Contributions of Psychology to Limiting Climate Change

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Psychology can make a significant contribution to limiting the magnitude of climate change by improving understanding of human behaviors that drive climate change and human reactions to climate-related technologies and policies, and by turning that understanding into effective interventions. This article develops a framework for psychological contributions, summarizes what psychology has learned, and sets out an agenda for making additional contributions. It emphasizes that the greatest potential for contributions from psychology comes not from direct application of psychological concepts but from integrating psychological knowledge and methods with knowledge from other fields of science and technology.

Keywords: climate change, energy consumption, environmentally significant behavior, behavioral change

As has been amply documented elsewhere, the processes of global climate change that have been increasingly observed in recent decades are driven largely by human activities (Intergovernmental Panel on Climate Change, 2007; National Research Council, 2010a). The human activities that directly produce physical changes in Earth's heat balance, such as burning fossil fuels, clearing forests, and raising cattle, are driven in turn by other human activities, including government policies, the growth and migration of human populations, economic and technological development, and the behavior of individuals and households as consumers, members of organizations, and citizens. These actions are influenced in turn by human attitudes, predispositions, beliefs, and social and economic structures (National Research Council, 1992; Swim et al., 2011, this issue). This article discusses what psychology has contributed and can contribute to limiting the magnitude of climate change by altering the human activities that affect it.

A Framework for Psychological Contributions

Psychology can contribute to limiting climate change by improving understanding of climate-relevant individual, household, and organizational behaviors that affect climate change and the many personal, social, economic, institutional, policy, and social-structural factors that affect these behaviors, as well as by helping devise ways to turn that understanding into effective interventions. Most of the efforts of psychologists, and most of this review, focus on consumer behaviors. These can be conveniently divided into choices that affect emissions of greenhouse gases directly through household purchases of energy and choices that affect emissions indirectly through the purchase of goods and services that affect the climate through their production, distribution, and disposal. This article focuses mainly on the direct effects because they are large (about 40% of carbon dioxide emissions in the United States; Bin & Dowlatabadi, 2005) and because more is known about the behavioral factors that drive those emissions. It also briefly discusses psychological factors in organizational behavior and in acceptance of policies and technologies.

Behavior Versus Impact

Although psychologists understandably focus on behavior, some behaviors are more important than others in terms of their impact on the physical processes of climate change. The impact of human actions on climate is normally quantified in terms of radiative forcing or global warming potential, which is often measured in units of carbon dioxide equivalent because carbon dioxide emissions are by far the largest forcing factor in climate change (Forster et al., 2007). Individual and household action in the United States has a larger aggregate climate impact than any other economic sector: As much as 38% of carbon dioxide emissions result from direct energy use by households, mainly in homes and for nonbusiness travel (Gardner & Stern, 2008; U.S. Energy Information Administration, 2007), and a large additional share results from indirect energy use through purchases of nonenergy goods and services that take energy to produce and distribute (Bin & Dowlatabadi, 2005). The most important household activities in terms of direct energy use and emissions, and therefore the most important targets for emissions reduction, are motor vehicle use and space heating (Gardner & Stern, 2008).

The impact of any behavioral change that might limit climate change can be expressed by the following equation:

$$I = tpn,$$

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Except where noted, the statements in this article are my own and do not represent conclusions from the National Research Council.

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where *I* is impact; *t* is technical potential, or the reduction in emissions or climate forcing from the particular action; *p* is the behavioral plasticity of the action, or the proportion of people, households, or organizations that could be induced to take the target action; and *n* is the total number of these actors that could possibly take the action. Behavioral science understandably focuses mainly on *p*; however, in setting policy priorities, *t* and *n* are critical to take into account because they determine the practical impact of any behavioral change that is achieved.

The potential for reducing carbon emissions through behavioral change at the household level is sufficient to yield a major effect on national emissions if well-designed interventions are scaled up nationally. Dietz, Gardner, Gilligan, Stern, and Vandenbergh (2009) estimated that scaling up the most effective documented nonregulatory interventions could reduce carbon emissions from household direct energy use by 20% in 10 years—a total of over 120 million metric tons of carbon in the 10th year, or more than the entire emissions of France in 2005. The potential impact varies greatly, however, across behaviors. Table 1 shows estimates of the potential carbon dioxide emissions reductions that would be achieved in Year 10 by applying the most effective interventions to 17 types of behavior.

Several points are worth making about these estimates. First, the potential impact of behaviors that involve adoption of energy-efficient equipment—those listed in the top half of the table—is considerably larger than that of changes in the use of equipment—the bottom half of the table. This is particularly the case when plasticity is taken into account, because high levels of plasticity have never been demonstrated for the use behaviors. Apparently, these behaviors are not easy to change—much like health-related behaviors such as those involving diet and smoking (Abroms & Maibach, 2008; Snyder et al., 2004). Related to this point, achieving the estimated savings requires serious policy interventions. There is no evidence that plasticity anywhere near the levels listed in the table has been achieved by exhortation or information alone, in spite of many well-meaning efforts to offer people tips on "green" behavior. As Kermit the Frog famously said, "It's not easy being green." Well-designed policies and programs can make it easier.

