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Nudging pro-environmental behavior: evidence and opportunities

Hilary Byerly

University of Vermont

Andrew Balmford

University of Cambridge

Paul J. Ferraro

Johns Hopkins Carey Business School

Courtney Hammond Wagner

University of Vermont

Elizabeth Palchak

University of Vermont

See next page for additional authors

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Authors

Hilary Byerly, Andrew Balmford, Paul J. Ferraro, Courtney Hammond Wagner, Elizabeth Palchak, Stephen Polasky, Taylor H. Ricketts, Aaron J. Schwartz, and Brendan Fisher

WebTable 1. Domain-specific terms used in literature search

Domain	Search terms
Family	birth + control / spacing; child; contraception; family + planning; fertility; pregnancy
Land	agriculture; conservation + soil / water; farm; land + “best management practices” / conservation / management / owner / use
Meat	diet; meat; vegetarian
Transportation	transport; travel
Waste	consumption; waste + food / paper / plastic / prevention / production / reduction
Water	water + conservation / household / residential / utility

Words separated by a slash (/) were used separately in combination with the word preceding the plus sign (+). For example, the words “birth” AND “control” were searched together, and then “birth” AND “spacing” were searched together. A semicolon indicates a separate search.

H Byerly *et al.* – Supporting Information

WebTable 2. Studies included in the review

Study	Domain	Behavior	Sampled population	Sample size	Setting	Measure	Target	Intervention specified	Intervention significant?
Ahmed <i>et al.</i> (2015)	Family planning	Reduce fertility rate	Women and girls	4083	Field	Observed	Education	Training	Yes
Ahmed <i>et al.</i> (2015)	Family planning	Use contraception	Women and girls	4083	Field	Reported	Education	Training	Yes
		Contribute resources to land							
Andrews <i>et al.</i> (2013)	Land management	conservation	Farmers	1537	Field	Observed	Salience	Framing	No
Ashraf <i>et al.</i> (2014)	Family planning	Reduce fertility rate	Women and girls	706	Field	Observed	Norms	Presence of husband	Yes
Ashraf <i>et al.</i> (2014)	Family planning	Use contraception	Women and girls	706	Field	Observed	Norms	Presence of husband	Yes
Baca-Motes <i>et al.</i> (2013)	Water use	Reuse hotel towels	Hotel guests	2416	Field	Observed	Commitments	Combo	Yes
Baca-Motes <i>et al.</i> (2013)	Water use	Reuse hotel towels	Hotel guests	2416	Field	Observed	Commitments	Goal-setting	Yes
Baca-Motes <i>et al.</i> (2013)	Water use	Reuse hotel towels	Hotel guests	2416	Field	Observed	Salience	Identity	No
Bachman and Katzev (1982)	Transportation choices	Use public transportation	Drivers	75	Field	Observed	Commitments	Goal-setting	Yes
Bachman and Katzev (1982)	Transportation choices	Use public transportation	Drivers	75	Field	Observed	Commitments	Goal-setting	Yes
Bachman and Katzev (1982)	Transportation choices	Use public transportation	Drivers	75	Field	Observed	Financial	Non-monetary	Yes
Bachman and Katzev (1982)	Transportation choices	Use public transportation	Drivers	75	Field	Observed	Financial	Non-monetary	Yes
Bachman and Katzev (1982)	Transportation choices	Use public transportation	Drivers	75	Field	Observed	Financial	Non-monetary	Yes
Bachman and Katzev (1982)	Transportation choices	Use public transportation	Drivers	75	Field	Observed	Financial	Non-monetary	Yes
								Implementation	
Bamberg (2002)	Transportation choices	Use public transportation	Undergraduates	90	Field	Observed	Commitments	intentions	Yes
Bamberg (2006)	Transportation choices	Use public transportation	Drivers	169	Field	Reported	Financial	Non-monetary	Yes
Bandiera <i>et al.</i> (2012)	Family planning	Reduce sexual activity	Women and girls	4888	Field	Reported	Education	Training	Yes
Bandiera <i>et al.</i> (2012)	Family planning	Use contraception	Women and girls	4888	Field	Reported	Education	Training	Yes
Bandiera <i>et al.</i> (2015)	Family planning	Reduce fertility rate	Women and girls	4888	Field	Observed	Education	Training	Yes
Bashour <i>et al.</i> (2008)	Family planning	Use contraception	Women and girls	876	Field	Reported	Education	How-to tips	No
Beale and Bonsall (2007)	Transportation choices	Use public transportation	Drivers	205	Field	Reported	Education	Data (general)	No
Beale and Bonsall (2007)	Transportation choices	Use public transportation	Drivers	71	Field	Reported	Norms	Descriptive	No
Beale and Bonsall (2007)	Transportation choices	Use public transportation	Drivers	71	Field	Reported	Financial	Non-monetary	No
Bolderdijk <i>et al.</i> (2013)	Transportation choices	Improve driving efficiency	Drivers	23	Field	Observed	Salience	Framing	Yes
		Participate in water conservation							
Brent <i>et al.</i> (2015)	Water use	programs	Households	2380	Field	Observed	Norms	Aligned	No
Brent <i>et al.</i> (2015)	Water use	Reduce water use	Households	2380	Field	Observed	Norms	Aligned	No
		Participate in water conservation							
Brent <i>et al.</i> (2015)	Water use	programs	Households	1889	Field	Observed	Norms	Aligned	Yes
Brent <i>et al.</i> (2015)	Water use	Reduce water use	Households	1889	Field	Observed	Norms	Aligned	Yes
		Participate in water conservation							
Brent <i>et al.</i> (2015)	Water use	programs	Households	3092	Field	Observed	Norms	Aligned	Yes
Brent <i>et al.</i> (2015)	Water use	Reduce water use	Households	3092	Field	Observed	Norms	Aligned	Yes
								Environmental	
Campbell-Arvai and Arvai (2015)	Meat consumption	Eat vegetarian	Undergraduates	160	Field	Observed	Education	impact	No
Campbell-Arvai and Arvai (2015)	Meat consumption	Eat vegetarian	Undergraduates	160	Field	Observed	Defaults	Opt-out	Yes
								Environmental	
Campbell-Arvai <i>et al.</i> (2014)	Meat consumption	Eat vegetarian	Undergraduates	320	Field	Observed	Education	impact	No
Campbell-Arvai <i>et al.</i> (2014)	Meat consumption	Eat vegetarian	Undergraduates	320	Field	Observed	Defaults	Opt-out	Yes
Chong <i>et al.</i> (2013)	Family planning	Use contraception	High-school students	3358	Field	Observed	Education	Training	Yes
Chong <i>et al.</i> (2013)	Family planning	Reduce sexual activity	High-school students	3857	Field	Reported	Education	Training	No
Chong <i>et al.</i> (2013)	Family planning	Reduce fertility rate	High-school students	4252	Field	Reported	Education	Training	No
Cobern <i>et al.</i> (1995)	Land management	Adopt conservation practices	Households	120	Field	Observed	Commitments	Goal-setting	No

