measures*. Washington, DC: Natl. Acad.
83. Schultz PW. 1999. Changing behavior with normative feedback interventions: a field experiment of curbside recycling. *Basic Appl. Soc. Psychol.* 21:25–36
84. Valente TW, Schuster DV. 2002. The public health perspective for communicating environmental issues. See Ref. 82, pp. 105–24
85. Gardner GT, Stern PC. 1996. *Environmental Problems and Human Behavior*. Boston, MA: Allyn & Bacon
86. Festinger L. 1957. *The Theory of Cognitive Dissonance*. Stanford, CA: Stanford Univ. Press
87. Festinger L, Schachter S, Gazzaniga M. 1989. *Extending Psychological Frontiers: Selected Works of Leon Festinger*. New York: Russell Sage Found.
88. Pallak MS, Cook DA, Sullivan JJ. 1980. Commitment and energy conservation. In *Applied Social Psychology Annual*, ed. L Bickman, pp. 235–54. Beverley Hills, CA: Sage
89. Fishbein M, Ajzen I. 1975. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*. Reading, MA: Addison-Wesley
90. Ajzen I. 1991. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50:179–211
91. Ajzen I, Madden TJ. 1986. Prediction of goal-directed behavior: attitudes, intentions, and perceived behavioral control. *J. Exp. Soc. Psychol.* 22:453–74
92. Armitage CJ, Conner M. 2001. Efficacy of the theory of planned behaviour: a meta-analytic review. *Br. J. Soc. Psychol.* 40:471–99
93. Kraus SJ. 1995. Attitudes and the prediction of behavior: a meta-analysis of the empirical literature. *Personal. Soc. Psychol. Bull.* 21:58–75
94. Bandura A. 1977. Self-efficacy: toward a unifying theory of behavioral change. *Psychol. Rev.* 84:191–215
95. Bandura A. 1991. Social cognitive theory of self-regulation. *Organ. Behav. Hum. Decis. Process.* 50:248–87

96. Becker LJ. 1978. The joint effect of feedback and goal-setting on performance: a field study of residential energy conservation. *J. Appl. Psychol.* 63:428–33
97. McGuire WJ. 1989. Theoretical foundations of campaigns. In *Public Communication Campaigns*, ed. RE Rice, CK Atkin, pp. 43–65. Newbury Park, CA: Sage
98. Olsen ME. 1981. Consumers' attitudes toward energy conservation. *J. Soc. Issues* 37:108–31
99. DiClemente CC, Prochaska JO. 1982. Self change and therapy change of smoking behavior: a comparison of processes of change in cessation and maintenance. *Addict. Behav.* 7:133–42
100. Prochaska JO, DiClemente CC, Norcross JC. 1992. In search of how people change: applications to addictive behaviors. *Am. Psychol.* 47:1102–14
101. Green LW, Kreuter M. 1999. *Health Promotion Planning: An Educational and Ecological Approach*. Mountain View, CA: Mayfield. 506 pp.
102. Faiers A, Neame C. 2006. Consumer attitudes towards domestic solar power systems. *Energy Policy* 34:1797–806
103. Moore G. 2002. *Crossing the Chasm*. New York: Harper Collins
104. Egmond C, Jonkers R, Kok G. 2006. One size fits all? Policy instruments should fit the segments of target groups. *Energy Policy* 34:3464–74
105. Darby S. 2006. Social learning and public policy: lessons from an energy-conscious village. *Energy Policy* 34:2929–40
106. Jager W. 2006. Stimulating the diffusion of photovoltaic systems: a behavioural perspective. *Energy Policy* 34:1935–43
107. Kaplan AW. 1999. From passive to active about solar electricity: innovation decision process and photovoltaic interest generation. *Technovation* 19:467–81
108. Hanson M, Bernstein M, Hammon R. 2006. *The role of energy efficiency in homebuying decisions: results of initial focus group discussions*. Presented at ACEEE Summer Study Energy Effic. Build., Asilomar, CA
109. McKenzie-Mohr D, Smith W. 1999. *Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing*. Gabriola Island, BC, Can.: New Society
110. Schultz PW. 2002. Knowledge, information, and household recycling: examining the knowledge-deficit model of behavior change. See Ref. 82, pp. 67–82
111. Kempton W, Darley JM, Stern PC. 1992. Psychological research for the new energy problems: strategies and opportunities. *Am. Psychol.* 47:1213–23
