AMERICAN ACADEMY
OF ARTS & SCIENCES

ALTERNATIVE ENERGY FUTURE PROJECT

Decision Science and Market Transformation Pathways

Workshop Report and Recommendations

American Academy of Arts & Sceinces

Cherishing Knowledge, Shaping the Future

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Acknowledgements

The American Academy of Arts and Sciences' project on the Alternative Energy Future was launched in 2010 with support from the U.S. Department of Energy (DOE) and the National Science Foundation with the goal of providing constructive guidance to shape the public policies that will govern the large-scale application of clean energy and energy efficiency technologies. Recognizing that changing the existing technological infrastructure will require modifications to legal, social, and economic structures, the Alternative Energy Future project is examining how the social and behavioral sciences could help provide guidance on these necessary changes. Through a series of workshops, publications, and consultations with scholars, utility representatives, business and NGO leaders, and government officials, the project has also identified priorities for future research on the societal aspects of energy and encouraged greater attention to these issues on the part of both researchers and funders.

In 2011, the American Academy published its report *Beyond Technology: Strengthening Energy Policy through Social Science*, which recommended five broad strategies for enhancing collaboration between social scientists and policy-makers. While much progress has been made since then, there are still numerous opportunities to improve the connections between the social and behavioral sciences research community and the energy community. To identify next steps, the American Academy convened a workshop in Washington, D.C., on December 3 – 4, 2015, in collaboration with DOE and the Association for Psychological Science. Workshop participants included experts from academia, industry, and government, including many individuals who have been involved with the Alternative Energy Future project since its conception. We are grateful to the workshop participants and speakers for providing their thoughts on unresolved issues at the interface of social science research and energy policy, as well as how to go about enhancing collaborations.

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We are indebted to Elaine Ulrich and her colleagues on the DOE SunShot team, especially Stephanie Johnson and Jared Langevin, for helping to organize the workshop and arrange for the participation of researchers funded by the SunShot Solar Energy Evolution and Diffusion Studies (SEEDS) program.

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Introduction

As the energy sector continues to evolve with new and improved technologies to meet the demands of American consumers, it has become increasingly apparent that the processes underlying technology adoption are just as important as the technology itself. A solar panel marketed at a competitive price point will not revolutionize national clean energy use if it sits in a warehouse. Consumers must not only hear about a new technology, but also be convinced that acquisition and use of that technology is worth the price and hassle. Research on human behavior and decision-making, subfields of the social sciences, can reveal information about the factors underlying adoption and use of a new technology and improve communication about energy choices, thus helping the United States to meet its energy policy goals and reduce greenhouse gas emissions.

The benefits of applying the decision sciences extend beyond the energy sector. Research in the decision sciences has revealed numerous quantifiable insights that help Americans save money and improve quality of life. For example, in the United States, many employees don't enroll in employee-sponsored retirement plans, such as 401(k) plans, when participation is voluntary.[1] Behavioral research has shown that automatic enrollment dramatically increases the average 401(k) participation rate, helping Americans save for the future.[2]

In addition to providing benefits to the individual consumer, the application of insights from the decision sciences can improve the design of government policies and programs, ensuring the highest return on investment for the American taxpayer. Behavioral science research creates a credible methodology by which past programs and policies can be evaluated, grounded in the scientific method. For programs that depend on participants completing an application process to benefit from the program, such as college financial aid, decision science research can identify not only barriers to engagement, but also information about how to remove those barriers. These insights are valuable to many organizations in addition to the government, including nongovernmental organizations (NGOs) and universities.

Despite the many benefits of the social sciences, this area of research has been historically undervalued. While the Department of Energy (DOE) has made significant advances in developing and improving clean energy technology since its creation in the 1970s, questions regarding how to inspire consumers to buy new energy-efficient appliances or install solar panels on their rooftops have remained secondary. The agency has traditionally viewed its role as a source of technology development, leaving fundamental questions regarding human decision-making to academic research laboratories. More recently, as climate change has become increasingly recognized as a threat to our economy and well-being, energy program managers are realizing that research and insights on societal factors can play a central role in properly addressing barriers to technology diffusion. In short, the decision science research community and energy community must unite.