Still, these estimates do not represent an upper limit of what household behavior can accomplish. Even greater savings can be achieved if households adopt lower carbon technologies than those presumed by these estimates or if interventions can yield greater plasticity than has so far been documented. Moreover, additional reductions are possible by changing household behaviors that produce emissions indirectly through the production, distribution, and disposal of food, building materials, and consumer products and services.

Policy Interventions and Their Behavioral Assumptions

One useful typology of interventions to influence energy-consuming behavior distinguishes five types (Kaufmann-Hayoz & Gutscher, 2001): command and control (e.g., environmental regulations, appliance and vehicle fuel efficiency standards); economic instruments (e.g., energy taxes, solar energy tax credits); changes in infrastructure (e.g., new energy-efficient technology, mass transit, zero net energy building design); institutional arrangements (e.g., establishing markets for emission permits, certification or labeling systems, public–private agreements); and communication and diffusion methods (e.g., providing information, persuasion, advertising, person-to-person contact).

These policy approaches embody implicit theories of behavior change (that people can be counted on to follow regulations or institutional rules and norms, that they do what is economically most advantageous, that useful technologies are readily adopted, etc.). Policies are often formulated on the basis of implicit assumptions that one or another of these theories adequately captures behavioral reality. Although the theories all contain grains of truth, none is nearly complete, and they can mislead (see, e.g., Lutzenhiser et al., 2009; Stern, 1986; Wilson & Dowlatabadi, 2007). For example, economic policy instruments such as energy price increases or financial incentives for investing in energy-efficient appliances or motor vehicles reliably change behavior in the expected directions, but the effect is usually much smaller than economic models predict. This so-called energy efficiency gap (Jaffe & Stavins, 1994)—the difference between actual behavior and what a principle of long-term cost minimization would dictate—is quite large (Creyts, Derkach, Nyquist, Ostrowski, & Stephenson, 2007) and also varies widely with the behavior (e.g., which appliance is being purchased; Ruderman, Levine, & McMahon, 1987).

Policymakers increasingly recognize that the dominant physical-technical-economic model of energy use is

Table 1
Reasonably Achievable Carbon Emission Reduction (RAER) From 17 Household Actions in Year 10 After Introduction of Interventions

Behavior change[a]	Technical potential reduction (MTC)[b]	Behavioral plasticity (%)	RAER (MTC)[c]	RAER (% I/H)[d]
Equipment adoption				
Weatherization	25.2	90	21.2	3.39
HVAC equipment	12.2	80	10.7	1.72
Low-flow showerheads	1.4	80	1.1	0.18
Efficient water heater	6.7	80	5.4	0.86
Appliances	14.7	80	11.7	1.87
Low rolling resistance tires	7.4	80	6.5	1.05
Fuel-efficient vehicle	56.3	50	31.4	5.02
Subtotal	123.9		88.0	14.09
Equipment use				
Change HVAC air filters	8.7	30	3.7	0.59
Tune up air conditioning	3.0	30	1.4	0.22
Routine auto maintenance	8.6	30	4.1	0.66
Laundry temperature	0.5	35	0.2	0.04
Water heater temperature	2.9	35	1.0	0.17
Standby electricity	9.2	35	3.2	0.52
Thermostat setbacks	10.1	35	4.5	0.71
Line drying	6.0	35	2.2	0.35
Driving behavior	24.1	25	7.7	1.23
Carpooling and trip-chaining	36.1	15	6.4	1.02
Subtotal	109.2		34.4	5.51
Total	233		123	20

Note. HVAC = heating, ventilating, and air conditioning. Adapted from "Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce US Carbon Emissions," by T. Dietz, G. T. Gardner, J. Gilligan, P. C. Stern, & M. P. Vandenbergh, 2009, *Proceedings of the National Academy of Sciences, USA, 106,* p. 18453. Copyright 2009 by National Academy of Sciences of the United States of America.
[a] For precise definitions of the behaviors, see Dietz et al. (2009). [b] Emissions reduction that would be achieved if all households that have not taken the action adopted it, corrected for double counting (e.g., changes in thermostat settings have a smaller effect if the household has also added insulation) and measured in millions of metric tons of carbon (MTC). [c] Reduction in national CO_2 emissions in Year 10 due to the behavioral change from plasticity, corrected for double counting and expressed in MTC saved per year. [d] Reduction in national CO_2 emissions in Year 10 due to the behavioral change from plasticity, corrected for double counting and expressed as a percentage of total U.S. individual/household sector emissions (% I/H).

incomplete, and they are turning to behavioral scientists for better conceptual models and for advice on how to implement them to make policies and programs more effective (Darnton, 2008; Lutzenhiser et al., 2009; Wilson & Dowlatabadi, 2007). Psychology can help by elucidating other processes underlying choice, as noted below.