Study	Domain	Behavior	Sampled population	Sample size	Setting	Measure	Target	Intervention specified	Intervention significant?
Cobern <i>et al.</i> (1995)	Land management	Adopt conservation practices	Households	120	Field	Observed	Commitments	Public	Yes
Datta <i>et al.</i> (2015)	Water use	Reduce water use	Households	5626	Field	Observed	Norms	Descriptive	No
Datta <i>et al.</i> (2015)	Water use	Reduce water use	Households	5626	Field	Observed	Norms	Descriptive	Yes
Datta <i>et al.</i> (2015)	Water use	Reduce water use	Households	5626	Field	Observed	Commitments	Goal-setting	Yes
de Groot <i>et al.</i> (2013)	Waste production	Reduce plastic waste	Shoppers	200	Field	Observed	Norms	Aligned	Yes
de Groot <i>et al.</i> (2013)	Waste production	Reduce plastic waste	Shoppers	200	Field	Observed	Norms	Injunctive	Yes
de Groot <i>et al.</i> (2013)	Waste production	Reduce plastic waste	Shoppers	200	Field	Observed	Norms	Personal	Yes
de Young <i>et al.</i> (1993)	Waste production	Reduce plastic waste	Households	103	Field	Reported	Education	Data (general)	Yes
de Young <i>et al.</i> (1993)	Waste production	Reduce plastic waste	Households	103	Field	Reported	Education	Data (general)	Yes
de Young <i>et al.</i> (1993)	Waste production	Reduce plastic waste	Households	103	Field	Reported	Education	Data (general)	Yes
Desai and Tarozzi (2011)	Family planning	Use contraception	Women and girls	6275	Field	Reported	Financial	Combo	No
Desai and Tarozzi (2011)	Family planning	Use contraception	Women and girls	6275	Field	Reported	Financial	Monetary	No
Desai and Tarozzi (2011)	Family planning	Use contraception	Women and girls	6275	Field	Reported	Education	Training	No
Dickerson <i>et al.</i> (1992)	Water use	Reduce water use	Women and girls	80	Field	Observed	Commitments	Combo	Yes
Dickerson <i>et al.</i> (1992)	Water use	Reduce water use	Undergraduates	80	Field	Observed	Commitments	Combo	Yes
Dickerson <i>et al.</i> (1992)	Water use	Reduce water use	Women and girls	80	Field	Observed	Commitments	Public	No
Dickerson <i>et al.</i> (1992)	Water use	Reduce water use	Undergraduates	80	Field	Observed	Commitments	Public	Yes
Dickerson <i>et al.</i> (1992)	Water use	Reduce water use	Women and girls	80	Field	Observed	Salience	Reminder	No
Dickerson <i>et al.</i> (1992)	Water use	Reduce water use	Undergraduates	80	Field	Observed	Salience	Reminder	Yes
Egebark and Ekstrom (2016)	Waste production	Reduce paper waste	University employees	1170	Field	Observed	Norms	Injunctive	No
Egebark and Ekstrom (2016)	Waste production	Reduce paper waste	University employees	1170	Field	Observed	Defaults	Opt-out	Yes
Eriksson <i>et al.</i> (2008)	Transportation choices	Reduce driving	Drivers	51	Field	Reported	Commitments	intentions	No
Ferraro and Price (2013)	Water use	Reduce water use	Households	106 669	Field	Observed	Norms	Aligned	Yes
Ferraro and Price (2013)	Water use	Reduce water use	Households	106 669	Field	Observed	Education	How-to tips	Yes
Ferraro and Price (2013)	Water use	Reduce water use	Households	106 669	Field	Observed	Norms	Injunctive	Yes
Fielding <i>et al.</i> (2013)	Water use	Reduce water use	Households	183	Field	Observed	Norms	Descriptive	Yes
Fielding <i>et al.</i> (2013)	Water use	Reduce water use	Households	183	Field	Observed	Education	Feedback (personal)	Yes
Fielding <i>et al.</i> (2013)	Water use	Reduce water use	Households	183	Field	Observed	Education	How-to tips	Yes
Geller <i>et al.</i> (1983)	Water use	Reduce water use	Households	129	Field	Observed	Education	Feedback (personal)	No
Geller <i>et al.</i> (1983)	Water use	Reduce water use	Households	129	Field	Observed	Education	How-to tips	No
Geller <i>et al.</i> (1983)	Water use	Reduce water use	Households	129	Field	Observed	Financial	Non-monetary	Yes
Goldstein <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	1058	Field	Observed	Norms	Aligned	Yes
Goldstein <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	1585	Field	Observed	Norms	Descriptive	Yes
Goldstein <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	1585	Field	Observed	Norms	Descriptive	Yes
Goldstein <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	1585	Field	Observed	Norms	Descriptive	Yes
Goldstein <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	1585	Field	Observed	Norms	Descriptive	Yes
Goldstein <i>et al.</i> (2011)	Water use	Reuse hotel towels	Hotel guests	634	Field	Observed	Financial	Charitable donation	No
Goldstein <i>et al.</i> (2011)	Water use	Reuse hotel towels	Hotel guests	634	Field	Observed	Norms	Reciprocation	Yes
Hamann <i>et al.</i> (2015)	Waste production	Reduce paper waste	Households	383	Field	Observed	Norms	Descriptive	No
Hamann <i>et al.</i> (2015)	Waste production	Reduce paper waste	Households	383	Field	Observed	Salience	Framing	Yes
Hamann <i>et al.</i> (2015)	Waste production	Reduce paper waste	Households	383	Field	Observed	Norms	Injunctive	Yes
Hou <i>et al.</i> (2010)	Family planning	Use contraception	Women and girls	73	Field	Observed	Salience	Reminder	No
Jakobsson <i>et al.</i> (2002)	Transportation choices	Reduce driving	Drivers	80	Field	Reported	Financial	Monetary	No
Jakobsson <i>et al.</i> (2002)	Transportation choices	Reduce driving	Drivers	80	Field	Reported	Financial	Monetary	No
Jakobsson <i>et al.</i> (2002)	Transportation choices	Reduce driving	Drivers	80	Field	Reported	Commitments	Implementation	No
Jakobsson <i>et al.</i> (2002)	Transportation choices	Reduce driving	Drivers	80	Field	Reported	Commitments	intentions	No
Jayachandran <i>et al.</i> (2016)	Land management	Contribute resources to land	Households	1099	Field	Observed	Financial	Monetary	Yes