In 2011, the American Academy of Arts and Sciences convened an interdisciplinary group of scholars, government officials, and industry experts to discuss methods to effectively integrate these two disciplines. This work culminated in the report *Beyond Technology: Strengthening Energy Policy through Social Science*. To address the behavioral and regulatory barriers to adoption of new energy technologies, the report suggests that DOE "demonstrate the value of social and behavioral research for enhancing the effectiveness of energy policy and transforming the energy system."[3] This recommendation stemmed from the observation that "because energy policy makers are largely unfamiliar with the tools of social science, they are often unaware of the value of those tools for policy development."[4]

DOE's first Quadrennial Technology Review (2011) reflected the recommendations laid out in *Beyond Technology* by confirming that a future goal of the department is to integrate decision science into technology

programs in order to better understand technology diffusion in various sectors.[5] Since then, decision science research has been successfully integrated into several DOE programs. For example, the Office of Energy Efficiency and Renewable Energy created the SunShot program in 2011 to improve deployment of solar energy by making it cost-competitive with traditional energy sources like coal, oil, and natural gas by 2020. Initial efforts at cost reduction primarily focused on solar panel hardware. However, continued slow adoption rates proved that soft costs – like supply chain costs, installation labor, and customer acquisition – and deployment barriers also needed to be addressed. This spurred the formation of the Solar Energy Evolution and Diffusion Studies (SEEDS) program, which employs insights from the decision sciences to investigate how to drive the development and deployment of solar energy technologies.

DOE's Better Buildings program has also taken significant steps toward incorporating information about institutional and individual behavior and decision-making. In May 2016, DOE formed an official partnership with the CoStar Group, a commercial real estate information and marketing provider, to advance and promote energy usage information for commercial and industrial buildings. This partnership will bring increased visibility to energy-efficient buildings in addition to promoting the benefits of these buildings for owners and occupants. Another example is the Outdoor Lighting Decision Tree Tool, which offers a visual representation of the choices municipalities and state, federal, or other public agencies may encounter when upgrading or replacing outdoor lighting for public places. The tool aims to help cities and states overcome common barriers in the market.

Building on the momentum of successful agency programs, the White House Office of Science and Technology Policy (OSTP) created the Social and Behavioral Sciences Team (SBST) in 2014 to further encourage the inclusion of social science research findings in policy-making and government programs. During its first year, SBST focused on streamlining access to programs and improving government efficiency. Among its successes, SBST was able to identify a mechanism to double the rate at which service members enroll in the Thrift Savings Plan, a workplace savings plan for federal employees. SBST also coordinated reminder emails to federal student loan borrowers, resulting in a 30 percent increase in the number of borrowers making a payment. The establishment of this team sent a clear signal from the White House that decision science research is applicable to all areas of government. Following this effort, President Barack Obama issued an executive order in September 2015 encouraging executive departments and agencies to "identify policies, programs, and operations where applying behavioral science insights may yield substantial improvements in public welfare, program outcomes, and program cost effectiveness."[6]

Although many of these initial attempts to include decision science research in government programs have proved successful, the decision sciences continue to be undervalued in energy research, largely because energy policy-makers remain unfamiliar with them. Social and behavioral science research remains underfunded and primarily confined to academia. While noteworthy discoveries are taking place in university research centers across the country, the connections between government agencies and this research community are not strong enough to allow the facile transfer of information. Opportunities to fully integrate decision science research into energy programs and within other government agencies are evident and should be seized.

On December 3 – 4, 2015, the American Academy of Arts and Sciences convened a meeting in partnership with DOE and the Association for Psychological Science to evaluate how DOE and other government agencies have applied insights from the decision sciences and to identify areas for further improvement. The "Decision Science and Market Transformation Pathways Workshop" brought together representatives from the social science research community, DOE, the National Laboratories, the National Science Foundation (NSF) Directorate for Social, Behavioral, and Economic Sciences, the National Research Council, and the White House SBST. The workshop participants identified barriers that continue to impede the incorporation of decision science research into government programs, with a specific focus on energy programs. In addition, they offered numerous strategies to overcome these barriers and ensure that energy programs meet their full potential. In the following sections, we describe the suggestions pre-

sented by workshop participants, followed by a proposed research agenda for a collaborative effort among government research agencies.