Realistic behavioral models for individual behavior show how internal factors (e.g., knowledge, feelings, values, attitudes) and external factors (physical and technological infrastructure; political, social, and cultural factors; economic incentives) combine to affect environmentally significant behavior (e.g., Black, Stern, & Elworth, 1985; Gardner & Stern, 2002; Guagnano, Stern, & Dietz, 1995; Kollmuss & Agyeman, 2002). For organizational and collective behavior, models may explicate the conditions under which organizations will undertake investments in energy efficiency (National Research Council, 2010b) or groups will fall prey to the commons dilemma (e.g., Kopelman, Weber, & Messick, 2002).

Psychological research can help improve on standard policy models by showing empirically how the effects of policy interventions depend on social influences on behavior, features of the policies or programs, and characteristics of the target actors, including their values, beliefs, and cognitive, affective, and motivational processes. It can increase the practical usefulness of empirical analyses by replacing simplistic assumptions with empirically supported ones (Gardner & Stern, 2002; Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008; Stern, 1986) and by uncovering important opportunities for intervention that have not been revealed by the dominant policy theories, as is discussed further below.

Individual and Household Behavior: What Psychology Has Learned

A body of research since the 1970s has focused specifically on developing and testing theories of environmentally significant behavior (ESB), sometimes referred to as pro-environmental behavior (PEB) (Darnton, 2008; Gardner & Stern, 2002; Geller, Winett, & Everett, 1982; Gifford, 2008; Stern, 2000a; Stern & Gardner, 1981; Wilson &

Dowlatabadi, 2007). ESB includes all actions with environmental consequences; PEB refers only to actions with beneficial environmental effects, so it is a term often used in studies aimed at inducing such behavior.

One stream of psychological research emphasizes individualistic motives and presumes that individuals maximize their material welfare, subjective well-being, or utility. Early psychological research in this mode applied operant conditioning theory to household energy use (e.g., Geller et al., 1982). More recently, psychologists have applied the theory of reasoned action, later developed into the theory of planned behavior (Ajzen, 1991; Ajzen & Fishbein, 1975, 1980). Another stream proceeds from the observation that the global environment is a commons in which pro-environmental actions generally present greater costs than benefits to the individual (e.g., Kopelman et al., 2002). Researchers in this stream sometimes suggest that factors beyond individualism may be necessary to engage such behavior. These include environmental consciousness (e.g., the new ecological paradigm; Dunlap & Van Liere, 1978; Dunlap, Van Liere, Mertig, & Jones, 2000), prosocial moral norms (Schwartz, 1977), normative goal frames (Lindenberg & Steg, 2007), self-transcendent values (Schwartz, 1992; for an application to ESB, see the value-belief-norm theory proposed by Stern, Dietz, Abel, Guagnano, & Kalof, 1999), and social value orientation (e.g., Van Lange, 1999; Van Lange & Joireman, 2008). These two perspectives are not mutually exclusive. Some definitions of utility are expansive enough to include internalized altruistic concerns. In fact, a recent meta-analysis found that variables from both types of theories had unique explanatory value across a set of ESBs (Bamberg & Möser, 2007).

Other psychological research has emphasized yet other determinants of behavior. Some examines social comparison and other social normative influences (Cialdini, 2003; Goldstein, Griskevicius, & Cialdini, 2007; Schultz, Khazian, & Zaleski, 2008). Other studies focus on stages of intentional behavioral change (e.g., precontemplation, contemplation, preparation, action, maintenance, termination; see Prochaska & Velicer, 1997). Other lines of research apply social network and innovation-diffusion theories that describe how ideas and actions spread through populations (e.g., Darley, 1978; Rogers, 2003), model processes of change in habits (Hobson, 2003; Maio et al., 2007), and elaborate systems theories that model transformational and incremental changes that may often be prompted by encountering problems (Darnton, 2008).

Much research has treated ESB as a uniform class of actions, perhaps implicitly assuming that the same determinants apply to all ESB. In support of this view, there is evidence of commonality among many ESBs (e.g., Kaiser, 1998; Kaiser & Gutscher, 2003; Kaiser, Wölfing, & Fuhrer, 1999). However, considerable evidence also points to the value of distinguishing subclasses of ESB that have different determinants (e.g., Black et al., 1985; Stern, 2000b). The following sections distinguish three topics that have been studied separately: (a) the determinants of aggregate environmentally significant consumption (ESC) by households; (b) the determinants of variation in adoption of ESBs, particularly behaviors of individuals and households that reduce greenhouse gas emissions; and (c) responses to interventions designed to change these behaviors. The available evidence suggests that these distinctions matter in the sense that psychological constructs that are enlightening in one area may have little explanatory value in others.