112. Stern PC. 1985. *Energy Efficiency in Buildings: Behavioral Issues*. Washington, DC: Natl. Acad.
113. Stern PC, Aronson E, Darley JM, Hill DH, Hirst E, et al. 1986. The effectiveness of incentives for residential energy conservation. *Eval. Rev.* 10:147–76
114. Katzev RD, Pardini AU. 1987. The comparative effectiveness of reward and commitment approaches in motivating community recycling. *J. Environ. Syst.* 17:93–113
115. Kempton W, Montgomery L. 1982. Folk quantification of energy. *Energy* 7:817–27
116. Yates SM, Aronson E. 1983. A social psychological perspective on energy conservation in residential buildings. *Am. Psychol.* 38:435–44
117. Craig CS, McCann JM. 1978. Assessing communication effects on energy conservation. *J. Consum. Res.* 5:82–88
118. Farhar BC, Buhrmann J. 1998. Public response to residential grid-tied PV systems in Colorado: a qualitative market assessment. *Rep. NREL/TP-550-24004*, Natl. Renew. Energy Lab., Golden, CO
119. Katzev RD, Johnson TR. 1987. *Promoting Energy Conservation*. Boulder, CO: Westview

120. Farhar BC, Fitzpatrick C. 1989. Effects of feedback on residential electricity consumption: a literature review. *Rep. SERI/TR-254-3386*, Solar Energy Res. Inst., Golden, CO
121. Stern PC, Gardner GT. 1981. Psychological research and energy policy. *Am. Psychol.* 36:329–42
122. Constanzo M, Archer D, Aronson E, Pettigrew T. 1986. Energy conservation behavior: the difficult path from information to action. *Am. Psychol.* 41:521–28
123. Seligman C, Becker LJ, Darley JM. 1978. Behavioral approaches to residential energy conservation. *Energy Build.* 1:325–37
124. McMakin AH, Malone E, Lundgren RE. 2002. Motivating residents to conserve energy without financial incentives. *Environ. Behav.* 34:848–63
125. Benders R, Kok R, Moll HC, Wiersma G, Noorman KJ. 2006. New approaches for household energy conservation: in search of personal household energy budgets and energy reduction options. *Energy Policy* 34:3612–22
126. King C, Chatterjee S. 2003. Predicting California demand response. *Public Util. Fortn.* 141:27–32
127. Herter K, McAuliffe P, Rosenfeld A. 2007. An exploratory analysis of California residential customer response to critical peak pricing of electricity. *Energy* 32:25–34
128. Olli E, Grendstad G, Wollebaek D. 2001. Correlates of environmental behavior: bringing back social context. *Environ. Behav.* 33:181–208
129. Kollmuss A, Agyeman M. 2002. Mind the gap: Why do people act environmentally, and what are the barriers to proenvironmental behavior? *Environ. Edu. Res.* 3:239–60
130. Hines JM, Hungerford HR, Tomera AN. 1987. Analysis and synthesis of research on responsible environmental behavior: a meta-analysis. *J. Environ. Edu.* 18:1–18
131. Schultz PW, Oskamp S. 1996. Effort as a moderator of the attitude-behavior relationship: general environmental concern and recycling. *Soc. Psychol. Q.* 59:375–83
132. Gatersleben B, Steg L, Vlek C. 2002. Measurement and determinants of environmentally significant consumer behavior. *Environ. Behav.* 34:335–62
133. Poortinga W, Steg L, Vlek C. 2004. Values, environmental concern, and environmental behavior: a study into household energy use. *Environ. Behav.* 36:70–93
134. Black JS, Stern PC, Elworth JT. 1985. Personal and contextual influences on household energy adaptations. *J. Appl. Psychol.* 70:3–21
135. Guerin GA, Yust BL, Coopet JG. 2000. Occupant predictors of household energy behavior and consumption change as found in energy studies since 1975. *Fam. Consum. Sci. Res. J.* 29:48–80
136. Dietz T, Stern PC, Guagnano GA. 1998. Social structure and social psychological bases of environmental concern. *Environ. Behav.* 30:450–71
137. Stern PC, Dietz T, Abel T, Guagnano GA, Kalof L. 1999. A value-belief-norm theory of support for social movements: the case of environmental concern. *Hum. Ecol. Rev.* 6:81–97