ENDNOTES

1. Shlomo Benartzi and Richard H. Thaler, "Behavioral Economics and the Retirement Savings Crisis," *Science* 339 (2013): 1152 – 1153.
2. Brigitte C. Madrian and Dennis F. Shea, "The Power of Suggestion: Inertia in 401(k) Participation and Savings Behavior," *The Quarterly Journal of Economics* 116 (2001): 1149 – 1187.
3. American Academy of Arts and Sciences, *Beyond Technology: Strengthening Energy Policy through Social Science* (Cambridge Mass.: American Academy of Arts and Sciences, 2011), 3, https://www.amacad.org/pdfs/alternativeenergy.pdf.
4. Ibid.
5. U.S. Department of Energy, *Report on the First Quadrennial Technology Review*, DOE-S/0001 (Washington, D.C.: U.S. Department of Energy, September 2011), http://energy.gov/under-secretary-science-and-energy/downloads/first-quadrennial-technology-review-qtr-2011.
6. "Using Behavioral Science Insights to Better Serve the American People," Executive Order No. 13707 of September 15, 2015, 80 FR 56365, https://federalregister.gov/a/2015-23630.

Overcoming Barriers to Utilizing Social Science to Build Effective Energy Programs

Barrier: Lack of incentives and mechanisms to incorporate decision science research in new and existing energy programs.

Strategy #1: Government agencies carrying out applied work should retain social science expertise by mandating the inclusion of social scientists in program staff and advisory committees.

DOE has a multitude of programs in both technology development and technology deployment whose success is determined in part by nontechnical factors such as human decision-making; for example, weatherization assistance programs for low-income households, the Better Buildings Challenge, and the Appliance and Equipment Standards Program. Many of these programs have taken steps to incorporate social science. For instance, ENERGY STAR labels that designate the most energy efficient, cost-effective products communicate the most relevant information to consumers in a recognizable, standardized way. Fully capitalizing on the benefits offered by new technologies would be facilitated by a more comprehensive effort to include decision science researchers within government agencies and within partner organizations.

Suggested Steps:

- The Intergovernmental Personnel Act Mobility Program supports temporary positions within the federal government and state and local governments, colleges and universities, Indian tribal governments, and federally funded research and development centers. Making use of this program could provide one avenue to bring decision science researchers into government programs and applied research programs.
- DOE could hire social scientists at the conception of a new program to ensure that insights from social science research are a core part of the program.
- DOE could include decision science researchers on Federal Advisory Committee Act committees.
- Government agencies should require implementation partners, including university and National Laboratory researchers and outside contractors, to hire and consult social scientists to address nontechnical factors in energy programs.

Strategy #2: Encourage and foster the success of new programs.

The creation of new energy programs within DOE and other government agencies presents an opportunity not only to incorporate insights from decision science research, but to treat decision science as a core principle on which new programs are built. Support from key stakeholders will be necessary to ensure new programs are an agency priority.

Suggested Steps:

- The leadership of each government agency could communicate to program managers and administrators the utility of including decision science research in new programs and could direct that making better use of this research should be a priority throughout the agency.
- Agencies should make greater use of grand challenges and big idea contests that have the capacity to crowd-source novel solutions from diverse groups of researchers. Prize contests encourage the formation of multidisciplinary teams, because a broad array of expertise is often advantageous in finding creative solutions to problems. These program challenges could be framed around societal solutions in addition to technical solutions and could even explicitly require the use of decision science.
- The designers of new programs should better anticipate potential regulatory roadblocks and stakeholder resistance. Addressing potential pushback upfront could facilitate not only introduction of new programs, but also their eventual expansion.

Barrier: Differences in disciplinary culture that separate the two communities and a paucity of existing programs supporting and funding interdisciplinary research.

Strategy: Create venues for encouraging and incentivizing collaborations between applied and basic research teams.

Currently, both applied research and basic research laboratories are producing informative, groundbreaking work. However, these two types of research are often siloed – with applied research mostly conducted at DOE and the National Laboratories, and basic research in the social sciences performed in academic laboratories. Further separating these two types of research is the fact that research funding is often provided by different agencies. This separation disincentivizes collaboration. Research that combines concepts from both applied research and basic research would facilitate the integration of concepts about human behavior and decision-making directly into research about new technologies. Another advantage of this approach is that it is likely to open up new directions in basic research. All stakeholders – utilities, vendors, industry representatives, academics, the National Laboratories, government agencies, city/state representatives – can promote collaborations and ensure their success.