Determinants of Environmentally Significant Consumption

ESC differs from ESB in that the former is measured in units of environmental impact, whereas the latter is measured in units of action (Stern, 1997). Also, ESB includes not only consumer actions but also citizenship behaviors, such as support for environmental policies (Stern, 2000b). ESC is the aggregation, across environmentally significant consumer behaviors, of a measure of impact, such as carbon dioxide emissions. The best predictors of total ESC (e.g., energy use) in households, absent interventions, are nonpsychological factors such as household income, size, life cycle stage, and geographic location, which in turn affect other major determinants of overall consumption, such as home size and ownership of motor vehicles and appliances (Gatersleben, Steg, & Vlek, 2002; Hunecke, Haustein, Grischkat, & Böhler, 2007; Lutzenhiser & Hackett, 1993). Psychological factors can affect overall consumption levels—some households lead much "greener" lives than their neighbors because of strong environmental value commitments—but across population samples, these factors have had far less of an effect on overall consumption than have sociodemographic factors such as income and household size (Abrahamse & Steg, 2009).

Determinants of Environmentally Significant Behaviors

Various typologies of household ESB have been presented in the literature (e.g., Dietz et al., 2009; Gatersleben et al., 2002; Kempton, Darley, & Stern, 1992; Schahn & Holzer, 1990; Stern & Gardner, 1981). The most useful typology likely depends on the purpose of the analysis. In energy studies, a coarse distinction between the adoption of household equipment (homes, vehicles, appliances, and so forth) and the use of that equipment is important because the two types tend to differ systematically in their frequency, in the importance of financial cost in decisions involving them, and in other ways that are likely to affect the relative explanatory power of different psychological variables, as noted below. They differ psychologically in that reduced use (curtailment) tends to be perceived as involving sacrifice, whereas adoption of more energy-efficient technology does not. Moreover, the environmental impact of changes in adoption of equipment is generally greater than that of changes in use of the same equipment because of higher *t* (Gardner & Stern, 2002, 2008; Stern & Gardner, 1981) and *p* (Dietz et al., 2009). Nevertheless, psychological research has focused predominantly on use behaviors. This focus may reflect the relative ease of measurement of use behaviors, which is due partly to their greater frequency. Whatever the reason, behaviors that have the largest effects on a

household's carbon footprint, such as choices of home location and size, motor vehicles, and home heating and cooling equipment, have received very little attention in psychological research.

A great many studies have demonstrated the explanatory value of various psychological constructs for various climate-related behaviors. For example, a recent meta-analytic review of 57 data sets (Bamberg & Möser, 2007) found that pro-environmental behavioral intentions were strongly and independently predicted by perceived behavioral control, attitude, and personal moral norms. Effects on self-reported behaviors were indirect and weaker than effects on intentions. However, the review did not disaggregate types of behavior to allow examination of whether different factors affect different types of ESB or evaluation of which factors are most important in terms of the aggregate impact of ESB. Some research has attempted to develop models that can be used for an integrated analysis across multiple behavioral types (e.g., Black et al., 1985; Stern, Black, & Elworth, 1983) or that can incorporate multiple theoretical perspectives (e.g, Harland, Staats, & Wilke, 2007; Matthies, 2003; Wall, Devine-Wright, & Mill, 2007). Considering that some very important ESBs have rarely been studied, it is premature to draw conclusions about the relative importance of psychological variables or theories for explaining ESB generally.

There is evidence that the relative importance of psychological and psychosocial (sometimes called personal) variables is behavior specific. Black et al. (1985) presented evidence that personal normative beliefs about energy conservation, which had explanatory power with reference to lower cost energy-saving behaviors (e.g., resetting thermostats, adding weather stripping), were not associated with behaviors that are strongly constrained by household infrastructure, home ownership, and financial cost (e.g., adding attic insulation, replacing inefficient furnaces). Contextual constraints can also reduce the relevance of psychological factors by pushing behavior strongly in pro-environmental directions. Guagnano et al. (1995) found that personal normative factors explained the frequency of recycling behavior only among households for whom curbside pickup was not available; increasing the convenience of the behavior increased its prevalence but reduced the explanatory power of psychological factors. These lines of evidence suggest that psychological factors such as values, beliefs, and norms have the greatest explanatory power in niches where external constraints are weak in either direction, leaving behavior relatively unconstrained (Gardner & Stern, 2002). The issue remains open for further research. Psychological constructs are also relevant for understanding environmentally important citizenship actions, such as public support for, opposition to, and activism about energy technologies and environmental policies (see below).

In sum, many psychological constructs have been shown to have explanatory value for at least some ESBs. However, this fact does not demonstrate their explanatory value for aggregated differences in greenhouse gas (GHG) emissions among households. Many of the most GHG-intensive consumer behaviors have been little studied, and available evidence suggests that they are more strongly affected by contextual factors than by psychological ones. We do not yet know how much explanatory value psychological constructs can add in explaining these behaviors beyond the explanatory value of contextual variables. Thus, it is important for psychological research to expand its focus to include more studies of high-impact ESB and to examine the interface between psychological predictors and contextual constraints and opportunities.

Responses to Interventions

Environmental policy analyses most commonly focus on regulatory instruments, infrastructure and technology development, and financial incentives. By contrast, psychological research on interventions has focused mainly on communication and diffusion instruments, such as information and persuasive appeals, and secondarily on financial incentives.