138. Rokeach M. 1973. *The Nature of Human Values*. New York: Free
139. Schwartz SH. 1973. Normative explanations of helping behavior: a critique, proposal, and empirical test. *J. Exp. Soc. Psychol.* 9:349–64
140. Schwartz SH. 1977. Normative influences on altruism. In *Advances in Experimental Social Psychology*, ed. L Berkowitz, pp. 221–79. New York: Academic
141. Thogerson J, Olander F. 2006. To what degree are environmentally beneficial choices reflective of a general conservation stance? *Environ. Behav.* 38:550–69
142. Kaplan S. 2000. Human nature and environmentally-responsible behavior. *J. Soc. Issues* 56:491–508

143. Dietz T, Fitzgerald A, Shwom R. 2005. Environmental values. *Annu. Rev. Environ. Resour.* 30:335–72
144. Newhouse N. 1991. Implications of attitude and behavior research for environmental conservation. *J. Environ. Edu.* 22:26–32
145. Gatersleben B, Steg L, Vlek C. 2002. Measurement and determinants of environmentally significant consumer behavior. *Environ. Behav.* 34:335–62
146. Guagnano GA, Stern PC, Dietz T. 1995. Influences on attitude-behavior relationships: a natural experiment with curbside recycling. *Environ. Behav.* 27:699–718
147. Heberlein TA, Warriner GK. 1983. The influence of price and attitude on shifting residential electricity consumption from on- to off-peak periods. *J. Econ. Psychol.* 4:107–30
148. Olander F, Thogerson J. 1995. Understanding of consumer behaviour as a prerequisite for environmental protection. *J. Consum. Policy* 18:345–85
149. Stern PC. 1999. Information, incentives, and proenvironmental consumer behavior. *J. Consum. Policy* 22:461–78
150. Stern PC. 2000. Toward a coherent theory of environmentally significant behavior. *J. Soc. Issues* 56:523–30
151. Stern PC. 2000. Psychology and the science of human-environment interactions. *Am. Psychol.* 55:523–30
152. Deleted in proof
153. Oskamp P. 2000. Psychological contributions to achieving a sustainable future for humanity. *J. Soc. Issues* 56:373–90
154. McKenzie-Mohr D. 2000. Promoting sustainable behavior: an introduction to community-based social marketing. *J. Soc. Issues* 56:543–54
155. Parker P, Rowlands IH, Scott D. 2003. Innovations to reduce residential energy use and carbon emissions: an integrated approach. *Can. Geogr.* 47:169–84
156. Boonekamp PGM. 2006. Actual interaction effects between policy measures for energy efficiency: a qualitative matrix method and quantitative simulation results for households. *Energy* 31:2848–73
157. Summerton J. 1992. *District Heating Comes to Town: The Social Shaping of an Energy System*. Linkoping, Swed.: Fac. Arts Sci., Linkoping Univ.
158. Wilhite H, Shove E, Lutzenhiser L, Kempton W. 2000. The legacy of twenty years of energy demand management: We know more about individual behaviour but next to nothing about demand. See Ref. 195, pp. 109–26
159. Shove E. 2003. *Comfort, Cleanliness, and Convenience: The Social Organisation of Normality*. Oxford, UK: Berg
160. Van Vliet B, Chappells H, Shove E. 2005. *Infrastructures of Consumption: Environmental Innovation in the Utilities Industries*. London, UK: Earthscan
161. Lutzenhiser L. 2002. Marketing household energy conservation: the message and the reality. See Ref. 82, pp. 49–65
162. Shove E. 1998. Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. *Energy Policy* 26:1105–12
163. Shove E, Lutzenhiser L, Guy S, Hackett B, Wilhite H. 1998. Energy and social systems. In *Human Choice and Climate Change*, ed. S Raynor, E Malone, pp. 291–326. Columbus, OH: Batelle
164. Kempton W, Lutzenhiser L. 1992. Introduction. *Energy Build.* 18:171–76
165. US EIA. 2001. *Residential Energy Consumption Survey. Tables HC4: Air-Conditioning*. US Energy Inf. Adm., Washington, DC. **http://www.eia.doe.gov/emeu/recs/recs2001/detail_tables.html**