Suggested Steps:

- White House SBST should form a working group to identify strategies to bridge the two communities.
- Use funding to incentivize collaborations and interdisciplinary work. Cofunding from multiple agencies, including DOE and NSF, could encourage joint research projects between DOE, academic researchers, and the White House SBST. For instance, in 2015, NSF had a solicitation for Interdisciplinary Behavioral and Social Science Research. This funding model could continue collaboratively with DOE, with the understanding that the NSF Social and Behavioral Sciences Directorate has been severely underfunded recently and NSF will not be able to equally cofund the work.
- To assist agency leadership, NGOs have a role to play by identifying champions at the leadership level of all major federal agencies and communicating the value of decision science research. Champions at DOE and NSF, in addition to the Department of Transportation, Department of Housing and Urban Development, Department of Commerce, and the Environmental Protection Agency, could elevate the importance of decision science research and identify areas where collaborations with decision scientists would be consistent with the agency's current priorities. These champions can foster successful collaborations between social science and applied science by providing focus, encouragement, support, and direction.
- Directors of National Laboratories should look for opportunities to incorporate decision science research into Laboratory Directed Research and Development. These activities often function as a proving ground for concepts that form the basis of DOE programs, and the work incentivizes interdisciplinary teams to work on creative, innovative projects.
- Professional societies should use their publications and annual meetings to present opportunities for how basic research can advance applied problems and to highlight applied problems that should form the basis of basic research questions.

Barrier: Lack of opportunities for bringing social and applied scientists together to learn about each other's work, and lack of mechanisms for effective communication between the two groups.

Strategy #1: Improve dissemination of information.

Findings from social science and applied research are predominantly published in specialized academic journals that are likely to be read by one but not both research groups, thus restricting the spread of key findings across groups. Additionally, social scientists and applied researchers may not have access to the prominent journals from the other field. On the other hand, utilities may not have access to any academic journal. However, all of these groups need access to information that could be used to shape research questions, conduct research, and inform new programs or practices. Considering all of the motivations for sharing and communication between stakeholders will help improve dissemination of information.

Suggested Steps:

- DOE could commission a project through the National Academy of Sciences that addresses information sharing between the social science research community and the applied research/programs community.
    - This project could publicize well-established insights from the social sciences within government agencies to ensure that these insights are applied to new programs in addition to past programs, thus ensuring institutional memory.
    - This project could aim to teach the social scientists the language of the applied research field and, conversely, teach applied scientists the language of the social sciences field. These groups may overlook each other's work if they do not know where to find key research findings. This project could also teach social scientists and applied scientists how to assess the quality of information from other fields.
- Professional societies could create and publicize an inventory for resources from the social sciences that would be applicable to energy research. This inventory could include a database of researchers who would agree to be consulted by government program officers for information regarding specific types of research in addition to social science strategies. The inventory may have the added benefit of incentivizing researchers to publish data that they otherwise would not.
- Utilities should make public the records of installations of technologies such as solar panels so that researchers can make use of this information in their studies.

Strategy #2: Bridge the social science research community and DOE.

The applied research community and the social science research community would each benefit from greater connections to the other side. The social science researchers can inform nontechnical aspects of a program, such as diffusion of a new technology, while applied researchers can suggest to the social science community research questions that are rooted in practical experience. Government agencies and nonprofit organizations like professional societies can both play key roles in fostering these connections to take advantage of existing and future research.

Suggested Steps:

- Professional societies could offer as a service a way to connect basic scientists, who might be able to contribute to applied problems.
- DOE should work with professional societies to arrange briefing sessions for DOE employees and policy fellows to learn about social science that could be useful for energy programs.
- OSTP, SBST, and NSTC should ensure that government agencies are sharing information and insight on similar programs and could also hold workshops to review efforts to incorporate social science within the government.
- Universities and professional societies should raise awareness within the government about the growth of multidisciplinary energy and environmental programs such as the Center for Research on Environmental Decisions at Columbia University and the Scott Institute for Energy Innovation at Carnegie Mellon University.

Conclusion: Setting a Research Agenda

Multiple reports have underscored the importance of a program that unites both social sciences and applied energy research. Workshop participants suggested five ways to accomplish this goal. DOE should consider funding a pilot research program to address each of the research areas below. NSF could administer the research programs.