Study	Domain	Behavior	Sampled population	Sample size	Setting	Measure	Target	Intervention specified	Intervention significant?
		conservation							
Kallbekken and Saelen (2013)	Waste production	Reduce food waste	Hotel guests	52	Field	Observed	Norms	Descriptive	Yes
Kallbekken and Saelen (2013)	Waste production	Reduce food waste	Hotel guests	52	Field	Observed	Defaults	Portion size	Yes
Katz <i>et al.</i> (2016)	Water use	Reduce water use	Households	934	Field	Observed	Norms	Injunctive	Yes
Katzev and Bachman (1982)	Transportation choices	Reduce driving	Households	152	Field	Reported	Financial	Monetary	No
Katzev and Bachman (1982)	Transportation choices	Reduce driving	Households	152	Field	Reported	Financial	Monetary	No
Katzev and Bachman (1982)	Transportation choices	Reduce driving	Households	152	Field	Reported	Defaults	Making it easy	No
Katzev and Bachman (1982)	Transportation choices	Reduce driving	Households	152	Field	Reported	Financial	Non-monetary	No
Katzev and Bachman (1982)	Transportation choices	Use public transportation	Households	152	Field	Observed	Financial	Monetary	No
Katzev and Bachman (1982)	Transportation choices	Use public transportation	Households	152	Field	Observed	Financial	Monetary	Yes
Katzev and Bachman (1982)	Transportation choices	Use public transportation	Households	152	Field	Observed	Defaults	Making it easy	No
Katzev and Bachman (1982)	Transportation choices	Use public transportation	Households	152	Field	Observed	Financial	Non-monetary	Yes
		Contribute resources to land							
Kerr <i>et al.</i> (2012)	Land management	conservation	Households	560	Field	Observed	Financial	Monetary	No
		Contribute resources to land							
Kerr <i>et al.</i> (2012)	Land management	conservation	Households	560	Field	Observed	Financial	Shared financial	No
Kondylis <i>et al.</i> (2016)	Land management	Adopt conservation practices	Farmers	5076	Field	Reported	Messenger	Gender	Yes
Kormos <i>et al.</i> (2014)	Transportation choices	Reduce driving	Drivers	78	Field	Reported	Norms	Descriptive	No
Kormos <i>et al.</i> (2014)	Transportation choices	Reduce driving	Drivers	78	Field	Reported	Norms	Descriptive	No
Kurz <i>et al.</i> (2005)	Water use	Reduce water use	Households	166	Field	Observed	Education	Data (general)	No
Kurz <i>et al.</i> (2005)	Water use	Reduce water use	Households	166	Field	Observed	Norms	Descriptive	No
Kurz <i>et al.</i> (2005)	Water use	Reduce water use	Households	166	Field	Observed	Salience	Reminder	Yes
Liebig and Rommel (2014)	Waste production	Reduce paper waste	Households	941	Field	Observed	Defaults	Forced choice	Yes
Lokhorst <i>et al.</i> (2010)	Land management	Adopt conservation practices	Farmers	58	Field	Reported	Education	Feedback (personal)	No
Lokhorst <i>et al.</i> (2010)	Land management	Adopt conservation practices	Farmers	58	Field	Reported	Commitments	Public	No
		Contribute resources to land							
Lokhorst <i>et al.</i> (2010)	Land management	conservation	Farmers	58	Field	Reported	Education	Feedback (personal)	No
		Contribute resources to land							
Lokhorst <i>et al.</i> (2010)	Land management	conservation	Farmers	58	Field	Reported	Commitments	Public Implementation	No
Loy <i>et al.</i> (2016)	Meat consumption	Reduce meat consumption	Undergraduates	55	Field	Reported	Commitments	intentions	Yes
Matthies <i>et al.</i> (2006)	Transportation choices	Use public transportation	Drivers	297	Field	Reported	Financial	Non-monetary	Yes
Matthies <i>et al.</i> (2006)	Transportation choices	Use public transportation	Drivers	297	Field	Reported	Commitments	Plea for commitment	No
		Contribute resources to land							
Messer <i>et al.</i> (2016)	Land management	conservation	Farmers	371	Field	Observed	Priming	Social desirability	No
		Contribute resources to land							
Messer <i>et al.</i> (2016)	Land management	conservation	Farmers	371	Field	Observed	Priming	Social desirability	Yes
		Contribute resources to land							
Messer <i>et al.</i> (2016)	Land management	conservation	Farmers	371	Field	Observed	Defaults	Status quo bias	Yes
Middlestadt <i>et al.</i> (2001)	Water use	Reduce water use	High school students	671	Field	Reported	Education	How-to tips	Yes
Monroe <i>et al.</i> (2015)	Meat consumption	Choose climate-friendly protein	Undergraduates	491	Field	Reported	Education	Training	Yes
Richetin <i>et al.</i> (2016)	Water use	Reduce water use	Undergraduates	41	Lab	Observed	Norms	Descriptive	Yes
Richetin <i>et al.</i> (2016)	Water use	Reduce water use	Undergraduates	41	Lab	Observed	Norms	Descriptive	Yes
Richetin <i>et al.</i> (2016)	Water use	Reduce water use	Undergraduates	40	Lab	Observed	Norms	Descriptive	Yes
Richetin <i>et al.</i> (2016)	Water use	Reduce water use	Undergraduates	109	Lab	Observed	Norms	Descriptive	Yes
								Environmental	
Rommel <i>et al.</i> (2015)	Waste production	Reduce paper waste	Households	822	Field	Observed	Education	impact	No
Rommel <i>et al.</i> (2015)	Waste production	Reduce paper waste	Households	822	Field	Observed	Financial	Non-monetary	Yes