Information. Communication and diffusion instruments, particularly persuasion campaigns and dissemination of information through the mass media on how to save energy or the environment, have long been popular—and usually ineffective—policy approaches. Information effects have been studied in residential energy consumption (e.g., Abrahamse, Steg, Vlek, & Rothengatter, 2005) and travel mode choice (e.g., Möser & Bamberg, 2008). Studies generally find that information can increase knowledge but has minimal effects on behavior (Gardner & Stern, 2002). However, some studies have demonstrated positive effects, sometimes even on the adoption of technology, from campaigns that take advantage of psychological knowledge about the framing of information. For example, by training energy auditors to use vivid, personalized messages and to frame energy choices as avoiding loss rather than achieving gain, Gonzales, Aronson, and Costanzo (1988) induced homeowners to take greater advantage of financial subsidies for home weatherization. Carbon labeling of consumer products, analogous to nutritional labeling of foods, is a promising informational strategy (Vandenbergh, Dietz, & Stern, in press).

There are unexplored possible applications of the cognitive psychology of equipment adoption choices. Consider that the added cost of more energy-efficient models of household equipment (vehicles, appliances, furnaces, cooling systems, etc.) could be considered as an investment that provides a financial return over the life of the equipment. If households compared the rate of return from such investments—often 10%–20% or more—to the returns from stocks or bank accounts, they might be more likely to put their money into such home equipment than they are now. An experiment of framing energy efficiency in this way does not seem to have been conducted.

Feedback. Immediate or frequent (e.g., daily) feedback about the amount or cost of energy used is a type of information that has yielded energy savings of 5%–12% in many studies of in-home energy use, with the savings often lasting six months or more (Fischer, 2008). A saving of 2.7% has been reported in a recent large-scale experimental trial (Allcott & Mullainathan, 2010). Effectiveness

is associated with feedback frequency, mode (direct monitoring vs. enhanced billing), and the combination of feedback with services such as tailored recommendations or motivational elements such as normative appeals (Ehrhardt-Martinez, Donnelly, & Laitner, 2010). Feedback is believed to be more effective than simple information provision because it is specific to the individual's situation and because its frequency facilitates learning how to achieve the savings. Its effectiveness may also be due to the fact that it is not purely an informational technique. As the behavioral psychologists who pioneered feedback research realized (e.g., Geller et al., 1982), feedback connects behavior more closely to its tangible rewards (financial consequences) by signaling material consequences immediately or daily, rather than with the delay characteristic of the typical monthly energy bill. Feedback changes behavior quickly, which suggests that its effects are probably achieved mainly by changes in the use of household equipment rather than by the adoption of more energy-efficient equipment. If this is true, the greatest potential impact from feedback probably lies in the areas of energy-smart driving and home heating and cooling (see Table 1).

Technological advances have made feedback much easier to provide than it was in the 1970s, making it much more practical as a large-scale policy option. In addition, feedback can be tied to specific pieces of equipment through such devices as miles-per-gallon monitors on automotive dashboards, in-line energy meters in appliance power cords, and "smart" utility meters. Human factors design of such new technologies for optimal effect is an obvious and potentially important practical use of psychological knowledge.

Social motives. Interventions employing social motives have included using "models" who demonstrate energy-conserving behavior (e.g., Aronson & O'Leary, 1983; Geller et al., 1982), using messages from friends (e.g., Darley, 1978), employing social marketing techniques (e.g., McKenzie-Mohr & Smith, 1999), and appealing to prosocial goals (Krantz & Kunreuther, 2007) or social norms (e.g., Cialdini, Reno, & Kallgren, 2004; Schultz et al., 2008). Such approaches have demonstrated effects in field experiments with frequently repeated energy-using actions, and they can potentiate feedback effects (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007), but they have rarely been studied as potential influences on the equipment adoption actions that account for large portions of household energy budgets.

Financial incentives. Psychologists and other researchers have also studied interventions that change financial incentives, for example, by time-of-use electricity pricing, rewards for reduced energy use, and financial incentives for investments in residential energy efficiency (e.g., Abrahamse et al., 2005; Heberlein & Warriner, 1983). Some of this work has improved on simple economic models that presume a constant response to changes in financial cost (i.e., price elasticity) regardless of their form or implementation by showing that price responses vary with the particular choice (e.g., which appliance is being purchased; Ruderman et al., 1987) and with the ways incentive programs are implemented. The form and structure of an incentive may, in fact, matter more than its size (Gallagher & Muehlegger, 2011; Stern et al., 1986). Household adoption of home weatherization measures in response to incentives commonly varies by a factor of 10 or more for the same incentive depending on program implementation (Stern et al., 1986). Among the nonfinancial factors that account for this variation are the strength of program marketing; the accessibility of actionable information on how to take advantage of the incentive and what benefits to expect; the convenience of the program (e.g., the degree to which it reduces cognitive burdens on households, such as those imposed by the need to find a competent contractor); and the extent to which a program provides for quality assurance for the products or services it is promoting (Gardner & Stern, 2002; Stern, Gardner, Vandenbergh, Dietz, & Gilligan, 2010).