1. Research institutional behavior and motivations in order to build on the research that has already been done on individual behavior. Information on organizational systemic effects may provide new insights that lead to larger savings. An understanding of how strategies for individuals work or do not work on an institutional level would be useful. Research on motivations and incentives for different groups, such as utilities and municipalities, is also needed.

2. Study the deployment and use of technology. Much research thus far has focused on insights and adoption of technology. More scholarship is needed on the process of translating research into a policy or program. It is important to understand why managers do not deploy behavioral insights in some cases and why, in other cases, those insights sometimes become locked in.

3. Include more research focused on the social sciences within communication studies. Specifically, research is needed on methods of improving communication and coordination across government entities (organization behavior studies, economics, etc.).

4. Study the methods for evaluating research potential; for instance, how to identify and evaluate the potential total effect of an initiative (technical potential) and the changeability of the target behavior (behavioral plasticity).

5. Study messaging. How can information regarding new technologies be made more relatable to people? How can different demographics be reached? How can a message be tailored based on the audience, whether an individual, a city, a state, or a utility?

Appendix A: Workshop Agenda

Day One: How DOE Programs like SEEDS Integrate with Energy Technology Research Hickok Cole Architects Classroom District Architecture Center, 421 7th Street NW, Washington, D.C. Thursday, December 3, 2015	
8:30 – 9:00	**Registration & Breakfast**
9:00 – 9:15	**Welcome** **Maxine Savitz**, Vice Chair, PCAST; General Manager, Honeywell, Inc., retired
9:15 – 10:00	**SunShot Overview & Workshop Objectives for Day One** **Elaine Ulrich**, Solar Energy Technologies Office, Team Lead Soft Costs of Solar Deployment, U.S. Department of Energy
10:00 – 11:30	**Breakout Session 1:** Advancing the state-of-the-art decision science research through comprehensive studies of solar technology, performance, and deployment data
11:30 – 11:40	**Break**
11:40 – 12:30	**SEEDS Panel 1 Discussion:** **Jeffrey Alexander**, Associate Director for Research and Analytics, Center for Science, Technology and Economic Development, SRI International **Benjamin Sigrin**, Energy Systems Modeling Engineer, Strategic Energy Analysis Center, National Renewable Energy Laboratory **Kiran Lakkaraju**, Senior Member of Technical Staff, Sandia National Laboratories & **Yevgeniy Vorobeychik**, Assistant Professor of Computer Science, Vanderbilt University (Three 10-minute talks followed by Q&A)
12:30 – 1:30	**Lunch and Keynote Address** **Ellen Williams**, Director, Advanced Research Projects Agency-Energy, U.S. Department of Energy
1:30 – 2:20	**SEEDS Panel 2 Discussion:** **Jessika Trancik**, Assistant Professor of Engineering Systems, Massachusetts Institute of Technology **Varun Rai**, Assistant Professor of Public Affairs, Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin Presented by **Joshua Huneycutt**, Solar Energy Technologies Office, U.S. Department of Energy **Bryan Bollinger**, Assistant Professor, The Fuqua School of Business, Duke University (Three 10-minute talks followed by Q&A)
2:20 – 3:30	**Breakout Session 2:** Outcomes from the SEEDS program and future opportunities
3:30 – 3:40	**Break**

3:40 – 4:50	**Breakout Session 3:** Evaluating energy grant programs' impact and effectiveness
4:50 – 5:20	**Report Out:** Review of the key takeaways from discussions in the breakout sessions **Beth Karlin**, Research Director, Norman Lear Center, University of Southern California
5:20 – 5:30	**Closing remarks** **Elaine Ulrich**