Study	Domain	Behavior	Sampled population	Sample size	Setting	Measure	Target	Intervention specified	Intervention significant?
Rommel <i>et al.</i> (2015)	Waste production	Reduce paper waste	Households	822	Field	Observed	Norms	Social influence	No
Rubens <i>et al.</i> (2015)	Waste production	Reduce plastic waste	Shoppers	74	Field	Observed	Commitments	Public	Yes
Rubens <i>et al.</i> (2015)	Waste production	Reduce plastic waste	Shoppers	74	Field	Observed	Salience	Reminder	No
Santos and van der Linden (2016)	Waste production	Reduce plastic waste	Undergraduates	1302	Field	Reported	Financial	Non-monetary	Yes
Schall and Mohnen (2015)	Transportation choices	Improve driving efficiency	Drivers	86	Field	Observed	Financial	Monetary	No
Schall and Mohnen (2015)	Transportation choices	Improve driving efficiency	Drivers	86	Field	Observed	Financial	Non-monetary	Yes
Schmidt (2016)	Waste production	Reduce food waste	Households	217	Field	Reported	Commitments	Goal-setting	Yes
Schultz <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	2359	Field	Observed	Norms	Aligned	Yes
Schultz <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	2359	Field	Observed	Norms	Descriptive	No
Schultz <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	2359	Field	Observed	Norms	Injunctive	No
Schultz <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	794	Field	Observed	Norms	Aligned	Yes
Schultz <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	865	Field	Observed	Norms	Descriptive	Yes
Schultz <i>et al.</i> (2008)	Water use	Reuse hotel towels	Hotel guests	865	Field	Observed	Norms	Social influence	Yes
Schultz <i>et al.</i> (2014)	Water use	Reduce water use	Households	301	Field	Observed	Norms	Aligned	Yes
Schultz <i>et al.</i> (2014)	Water use	Reduce water use	Households	301	Field	Observed	Norms	Descriptive	Yes
Schultz <i>et al.</i> (2014)	Water use	Reduce water use	Households	301	Field	Observed	Education	How-to tips	No
Sebastian <i>et al.</i> (2012)	Family planning	Use contraception	Women and girls	959	Field	Reported	Education	How-to tips	Yes
Seyranian <i>et al.</i> (2015)	Water use	Reduce water use	Households	374	Field	Observed	Norms	Aligned	Yes
Seyranian <i>et al.</i> (2015)	Water use	Reduce water use	Households	374	Field	Observed	Education	How-to tips	No
Seyranian <i>et al.</i> (2015)	Water use	Reduce water use	Households	374	Field	Observed	Salience	Identity	Yes
Seyranian <i>et al.</i> (2015)	Water use	Reduce water use	Households	374	Field	Observed	Salience	Identity	Yes
Taniguchi and Fujii (2007)	Transportation choices	Use public transportation	Households	494	Field	Reported	Commitments	Implementation intentions	Yes
Terrier and Marfaing (2015a)	Water use	Reuse hotel towels	Hotel guests	803	Field	Observed	Norms	Descriptive	Yes
Terrier and Marfaing (2015a)	Water use	Reuse hotel towels	Hotel guests	803	Field	Observed	Norms	Descriptive	Yes
Terrier and Marfaing (2015a)	Water use	Reuse hotel towels	Hotel guests	803	Field	Observed	Commitments	Implementation intentions	Yes
Terrier and Marfaing (2015a)	Water use	Reuse hotel towels	Hotel guests	803	Field	Observed	Commitments	Implementation intentions	Yes
Terrier and Marfaing (2015b)	Water use	Reuse hotel towels	Hotel guests	187	Field	Observed	Commitments	Implementation intentions	Yes
Tertoolen <i>et al.</i> (1998)	Transportation choices	Use public transportation	Drivers	350	Field	Reported	Education	Economic impact	No
Tertoolen <i>et al.</i> (1998)	Transportation choices	Use public transportation	Drivers	350	Field	Reported	Education	Environmental impact	No
Thogerson (2009)	Transportation choices	Use public transportation	Drivers	597	Field	Reported	Financial	Non-monetary	Yes
Thompson and Stoutemyer (1991)	Water use	Reduce water use	Households	171	Field	Observed	Education	Economic impact	No
Thompson and Stoutemyer (1991)	Water use	Reduce water use	Households	171	Field	Observed	Education	Environmental impact	Yes
Thompson and Stoutemyer (1991)	Water use	Reduce water use	Households	171	Field	Observed	Education	How-to tips	Yes
Yeomans and Herberich (2014)	Transportation choices	Improve driving efficiency	Drivers	700	Field	Observed	Education	Data (general)	No
Yeomans and Herberich (2014)	Transportation choices	Improve driving efficiency	Drivers	700	Field	Observed	Norms	Descriptive	No
Yeomans and Herberich (2014)	Transportation choices	Improve driving efficiency	Drivers	700	Field	Observed	Financial	Monetary	Yes
Yeomans and Herberich (2014)	Transportation choices	Improve driving efficiency	Drivers	700	Field	Observed	Financial	Non-monetary	Yes

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Nudging pro-environmental behavior: evidence and opportunities

Hilary Byerly^{1,2*}, Andrew Balmford³, Paul J Ferraro⁴, Courtney Hammond Wagner^{1,2}, Elizabeth Palchak^{1,2}, Stephen Polasky⁵, Taylor H Ricketts^{1,2}, Aaron J Schwartz^{1,2}, and Brendan Fisher^{1,2}

Human behavior is responsible for many of our greatest environmental challenges. The accumulated effects of many individual and household decisions have major negative impacts on biodiversity and ecosystem health. Human behavioral science blends psychology and economics to understand how people respond to the context in which they make decisions (eg who presents the information and how it is framed). Behavioral insights have informed new strategies to improve personal health and financial choices. However, less is known about whether and how these insights can encourage choices that are better for the environment. We review 160 experimental interventions that attempt to alter behavior in six domains in which decisions have major environmental impacts: family planning, land management, meat consumption, transportation choices, waste production, and water use. The evidence suggests that social influence and simple adjustments to decision settings can influence pro-environmental decisions. We identify four important gaps in the evidence that provide opportunities for future research. To address these gaps, we encourage collaborations between researchers and practitioners that look at the effects of embedding tests of behavior-change interventions within environmental programs.