166. IEA. 2004. *Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries*, Int. Energy Agency, Paris, Fr.
167. Wilhite H, Lutzenhiser L. 1999. Social loading and sustainable consumption. *Adv. Consum. Res.* 26:281–87
168. Henning A. 2005. Climate change and energy use: the role for anthropological research. *Anthropol. Today* 21:8–13
169. Wilhite HL, Wilk R. 1987. A method for self-recording household energy-use behavior. *Energy Build.* 10:73–79
170. Lutzenhiser L, Lutzenhiser S. 2006. *Looking at lifestyle: the impacts of American ways of life on energy/resource demands and pollution patterns*. Presented at ACEEE Summer Study Energy Effic. Build., Asilomar, CA
171. Wilhite H. 2005. Why energy needs anthropology. *Anthropol. Today* 21:1–2
172. EPRI. 1990. Residential customer preference and behavior: market segmentation using CLASSIFY. *Rep. EM-5908*, Electr. Power Res. Inst., Palo Alto, CA
173. Bin S, Dowlatabadi H. 2005. Consumer lifestyle approach to US energy use and the related CO_2 emissions. *Energy Policy* 33:197–208
174. Reinders AHME, Vringer K, Blok K. 2003. The direct and indirect energy requirement of households in the European Union. *Energy Policy* 31:139–53
175. Weber C, Perrels A. 2000. Modelling lifestyle effects on energy demand and related emissions. *Energy Policy* 28:549–66
176. Nader L, Beckerman S. 1978. Energy as it relates to the quality and style of life. *Annu. Rev. Energy* 3:1–28
177. Mazur A, Rosa E. 1974. Energy and life-style. *Science* 186:607–10
178. Schipper L, Bartlett S, Hawk D, Vine E. 1989. Linking life-styles and energy use: a matter of time? *Annu. Rev. Energy* 14:273–320
179. Schipper L, Unander F, Murtishaw S, Ting M. 2001. Indicators of energy use and carbon emissions: Explaining the energy economy link. *Annu. Rev. Energy Environ.* 26:49–81
180. Lovins AB, Kyle Datta E, Feiler T, Rábago KR, Swisher JN, et al. 2003. *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*. Snowmass, CO: Rocky Mountain Inst.
181. Swart RJ, Raskin P, Robinson J. 2004. The problem of the future: sustainability science and scenario analysis. *Glob. Environ. Change Part A* 14:137–46
182. Skumatz LA, Dickerson CA, Coates B. 2000. *Non-energy benefits in the residential and nonresidential sectors—innovative measurements and results for participant benefits*. Presented at ACEEE Summer Study Energy Effic. Build., Asilomar, CA
183. Abell P. 2003. On the prospects for a unified social science: economics and sociology. *Socio-Econ. Rev.* 1:1–26
184. Wirl F. 2000. Lessons from utility conservation programs. *Energy J.* 21:87–108
185. Loughran DS, Kulick J. 2004. Demand-side management and energy efficiency in the united states. *Energy J.* 25:19–43
186. Keirstead J. 2006. Evaluating the applicability of integrated domestic energy consumption frameworks in the UK. *Energy Policy* 34:3065–77
187. Buchanan JM. 1994. Choosing what to choose. *J. Inst. Theor. Econ.* 150:123–44
188. McDaniels TL, Dowlatabadi H, Stevens S. 2005. Multiple scales and regulatory gaps in environmental change: the case of salmon aquaculture. *Glob. Environ. Change* 15:9–21
189. Dillman DA, Rosa EA, Dillman JJ. 1983. Lifestyle and home energy conservation in the United States: The poor accept lifestyle cutbacks while the wealthy invest in conservation. *J. Econ. Psychol.* 3:299–315

190. Parker P, Rowlands I, Scott D. 2005. Who changes consumption following residential energy evaluations? Local programs need all income groups to achieve Kyoto targets. *Local Environ.* 10:173–87
191. Holling CS. 1978. *Adaptive Environmental Assessment and Management*. London, UK: Wiley
192. Fischhoff B. 2005. Cognitive processes in stated preference methods. In *Handbook of Environmental Economics*, ed. K-G Maler, JR Vincent, pp. 937–68. Amsterdam, Neth.: Elsevier
193. Lichtenstein S, Slovic P, eds. 2006. *The Construction of Preference*. Cambridge, UK: Cambridge Univ. Press
194. Gregory R, Lichtenstein S, Slovic P. 1993. Valuing environmental resources: a constructive approach. *J. Risk Uncertain.* 7:177–97
195. Jochem E, Sathaye J, Bouille D, eds. 2000. *Society, Behaviour, and Climate Change Mitigation*. Dordrecht, Neth.: Kluwer Acad.
196. Camerer C, Loewenstein G, Rabin M, eds. 2004. *Advances in Behavioral Economics*. Princeton, NJ: Princeton Univ. Press

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