Day Two: Identifying New Opportunities for Collaborative Research Programs Hickok Cole Architects Classroom District Architecture Center, 421 7th Street NW, Washington, D.C. Friday, December 4, 2015	
8:00 – 8:30	**Breakfast**
8:30 – 8:45	**Overview of Day Two** **Maxine Savitz**, Vice Chair, PCAST; General Manager, Honeywell, Inc., retired
8:45 – 9:15	**Update from The White House Social and Behavioral Sciences Team** **Michael Hand**, Fellow, Social and Behavioral Sciences Team; Office of Evaluation Services, General Services Administration Introduction: **Sarah Brookhart**, Executive Director, Association for Psychological Science (15-minute presentation; 15 minutes for Q&A)
9:15 – 9:45	**Insights from NSF programs** **Cheryl Eavey**, Program Director, Methodology, Measurement, and Statistics, Directorate for Social, Behavioral and Economic Sciences, National Science Foundation **Robert O'Connor**, Program Director, Decision, Risk and Management Sciences, Division of Social and Economic Sciences, Directorate for Social, Behavioral and Economic Sciences, National Science Foundation **Moderator: Granger Morgan**, Hamerschlag University Professor of Engineering; Professor, Department of Engineering and Public Policy, Carnegie Mellon University; Codirector, Center for Climate and Energy Decision Making (10 minutes for presentations and 20 minutes of discussion)
9:45 – 10:05	**Lessons from Energy Conservation and Efficiency Field Studies** **Alex Davis**, Assistant Professor, Department of Engineering and Public Policy, Carnegie Mellon University **Moderator: Granger Morgan**
10:05 – 10:15	**Discussion**
10:15 – 10:30	**Break**

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10:30 – 11:30	**Thoughts on Social Science in Energy Research: Scholars from Academia** **Beth Karlin**, Research Director, Norman Lear Center, University of Southern California **Shahzeen Attari**, Assistant Professor, School of Public and Environmental Affairs, Indiana University Bloomington **Michael Vandenbergh**, David Daniels Allen Distinguished Chair of Law; Director, Climate Change Research Network; Codirector, Energy, Environment and Land Use Program, Vanderbilt Law School **Moderator: Beth Karlin**
11:30 – 12:30	**Thoughts on Social Science in Energy Research: Scholars from National Labs** **Doug Arent**, Executive Director, Joint Institute for Strategic Energy Analysis, National Renewable Energy Laboratory **Margaret Taylor**, Project Scientist, Lawrence Berkeley National Laboratory; Engineering Research Associate, Stanford University **Steve Isley**, Postdoctoral Researcher, National Renewable Energy Laboratory **Moderator: Doug Arent**
12:30 – 1:30	**Lunch and Keynote Address** **Fay Lomax Cook**, Assistant Director for Social, Behavioral, and Economic Sciences, National Science Foundation; Professor, Human Development and Social Policy (on leave); Faculty Fellow, Institute for Policy Research, Northwestern University "How Can the Social and Behavioral Sciences Contribute to Energy Research and Policy?"
1:30 – 3:20	**Concurrent Breakout Sessions** Developing Behavioral-Based Programs at the National Laboratories and Other Agencies 1. **Key insights**: What key insights emerged from the day's session(s)? 2. **Gaps/Issues**: Were there any gaps or unresolved issues? 3. **Opportunities**: What are the opportunities for enhanced collaboration? 4. **Next steps**: What are the next steps to take action on these ideas?
3:20 – 3:50	**Reports from breakout sessions**
3:50 – 4:00	**Closing Remarks** **Maxine Savitz**

Appendix B: Speaker Biographies

Jeffrey Alexander is Associate Director for Research and Analytics at the Center for Science, Technology, and Economic Development, SRI International. He has over twenty years of experience in developing, conducting, and supervising in-depth studies analyzing critical topics in science and technology policy, including the management of R&D initiatives and organizations, evaluation of government-supported R&D programs, strategy development for technology-based regional clusters, and an understanding of the nature and dynamics of technological innovation. As part of his work at SRI, Alexander developed new methodologies for assessing regional innovation assets and workforce capabilities related to emerging industries; explored the use of machine learning to investigate the detection and forecasting of emerging technologies; and studied new techniques for measuring innovation and innovative capacity in organizations, regions, and nations. He has provided technical and strategic consultation to the National Science Foundation; to state agencies in Utah, New York, and Georgia; to private corporate R&D organizations, and to government R&D agencies in Saudi Arabia and Lithuania. He is the coauthor of *Global and Local Knowledge: Global Transatlantic Public-Private Partnerships for Research and Technology Development* and has published articles in journals such as *Research Policy*, *Research Evaluation*, *The Journal of Technology Transfer*, *Technovation*, and the *International Journal of Technology Management*. Alexander is also President of the Washington, D.C., chapter of the Technology Transfer Society and is active in the Industrial Research Institute. He received his Ph.D. in the Management of Science, Technology, and Innovation from the School of Business at George Washington University. He holds a B.A. in International Relations from Stanford University, where he also earned honors from the Program in Science, Technology, and Society.