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Human behavior is a key determinant of the state of the environment. Individual consumption and lifestyle choices contribute greatly to climate change (IPCC 2014), ecosystem conversion and biodiversity loss (Foley *et al.* 2005), and water scarcity (Wada and Bierkens 2014). These impacts are projected to worsen as the size and wealth of the global human population continue to grow (Ferrara and Serrat 2008); as such, modifying human behavior is essential for addressing environmental challenges (Fischer *et al.* 2012; Cowling 2014).

In a nutshell:

- Insights into human behavior offer new options for influencing people's choices in ways that will affect the environment
- Experimental evidence suggests that information about social norms and changes to the decision context can encourage pro-environmental behavior, especially in relation to water conservation, sustainable land management, and reduced meat consumption
- Large gaps in our understanding of how particular interventions can influence people's choices will require further research using well-designed experiments that measure cost-effectiveness and behavior-change over time

Non-regulatory policies and programs designed to influence decision making have historically been shaped by the economic model of the “rational actor”. With limitless cognitive capacity for evaluating decisions and attention only to private costs and benefits, this actor responds to information and incentives. However, there is ample evidence that people are sensitive to the behavior of others and are not strictly self-interested (Ostrom 2000; Nyborg *et al.* 2016). Insights from psychology, economics, and neuroscience further suggest that cognitive constraints and biases play important roles in how people make decisions (Simon 1955; Tversky and Kahneman 1974).

In fact, people respond not only to incentives, information, and persuasion, but also to how these interventions are framed and communicated (Kahneman *et al.* 1991; Kamenica 2012). Altering the context within which decisions are made can encourage socially desirable behaviors and discourage socially undesirable ones (Figure 1). For example, people are generally motivated to keep their promises and attain their goals, so asking for *commitments* (whether written or oral, public or private) may increase the likelihood of certain actions. Other behaviors are more likely to follow the status quo, or the *default setting*, in a given situation. Choices can be swayed by the identity of the person, or *messenger*, who suggests the behavior change, and communicating social norms, such as expectations or peer comparisons, can influence how individuals behave. People also respond to information that is made accessible in their mind (via *priming*) and to which their attention is repeatedly drawn (via *saliency*) (Figure 2). Unlike financial incentives and education, which target controlled, conscious delibera-

¹Gund Institute for Environment, University of Vermont, Burlington, VT; ²Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT (*hbyerly@uvm.edu);

³Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge, UK; ⁴Carey Business School and Department of Environmental Health and Engineering, Bloomberg School of Public Health and Whiting School of Engineering, Johns Hopkins University, Baltimore, MD; ⁵Department of Applied Economics, University of Minnesota, St Paul, MN

Figure 1. Examples of targeting contextual variables to increase pro-social and pro-environmental behavior. (a) Pledges elicit commitments that spur action to reduce energy use; (b) automatically enrolling consumers in green energy programs increases participation compared to a default where people must opt in; (c) health information is more effective when the messenger suggesting the behavior change is perceived as similar; (d) the behavior of peers and neighbors indicates social norms that promote recycling.

tion, these contextual variables often moderate behavior through automatic, unconscious cognitive processes (Dolan et al. 2012).

Applications of these insights from behavioral science have been shown to have positive effects on both individual and social welfare. Changing the context in which choices are presented can encourage people to save for retirement (Thaler and Benartzi 2004), make healthier diet and lifestyle choices (Downs et al. 2009; Volpp et al. 2011), and participate in socially beneficial programs such as organ donation (Johnson and Goldstein 2003). Yet the potential for behavioral insights to advance sustainability is unrealized in many environmental policies and programs (Clayton et al. 2013; Dietz 2014; Reddy et al. 2017).

There is evidence that interventions targeting these contextual variables can improve recycling rates and reduce energy use (see Panel 1 for an overview), but whether such approaches can influence other environ-

mentally relevant behaviors is not as well understood. We review the experimental evidence on behavior-change interventions in six other domains in which individual decisions have large environmental impacts (hereafter, “domains”): family planning, land management, meat consumption, transportation choices, waste production, and water use. For each of these six domains, we evaluate the effectiveness of eight sets of contextual interventions (hereafter, “interventions”; Figure 3). Six of these sets of interventions aim to affect the contextual variables – commitments, defaults, messenger, norms, priming, and salience – described above. We contrast these contextual interventions with two sets of traditional behavior-change interventions – financial incentives and education – that target the cost-benefit calculations of the rational actor. These traditional interventions set the performance benchmark against which contextual interventions can be compared – a comparison that allows us to draw conclusions on the full suite of behavior-change

Figure 2. Examples of using priming and salience to influence behavior. (a) Displays of healthy foods prime shoppers to purchase healthier food items; (b) reminders and prompts make energy use and conservation salient.

options available to policy makers and those designing conservation programs.

We seek to address three questions: (1) What is already known about using contextual interventions to change environmentally important behaviors? (2) Are there interventions that have proven effective across domains? (3) How should we prioritize further research on behavioral science to address environmental challenges?

Methods

We conducted a systematic literature review to examine the effects of contextual interventions on pro-environmental behavior in the six environmentally

relevant domains described above (Figure 3). We confined our review to studies that employed experimental designs in order to draw conclusions about the causal impact of interventions on behavior. Our review was guided by four criteria: (1) experiments that (2) focused on pro-environmental behavior changes (3) in contexts related to our six domains and (4) reported statistical inferences. “Experiments” refer to empirical designs in which exposure to a condition/treatment was experimentally manipulated across or within subjects to permit unbiased causal inference. “Behavior changes” refer to self-reported or observed behaviors rather than knowledge, attitudes, or intentions. The behaviors of interest in each domain were those that have the potential

Panel 1. Behavioral evidence in recycling and energy use

Recycling

The experimental literature on recycling dates back to the 1980s. Today, waste management behaviors – recycling and not littering, in particular – have become so embedded in some countries that many consider them normative (Gould *et al.* 2016).