Combined approaches. By far the most effective behavioral interventions in terms of reducing household carbon emissions have been those that combined financial incentives with nonfinancial features. Multipronged interventions that combined strong financial incentives, attention to customer convenience and quality assurance, and strong social marketing have led to plasticity of 20% or more in the first year of community home weatherization programs (Hirst, 1988).

The most effective interventions integrate program elements that might be considered psychological and nonpsychological. Stern et al. (2010) distilled six principles of program design from the research: prioritize high-impact actions, provide sufficient financial incentives, strongly market the program, provide credible information at points of decision, keep it simple, and provide quality assurance. Interventions seem to be far less effective when any of these principles is ignored. Thus, even though psychological manipulations may not be able to induce major change in high-impact behaviors by themselves, they can be valuable complements to programs that rely on financial incentives or other essentially nonpsychological policies—which also rarely produce major change by themselves.

The barriers to household behavioral change can vary with the behavior and the household. An obvious example is the initial cost of energy-efficient household equipment. The importance of this barrier depends on the initial cost of the equipment, household income, and the availability of financing or policies that lower the cost barrier. Depending on the type of behavior, barriers may relate to household income, size, and life cycle stage; geographical relationships between home and travel destinations; home ownership status; decision-relevant knowledge; and cognitive, affective, and personality factors. Behavioral research can help determine which of these differences matter most for changing which behaviors in which social, economic, and technological contexts or in particular target populations. Generally, the most effective interventions are tailored to address the barriers to change for the target individual or household. To design effective programs for a population means addressing all the significant barriers that matter in the target population. This is probably why it is important

to combine intervention strategies (Gardner & Stern, 2002; McKenzie-Mohr, 2000; Stern, 2008). Many of the shortcomings of policies based on only a single intervention type, such as technology, economic incentives, or regulation, may be surmountable if policy implementers make better use of psychological knowledge. Similarly, the shortcomings of communication and diffusion instruments can be addressed by combining them with other policy instruments. It is possible to plan effective interventions on the basis of the multiple-barriers principle combined with knowledge of the barriers operating within a target population, context, and behavior (e.g., Matthies & Hansmeier, 2008).

It is important to recognize certain major barriers to reducing energy use that are built into societal infrastructure—for instance, the unavailability of viable alternatives to private motor vehicles for daily transportation in many places and the sprawling style of urban development that makes it difficult to provide such alternatives. Changes in such structural barriers can take decades. Psychological research can be helpful in facilitating the changes by helping with the design of new communities or revitalized older, compact cities so as to attract people to live there and help induce them to do so in a manner consistent with the designers' goals. Useful insights can be drawn from community, organizational, and human factors psychology.

Organizational, Policy, and Cultural Change

Organizational Change

Only a few psychological studies so far have examined energy conservation in organizations (e.g., Daamen, Staats, Wilke, & Engelen, 2001; Matthies & Hansmeier, 2008; Siero, Bakker, Dekker, & Van Den Burg, 1996). It is often presumed that profit-making organizations reliably act on standard economic principles of choice. However, the extent to which this is the case remains an empirical question. A set of surveys of business managers by Johnson Controls, Inc. (2008) suggests that businesses have a more complex set of objectives than can be encompassed by simple models of profit maximization. For example, many managers report that they do not invest in energy efficiency improvements that have an expected rate of return of 30% per year because they set higher "hurdle rates" for those investments than for other investments, such as in product development, which they value more highly. This finding suggests that further behavioral studies of business decision making about energy use may reveal useful insights that could inform the design of energy efficiency programs by addressing nonfinancial barriers to action.

Concepts of organizational behavior can suggest useful hypotheses to examine. The greening of business can be a matter of organizational leadership, assignment of responsibilities (e.g., for capital investment and maintenance to different departments), communication across organizational units, accounting procedures, and the routine behavior of building management personnel and occupants (National Research Council, 2010b). Psychological principles may need to be applied differentially to actors in organizations according to their roles and the choices they control. For example, building occupants may control the operation of windows and office space conditioning equipment and so might be influenced by feedback and normative appeals; for building maintenance personnel, however, new routines and training programs might prove a higher impact strategy.

Policy Change

A growing body of research concerns the effects of values, attitudes, beliefs, worldviews, and emotional reactions on public support and activism for pro-environmental policies. Some of these studies show that public support for policies to limit climate change is associated with environmental worldviews and fundamental values (Dietz, Dan, & Shwom, 2007; Dunlap & Van Liere, 1978; Dunlap et al., 2000; Nilsson, von Borgstede, & Biel, 2004; Shwom, Bidwell, Dan, & Dietz, 2010; Steg, Dreijerink, & Abrahamse, 2005; Stern et al., 1999; Stern, Dietz, & Guagnano, 1995) and suggest that efforts to frame the climate problem in terms of widely held environmental values might increase policy support. Opposition to such policies is also linked to values and political ideology (e.g., Dunlap & McCright, 2008; Leiserowitz, Maibach, & Roser-Renouf, 2008).