Doug Arent is the Executive Director of the Joint Institute for Strategic Energy Analysis at the National Renewable Energy Laboratory. Arent specializes in strategic planning and financial analysis competencies, clean energy technologies, and energy and water issues, as well as international and governmental policies. In addition to his responsibilities at the National Renewable Energy Laboratory, he is a Senior Visiting Fellow at the Center for Strategic and International Studies, a member of the National Research Council Committee to Advise the U.S. Global Change Research Program, a Member of the Keystone Energy Board, and Associate Editor for the journal *Renewable and Sustainable Energy Reviews*. Arent was recently invited to serve on the World Economic Forum Future of Electricity Working Group and is a member of the International Advisory Board for the journal *Energy Policy*. He was a Coordinating Lead Author for the 5th Assessment Report of the Intergovernmental Panel on Climate Change. He served on the National Academy of Sciences panel on Limiting the Magnitude of Future Climate Change from 2008 to 2010, and on the Executive Council of the U.S. Association of Energy Economists.

Shahzeen Attari's research focuses on the psychology of resource use. In particular, her work aims to identify factors that promote resource conservation and sustainability. Her papers entitled "Public Perceptions of Energy Consumption and Savings" and "Perceptions of Water Use" were published in the *Proceedings of the National Academies of Sciences* and have been summarized in a variety of venues, including *The Economist*, *The New York Times*, CNN, and BBC. She is an Assistant Professor at the School of Public and Environmental Affairs at Indiana University Bloomington. Previously, she was a postdoctoral fellow at the Earth Institute and the Center for Research on Environmental Decisions at Columbia University. She holds a Ph.D. in Civil and Environmental Engineering and Engineering and Public Policy from Carnegie Mellon University, and a B.S. in Engineering Physics from the University of Illinois at Urbana-Champaign.

Bryan Bollinger is an Assistant Professor of Marketing at Duke University's Fuqua School of Business. His research interests lie at the intersection of marketing, empirical industrial organization, and economic policy. Current research includes technology adoption decisions by consumers and firms, demand- and supply-side spillover effects, and the effectiveness of marketing-mix variables and policy tools in affecting con-

sumer and firm behavior. Examples include work on solar photovoltaic adoption, learning-by-doing in solar photovoltaic installations, green technology adoption by dry cleaning firms, heterogeneous demand effects of smart meter technologies, the effect of nutritional labeling, dynamic network formation and propagation of information, advertising, and channel interaction effects, and prosocial marketing. Bollinger received his B.A. and B.E. in engineering at Dartmouth College and his M.A. in Economics and Ph.D. in Marketing at Stanford University.

Sarah Brookhart was named Executive Director of the Association for Psychological Science (APS) on September 1, 2015. Brookhart has been with APS since 1990, when she was hired as APS's first Director of Government Relations, and has been instrumental in shaping the organization's growth and impact particularly in public policy and public outreach. She became APS's first Director of Policy and Communications in 1997. Prior to assuming the post of Executive Director, Brookhart served as APS Deputy Director for thirteen years. In her capacity as Executive Director, Brookhart also serves as Publisher of the *Observer*, the APS's online and print magazine and as an ex officio member of the APS Board. Brookhart has an M.A. in Public Policy from George Washington University and a B.A. in English from The American University.

Fay Lomax Cook is Assistant Director of the National Science Foundation, where she has headed the Directorate for Social, Behavioral and Economic Sciences (SBE) since September 2014. SBE's mission is to promote the understanding of human behavior and social institutions, the ways economic, environmental, political, and social forces affect the lives of people from birth to old age, and the ways people affect these forces. She is on leave as a Professor at Northwestern University, where she is a Faculty Fellow of the Institute for Policy Research and a Professor of Human Development and Social Policy in the School of Education and Social Policy. From 1996 to fall 2012, she directed the Institute for Policy Research at Northwestern University. Her research focuses on the interrelationships between public opinion and social policy, the politics of public policy, public deliberation, energy policy, and the dynamics of public and elite support for programs for older Americans, particularly Social Security. She is the author of many scholarly articles and book chapters as well as five books, including most recently *Talking Together: Public Deliberation and Political Participation in America*. She is Past President of the Gerontological Society of America, an Elected Member of the National Academy of Social Insurance, and a Fellow of the Gerontological Society of America. She has been a Fellow at the Center for Advanced Study in the Behavioral Sciences and a Visiting Scholar at the Russell Sage Foundation.