Changing defaults, such as adding bins for recycled goods alongside trashcans and offering curbside pickup on the same day as trash pickup, has been shown to encourage recycling. Messenger interventions (via neighbors) and commitments (via goal setting, verbal promises, and public statements) have also increased recycling. Social norms, in the form of comparative feedback and visual presence of curbside pickup, promoted recycling behavior, but the effect was often mediated by personal values. Recent reviews have demonstrated that large gaps remain in our understanding of the specific moderators and mechanisms that influence recycling behavior-change, particularly over the long term.

See reviews by Schultz *et al.* (1995); Osbaldiston and Schott (2012); Abrahamse and Steg (2013); Kirakozian (2016); and Maki *et al.* (2016).

Energy

Research on behavioral interventions for energy use began in the 1970s, and has focused largely on reducing residential energy consumption and improving energy efficiency. Multiple meta-analyses and review articles synthesize the experimental evidence on energy behavior research.

Salience (frequent, in-home reminders of current use) and commitments (goals for reducing use) have made energy-use feedback more effective in changing individual behavior toward energy conservation. Defaults that automatically enroll customers in efficiency or green energy programs have also increased participation compared to opt-in programs. Comparison messages about neighbors’ energy use have been widely employed to target social norms and have resulted in a range of treatment effects, although they can be less impactful than other contextual interventions in reducing energy use. Messenger effects warrant further research; for instance, engaging “block leaders” in neighborhoods and model employees in offices have been shown to influence energy behavior, but the results and contexts are limited.

See reviews by Abrahamse *et al.* (2005); Osbaldiston and Schott (2012); Abrahamse and Steg (2013); Delmas *et al.* (2013); and Karlin *et al.* (2015).

Figure 3. Behavior-change interventions that target decision making in six domains where human behavior has large impacts on the environment. See Panel 1 for a summary of evidence on energy use and recycling. Variables are adapted from Dolan *et al.* (2012).

to mitigate negative environmental impacts, such as using contraception (as a means of reducing population growth), regardless of whether the intent of the experimenter was environmentally motivated. We identified search terms within each of these domains (WebTable 1) and used them in combination with the words *experiment*, *intervention*, *treatment*, *control*, *behavior*, *sustainable*, and *pro-environmental*, and with the eight behavior-change interventions *commitment*, *default*, *messenger*, *norms*, *priming*, *salience*, *financial incentives*, and *education*. Searches were conducted in Web of Science, PsycINFO, EconLit, other electronic databases, relevant journals, and the citations listed in included papers. Our search centered on peer-reviewed literature but working papers from active researchers in the field were also included.

The studies that met our criteria were coded according to domain, behavior, sampled population, sample size, setting (field or lab), measure (reported or observed), intervention target, intervention tested, and statistical significance of each treatment. Our unit of analysis was a single intervention within a study; by intervention, we are referring to a treatment and its measured impact on a unique behavioral outcome. For experiments that measured multiple behavioral outcomes (eg used contraception and reduced sexual activity), each behavior counted separately. Two authors independently coded each study (81% agreement) and discrepancies were reconciled through discussion. The full set of reviewed studies is listed in WebTable 2.

Our objective was to give the reader a broad survey of multiple domains and interventions, and to achieve this we constrained our review in several ways. First, we do

not report study effect sizes or weight the studies by quality. The behavioral outcomes across domains vary greatly and a large number of studies did not report all the elements necessary to calculate standardized effect sizes. Moreover, some studies used self-reported outcomes or experienced treatment non-compliance, which can affect their internal validity. Second, because we count multiple outcome estimates from a single study separately, our review is prone to the “multiple comparison problem” (inflated Type I errors). Third, despite inclusion of six unpublished papers, selective publication of studies may have biased conclusions toward statistically significant effects. Also, researchers themselves are possibly biased in their selection of interventions to test. Finally, not all tested interventions fit perfectly into our defined categories. Despite these limitations, we believe our analysis offers a useful perspective on the state of the evidence.

■ Evidence for pro-environmental behavior change

We identified 72 studies that tested a total of 160 interventions across our six domains (Table 1). Nearly all studies (96%) were conducted in the field, as opposed to a laboratory, and almost three-quarters (73%) measured observed, rather than self-reported, behaviors. Sample sizes ranged from 23 to over 100,000 participants, with a median of 379. The majority of estimates addressed water use and transportation choices, whereas the fewest targeted land management and meat consumption (Figure 4). Norms were the most frequently affected contextual variable (48 times), followed by commitments (25), salience (11), defaults (8), priming (2), and messenger (1). The two traditional approaches of financial incentives and education were targeted 29 and 36 times, respectively.

Family planning

The behavioral outcomes in this domain were measured by contraception use, fertility rate (actual births), and sexual activity (Table 1). Although tested only once, an intervention targeting norms showed a strong effect on family planning. Women offered contraception vouchers when alone were 25% more likely to use contraception and 27% less likely to give birth than women who received the voucher in the presence of their husbands (Ashraf *et al.* 2014). A single study of

Table 1. Summary of included studies

Domain	Behavior	Interventions	Observed	Studies	Sample size
Family planning	Reduce fertility rate	4	75%	9	73–6275
	Reduce sexual activity	2	0%		
	Use contraception	10	30%		
Land management	Adopt conservation practices	5	40%	7	58–5076
	Contribute resources to conservation	9	78%		
Meat consumption	Choose climate-friendly protein	1	0%	4	55–491
	Eat vegetarian foods	4	100%		
	Reduce meat consumption	1	0%		
Transportation choices	Improve driving efficiency	7	100%	16	23–700
	Reduce driving	11	0%		
	Use public transport	21	52%		
Waste production	Reduce food waste	3	67%	10	52–1302
	Reduce paper waste	9	100%		
	Reduce plastic waste	9	56%		
Water use	Participate in conservation programs	3	100%	26	40–106,669
	Reduce water use	40	98%		
	Reuse hotel towels	21	100%		
Total		160	73%	72	

Notes: Behavior is the outcome variable used to measure the effect of an Intervention (see Figure 3); a single Study may test multiple interventions; Observed shows the proportion of interventions that are evaluated on an observed (versus self-reported) behavior change; and Sample size shows the lower and upper bounds of the sample sizes for studies in that domain.

the effect of salience, via daily reminders to use contraception, failed to detect an effect on the rate of missed birth control pills compared to a control group that received no reminder (Hou *et al.* 2010).