Psychological research is also relevant to public support for technologies for limiting climate change. For example, the extensive body of research on risk perception is relevant to the public acceptance of energy technologies (Slovic, 2000). Past research on perceptions of the risks of nuclear power and other technologies (e.g., Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, Flynn, & Layman, 1991) suggests that beliefs and feelings about a technology will affect public acceptance not only of new nuclear power projects but also of large wind energy projects, "geoengineering" proposals, bioenergy projects, and other technologies and policy proposals for limiting climate change. Policy activists often present climate change issues and policies so as to take advantage of such cognitive and affective tendencies (for more detailed discussion, see Weber & Stern, 2011, this issue). Public acceptance may also be affected by other psychological factors, including trust in the responsible organizations and perceptions about the decision processes (Tuler, 2009).

Cultural and Social-Structural Change

Finally, fundamental societal changes may be desirable or even necessary for achieving desired emissions reduction targets. The relevant cultural and social-structural forces include consumerism and associated desires and a pattern of development of low-density communities that effectively requires personal motor vehicles for mobility. These forces have developed together and might change together. Such large-scale societal changes are difficult to study, but they nevertheless deserve attention from behavioral and social scientists.

What Can Psychologists Do to Be Helpful?

There are many promising opportunities for behavioral scientists to contribute to limiting climate change by conducting research and advising on policy. In all these efforts, psychologists will need to take an interdisciplinary approach for optimal effect. This section summarizes several promising lines of problem-focused research in which psychologists can work with scientists from other fields, government agencies, utility companies, and technical experts. Depending on the problem, psychologists may need to work with economists, sociologists, architects, engineers, or researchers and practitioners from other areas of expertise. The areas of opportunity include those listed in the following sections.

Understanding ESB

Psychology can provide finer grained analysis of high-impact household behaviors to identify the most important ones, their determinants, and the barriers to behavioral change in different populations and communities (climatic regions, urban vs. rural, etc.). The behaviors worthy of further study include both high-impact purchase decisions (e.g., of homes and energy-efficient vehicles and appliances) and high-impact equipment use behaviors (e.g., travel mode choice, vehicle driving behavior, resetting thermostats). Psychologists can illuminate the critical behavioral factors at the human–technology interface that determine whether new, low-emissions technologies are accepted by the intended users and operated in ways that achieve their technical potential (see below). Psychology can also help provide an understanding of the household actions that have important indirect effects on climate through the production, distribution, purchase, and disposal of food and other household products.

At the level of organizational behavior, psychology can help identify the barriers to high-impact behavioral changes, including the adoption, proper maintenance, and use of major energy-consuming equipment. Another important opportunity lies in behavioral studies of the energy-related choices of the suppliers of high-impact consumer products (e.g., appliance retailers and installers, home builders and developers, home repair contractors, automobile dealers). Little is known about how their choices of which products to produce and market are affected by their perceptions of their customers' desires and by other influences in their decision environments. Finally, in the policy arena, psychology can further illuminate the determinants of support for or opposition to climate response policies and new energy technologies.

Changing ESB to Limit Climate Change

Psychology can also help design more effective policies and programs by identifying behaviorally sound design principles and suggesting ways to implement them in programs that combine financial and nonfinancial elements to induce high-impact household investments in energy efficiency and renewable energy (Gardner, Stern, Dietz, Vandenbergh, & Gilligan, 2010; Stern et al., 2010; Vandenbergh, Stern, Gardner, Dietz, & Gilligan, 2010). It can help design and test campaigns for changing high-impact household behaviors, including understudied behaviors such as housing choice, travel mode choice, appliance purchases, and vehicle driving behavior. By working with the appropriate technical specialists, psychologists can help improve information such as energy rating and labeling systems for homes and carbon calculators for consumers (Vandenbergh et al., in press). They can develop and test interventions to encourage energy-efficient equipment acquisition and use in organizations and can examine community-based approaches to diffusing climate-friendly technologies and practices and establishing and enforcing social norms. Finally, psychologists can apply the methods of evaluation research to measure the effects of energy efficiency and conservation programs. Much can be learned by treating programs as experiments and carefully investigating the processes that determine how effective these programs are. Understanding these processes is key to learning from experience with interventions.

Assisting With Technological Development

By working with designers and engineers, psychologists can help in the development and implementation of new technologies that can reduce GHG emissions by improving energy efficiency, supplying low-carbon energy services, and redesigning human settlements. A few examples on the energy demand side illustrate the possibilities. Cognitive and human factors psychology can help improve the design of so-called smart meters, which could provide very valuable energy-use feedback to consumers but are currently being designed mainly to meet the needs of energy supply companies. California and some other states are beginning to mandate that new buildings use "zero net energy" technologies (commercial buildings by 2020; residential buildings by 2030). Engineers and architects are designing buildings to have the desired energy properties, but such buildings will not become commonplace unless people want to occupy them and will not achieve their technical potential if the occupants behave in ways that counteract the designers' intent. It has long been known that occupant behavior is a major source of variation in energy use in buildings (e.g., Sonderegger, 1978). As buildings are engineered to more exacting standards to achieve policy and economic goals, the influence of occupant behavior on building performance is likely to become a more important issue. The building science community is beginning to recognize the need for postoccupancy behavioral research to understand the actual performance of buildings that have been designed for zero or low energy consumption but that do not always meet those goals (e.g., Stevenson & Leaman, 2010; Vale & Vale, 2010).