More than two-thirds of tested interventions in our search were educational, with overall mixed results (similar to the results of a systematic review performed by Mwaikambo *et al.* [2011]). Financial incentives were tested in only one study, in which neither access to micro-credit nor microcredit combined with family planning services affected contraception use compared to a control group that received neither (Desai and Tarozzi 2011).

Land management

Outcome measures in this domain were divided between adopting sustainable land management practices and committing resources toward conservation. In one example of a messenger intervention, adoption of sustainable agriculture increased when the gender of the farmer was the same as the gender of the agricultural extension agent (Kondylis *et al.* 2016). Switching the default cost-share from 0% to 100% in an auction to engage farmers in conservation actions increased the amount farmers were willing to pay by 9% (Messer *et al.* 2016). In the same study, priming farmers to perceive a conservation practice as socially desirable (ie by indicating that their peers approved of the practice) increased the likelihood

of bidding but had no effect on the amount farmers were willing to pay. Commitments to dedicate land or time toward conservation had mixed results, and no effect was detected for a test of salience, which framed information about conservation tillage as either profitable or environmentally beneficial (Andrews *et al.* 2013).

Traditional interventions produced mixed findings. Paying forest-owning Ugandan households not to cut trees reduced the rate of deforestation by one-half as compared to forests owned by households that did not receive such financial incentives (Jayachandran *et al.* 2016), but no effect was detected where payments were made in exchange for communal litter collection (Kerr *et al.* 2012), nor did information about conservation practices have an effect on farmers' time spent on those practices (Lokhorst *et al.* 2010).

Meat consumption

Studies on meat consumption measured vegetarian meal purchases and self-reported changes in eating meat. Changing the default cafeteria menu to vegetarian-only and moving meat-based options to a separate menu increased the proportion of vegetarian meals ordered by 50% (Campbell-Arvai *et al.* 2014) and increased the odds of choosing vegetarian meals by a factor of 15 (Campbell-Arvai and Arvai 2015). Commitments to eat less meat reduced meat consumption by 15% compared

Figure 4. Number of tested behavior-change interventions across six domains of environmentally impactful behavior. Column order is expressed in the key at the bottom of the chart. An empty column indicates we found no tested interventions targeting that contextual variable in that domain.

to a group that only received information about the impacts of meat consumption (Loy *et al.* 2016).

Of the three experiments that tested education interventions, one study found that education resulted in a self-reported reduction of meat consumption, although the estimated effect was small (Monroe *et al.* 2015), and two studies could not detect differences in the levels of meat consumption between groups that received education and those that did not (Campbell-Arvai *et al.* 2014; Campbell-Arvai and Arvai 2015).

Transportation choices

Studies in this domain focused on three types of transportation behavior: driving efficiency, self-reported driving behavior, and public transportation use. Only one contextual intervention, which targeted salience, showed an effect on transportation behavior. Targeting salience by highlighting the environmental, rather than the economic, impacts of driving increased the likelihood of improving driving efficiency, although the sample size was small ($n = 23$; Bolderdijk *et al.* 2013). Evidence on commitments was split: three studies found that personal goals to use public transportation were effective, whereas three other studies failed to detect effects. No effect was found when social norms were targeted, nor did facilitating the purchase of tickets by bus riders (by changing the default payment method) have an effect (Katzew and Bachman 1982).

Most of the experimental literature within this domain focused on financial interventions (Figure 4). Direct financial incentives, such as monetary payments, charges, and

discounts, largely had no effect. However, other non-monetary incentives, including free bus tickets, travel vouchers, and prizes, encouraged sustainable transportation behavior.

Waste production

This domain focused on behavioral outcomes related to waste production (ie reducing consumption) rather than waste disposal (but see the section on recycling in Panel 1). Results here offer evidence in favor of defaults and commitments in lowering the amount of food, paper, and plastic waste. Making the default plate size smaller reduced food waste by 20% (Kallbekken and Sælen 2013) and switching default printer settings to double-sided printing reduced paper consumption at a university by 15% per day (Egebark and Ekström 2016). Commitments increased self-

reported food waste prevention behaviors in households and made shoppers 29% more likely to refrain from using plastic bags at a grocery store (Rubens *et al.* 2015). Mixed results were found for norms and salience. Communicating social norms reduced plastic bag use and buffet food waste, but no effect was detected on reducing paper waste. Salience had an effect on opting out of receiving junk mail but not refusing plastic bags for groceries (Hamann *et al.* 2015; Rubens *et al.* 2015).

Traditional interventions changed behavior in this domain. Financial incentives and education were effective in reducing junk mail and plastic waste (Rommel *et al.* 2015; Santos and van der Linden 2016).

Water use

Commitments and norms showed an effect on reducing water consumption by households, students, and hotel guests. Interventions employing commitments were effective nine of the 10 times they were tested, particularly those encouraging hotel guests to reuse towels (Baca-Motes *et al.* 2013). Targeting norms by exposing participants to messages about the water-saving behavior of their peers also reduced water use, and increased both towel reuse and participation in conservation programs (Goldstein *et al.* 2008; Ferraro and Price 2013; Brent *et al.* 2015). Making personal identity salient had mixed effects on water use but simple reminders proved effective: water use was 23% lower in households in which water-use labels were attached to showers and appliances than in households that received the same information via leaflets (Kurz *et al.* 2005).

Table 2. Balance of evidence to change environmentally relevant behaviors

Intervention	Promising	Mixed	No effect
Commitments
Defaults
Messenger
Norms
Priming
Salience
Education
Financial

Notes. = family planning; = land management; = meat consumption; = transportation choices; = waste production; = water use. Domains are allocated to a particular column according to the proportion of studies in that domain that measured a statistically significant effect of that intervention, as reported by the studies' authors. *Promising* = 75% or more results found an effect; *Mixed* = less than 75% but more than zero results; *No effect* = none of the studies that tested that intervention detected an effect. See Figure 4 for the relative frequency of tested interventions within each domain.