Psychologists can work with building design professionals to study people's reactions to designs and prototypes and their postoccupancy behavior and to develop designs that will be attractive and effective as well as technologically advanced. Similar opportunities arise with designs at the community level to reduce the need for

motorized travel in new communities, which can yield benefits for public health as well as for the environment. These designs will require numerous changes in people's daily routines and perhaps in their social relationships, and these changes could be made more or less attractive by design choices. Psychologists can help make new designs more practical and attractive by learning more about people's responses to a new geography of communities. There may also be opportunities for psychologists to contribute to the design of telecommunication systems attractive enough to reduce travel demand.

On the energy supply side, psychology has already contributed to understanding the bases of public reactions to nuclear power development (e.g., Slovic et al., 1991) and green electricity (Clark, Kotchen, & Moore, 2003) as well as to the development of processes to better inform decisions about risky or hazardous technologies (National Research Council, 1989, 1996, 2008). Public concerns are beginning to arise over new proposals to address the climate change problem by developing and expanding technologies such as wind and biomass energy production and carbon capture and sequestration in geological formations or biological systems. Psychologists can work with other scientists and engineers to anticipate public concerns and to develop processes by which society can conduct informed debate about whether and how to proceed with such proposals and how to weigh their risks and benefits.

Fundamental Psychological Research

In addition to the above research areas, which are focused on fairly specific questions, there remains a need for research on fundamental psychological questions relevant to limiting climate change. Fundamental research on risk perception is a well-known example, and this is still an active field (see Weber & Stern, 2011). Other fundamental questions are of comparable importance for limiting climate change. One concerns explaining the energy efficiency gap: Why do people fail to take energy-saving actions that would provide highly attractive returns on their investments of money or time? This is a riddle if financial returns are presumed to be the predominant motive for behavior, but the riddle might be solved and the gap narrowed by research that examines the full range of factors that can promote or inhibit behavioral plasticity (Dietz, 2010; National Research Council, 2010b).

Another fundamental question concerns the effect of taking one pro-environmental action on subsequent actions. Some arguments predict positive "spillover" effects that are based on mechanisms such as changes in self-perception, dissonance reduction, acquisition of knowledge or skills, and the foot-in-the-door effect. Others predict negative effects through such mechanisms as crowding out, resting on one's laurels, and "take-back," a process by which increases in energy efficiency result in changes in behavior or in product design that undermine potential energy savings (for a review of the evidence on spillover, see Thøgersen and Crompton, 2009). Which of these mechanisms predominates with high-impact behaviors, and under what conditions, are fundamental research questions of obvious importance to limiting climate change.

At an even more fundamental level are psychological questions about the drivers of "consumption," which underlies demand for energy-using goods and services (National Research Council, 1997; also see Swim et al., 2011). Consumption is commonly understood in relation to consumer expenditures, but a much more nuanced understanding of consumption is needed to inform behavioral research related to environmental issues such as climate change (Stern, 1997). Economic consumption is not necessarily the same as environmental consumption—$500 spent on computer software has a much different effect on the climate than $500 spent on an airline ticket—even though they are the same in economic accounts. The human wants that drive economic expenditures—to visit families, heat and cool homes, impress neighbors, and so on—are related to climate change only indirectly, through the technologies available to fulfill them. Psychological research can help unpack the idea of consumption and might help identify ways to satisfy people's needs while reducing GHG emissions. It may also help by building fundamental understanding of how people's desires change—knowledge that may become critically important in the longer run.

Conclusion

The actions of households and organizations drive climate change, and changes in these behaviors have major potential to limit the magnitude of climate change. Psychological factors, often acting in conjunction with other influences, are important determinants of these behaviors and also influence the acceptance and implementation of public policies to limit climate change and the adoption of low-carbon energy technologies. Behavioral science has made important contributions, and can make more, to the understanding of what drives these choices. Using that understanding, it can help inform the design of interventions and the design and implementation of new technologies. This contribution is best made when psychologists stretch beyond the discipline, collaborate with experts in other areas, and combine psychological insights with those of other fields. A good way to initiate such collaborations is by participating in interdisciplinary, problem-oriented conferences and programs such as the annual Behavior, Energy, and Climate Change Conference (http://peec.stanford.edu/events/2011/becc/) and in events sponsored by such groups as the American Council for an Energy Efficient Economy (http://www.aceee.org) and the Green Building Council (http://www.usgbc.org/).

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