Education and financial incentives showed mixed results, leading to lower water use in some cases but not others.

■ What we know about contextual interventions

Experimental evidence suggests that the use of behavioral insights may alter environmentally relevant behaviors (Table 2). Interventions aimed at affecting norms or defaults produced consistent effects on behaviors across multiple studies and domains. Several large-scale field experiments demonstrated that normative messages reduced household water consumption by 2.5–7.7% compared to control groups who did not receive the contextual intervention (Ferraro and Price 2013; Brent *et al.* 2015; Datta *et al.* 2015). Switching default buffet

plate size, printer settings, menu offerings, and cost-share baseline amounts made it easier for individuals to act in a pro-environmental manner.

The evidence for the effects of commitments and salience is less straightforward. Although commitments to reuse towels and to reduce waste and meat consumption were effective, no effect was found on reducing driving or adopting land conservation practices. Reminders to change behavior had an effect on water consumption but not on taking daily contraception or reducing plastic bag use at the supermarket. Reminders about financial benefits did not increase pro-environmental behavior more than facts alone, and actually had a negative effect compared to reminders about environmental benefits. Priming and messenger effects were each only tested in one study.

■ Contextual interventions in practice

Overall, contextual interventions outperform education interventions. Six studies that compared contextual interventions directly against an education intervention and a no-intervention control reported that the contextual intervention produced the largest gain in pro-environmental behavior (Ferraro and Price 2013; Campbell-Arvari *et al.* 2014; Rommel *et al.* 2015). Financial incentives also outperformed education interventions. However, it is less clear how contextual interventions compared to financial incentives. The two may be substitutes, with one being more effective than the other in certain instances. Or they may be complementary: appropriately tailored contextual interventions may optimize the acceptability and impact of financial incentives.

Indeed, our findings indicated that some interventions work best in combination. Several family planning studies showed education interventions to be most effective when combined with health visits, vocational training, or social networking (Chong *et al.* 2013; Ahmed *et al.* 2015; Bandiera *et al.* 2015). A number of studies combined multiple interventions into a single treatment, making it difficult to discern the causal effects of any one intervention or their interactions.

The effectiveness of contextual interventions is often conditional on who receives the intervention and in what context. Whereas targeting norms reduced water consumption, effects were repeatedly moderated by other factors such as delivery method, baseline water use, and socioeconomic status. Communication of norms also influenced family planning behavior, but gains in contraception use were offset by a negative effect on women's subjective well-being. These caveats illustrate an important limitation of behavioral interventions: because their success is often conditional on prior beliefs, characteristics, and context, the development of universally effective solutions is unlikely. Accounting for such complexity may require combinations of interventions that target both deliberative and subconscious thought to change behaviors (van der Linden 2013).

■ Future research and program design

Our review identified four areas where additional research could yield guidance for policy making that encourages pro-environmental behavior changes.

Test interventions in domains that have the greatest impact on the environment

Meat consumption, unsustainable land management, and population growth put considerable stress on the environment (Wynes and Nicholas 2017), yet we could find only four, seven, and nine studies, respectively, that tested behavior changes in these domains. More

experimental research on reducing meat consumption, for example, could slow the rate of land conversion (Foley *et al.* 2011), and lower greenhouse-gas emissions (Garnett 2011) and biodiversity loss across land- and seascapes (Machovina *et al.* 2015). Future research should also target producer behavior. Whereas financial incentives and regulation will remain important tools for influencing corporate decisions, contextual interventions may encourage low-cost, potentially high-benefit behavioral changes that are good for the environment.

Test interventions that have not been well examined with respect to pro-environmental behaviors

More research on messenger effects could be useful to environmental programs and policy makers. Given the strength of these factors in influencing health behaviors and charitable donations (Durantini *et al.* 2006; Landry *et al.* 2006), such interventions may prove to be important tools for conservation.

Test interventions using randomized controlled designs of adequate size

Well-designed experiments allow us to determine cause-and-effect relationships between interventions and desired environmental outcomes, yet many pro-environmental behavior-change studies are poorly designed, lacking adequate controls and randomization (Frederiks *et al.* 2016). Fewer than 10% of the studies in our literature review explicitly discussed the statistical power of their results, and given that nearly one-quarter of the studies we reviewed had sample sizes of fewer than 100 participants, many results are likely underpowered. Studies involving appropriate experimental designs and sufficient sample sizes will allow us to draw stronger conclusions about the causal effects and magnitude of behavior-change interventions.

Evaluate conditions, cost-effectiveness, and persistence of behavior-change interventions

In order to translate experimental evidence into environmental policy, more research is required to understand the contexts in which certain interventions work, at what cost, and for how long. There are roadmaps for implementation (see Clayton *et al.* 2013; Reddy *et al.* 2017), but little is known about the combinations and moderators of interventions that will determine their relevance to policy. A meta-analysis on commitments similarly highlights a lack of empirical evidence explaining why and under what conditions a given intervention will be effective (Lokhorst *et al.* 2013). Although advocates of contextual interventions highlight their low cost (Benartzi *et al.* 2017), only 15 of the 72 studies included in our review addressed the cost-effectiveness of the tested interventions. Twenty studies considered

the duration of behavior change, but only nine measured the effect beyond 6 months. If the effects of promising interventions expire with the end of their implementation, there is little hope for addressing the scale of current environmental challenges (van der Linden 2015). Future experiments should prioritize evidence on the net value of the behavioral insight and the persistence of the behavioral changes even after the interventions are no longer being implemented.

■ Looking ahead

Behavioral insights show promise for sustainability, but much work remains to make them actionable for environmental policy design and program implementation. We encourage collaboration between scholars and practitioners to embed tests of behavioral interventions within existing environmental programs, given that such tests provide both generalizable scientific knowledge and specific applications that can be incorporated into scaled-up programs. A variety of researcher–practitioner collaborations are doing just this for programs in poverty alleviation, public health, criminal justice, tax compliance, and education. Similar efforts have begun to address environmental challenges. Our review suggests that there is both a need and an opportunity to build an evidence base of behavioral insights tailored to achieving sustainability goals.

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