Alex Davis is an Assistant Professor in the Department of Engineering and Public Policy at Carnegie Mellon University. He is a member of the Behavior, Decision, and Policy Group, the Carnegie Electricity Industry Center, and the Center for Climate and Energy Decision Making. His research focuses on the behavioral foundations of policy, applied to innovation and entrepreneurship, energy, the environment, health, and information and communication technologies. Davis earned his B.S. in Psychology from Northern Arizona University and his M.S. and Ph.D. in Behavioral Decision Research from Carnegie Mellon University. He worked as a Postdoctoral Fellow and Research Scientist at Carnegie Mellon University prior to joining the faculty at Carnegie Mellon.

Cheryl L. Eavey is Program Director of the Methodology, Measurement, and Statistics (MMS) Program in the Division of Social and Economic Sciences at the National Science Foundation. She has been at the Foundation since 1993. In addition to MMS, she has been involved in a number of National Science Foundation (NSF) activities, including most recently the NSF-Census Research Network, Software Infrastructure for Sustained Innovation (SI2), Water Sustainability and Climate, and Data Infrastructure Building Blocks. She coordinates the management of the SBE large-scale projects on Decision Making Under Uncertainty, and chaired NSF's Art of Science Project from 2001 to 2010. Eavey earned a B.S. in Mathematics and Political Science from Valparaiso University and an M.A. and Ph.D. in Political Science from Michigan State University. She has served on the faculty of the Political Science Department at Florida State University, the Business School at Washington University in St. Louis, and the U.S. Business School in Prague.

Michael Hand is a Research Economist with the U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station in Missoula, Montana, currently serving as a Forest Service – sponsored Fellow on the White House Social and Behavioral Sciences Team (SBST). Hand's work with SBST focuses primarily on projects related to energy efficiency, environmental quality, and natural resource management. His research interests include the benefits people derive from the natural environment, economic vulnerability and resilience to climate-related ecological changes, the economics of wildfire suppression, and the role of risk attitudes in public decision-making. He holds a Ph.D. in Economics from the University of New Mexico.

Steve Isley is a Postdoctoral Researcher at the National Renewable Energy Laboratory (NREL). His research centers on human behavior, energy use, and how new technology can be used to help people make more energy-efficient decisions and inform energy systems integration. Prior to joining NREL, Isley completed his Ph.D. at the Pardee RAND Graduate School – a graduate program housed within The RAND Corporation – where he worked on an array of projects involving aspects of law enforcement, mobile technology, privacy, agent-based modeling, and political economics. He also has an M.S. in Aerospace Engineering from the Georgia Institute of Technology and a B.S. in the same from the University of Washington.

Beth Karlin is Research Director at the University of Southern California's Norman Lear Center, where she studies the role of new media and technology in social and environmental change. Current projects investigate energy efficiency, documentary film, and digital activism. She has published her work in venues ranging from *Psychological Bulletin* to *Peace Studies* (as well as some that don't start with the letter p) and lectures regularly on transformational media and the psychology of sustainability. Before receiving her Ph.D. in Social Ecology, Karlin spent nearly a decade working in K-12 education, holding positions as a teacher, counselor, curriculum consultant, and school administrator. She believes that the role of a researcher is not only to better understand the world but to improve it, and she hopes her work is able to serve both purposes.

Kiran Lakkaraju is a Senior Member of the Technical Staff at Sandia National Laboratories, New Mexico, in the Cognitive Science and Applications group. He received his Ph.D. in Computer Science from the University of Illinois. He has extensive experience in agent-based modeling and simulation of social systems. His interests include developing agent models that capture "heavyweight" actions, such as adopting solar photovoltaics, and understanding human behavior online (both observationally and experimentally) for validation of social models. He is currently building a social experimentation platform (the Controlled, Large, Online Social Experimentation platform). In addition, he has led an effort to study player behavior in massively multiplayer online games at Sandia National Laboratories. He is Coprincipal Investigator of a SunShot-funded project to develop data-driven models of residential photovoltaic adoption.

M. Granger Morgan is Hamerschlag University Professor of Engineering at Carnegie Mellon University, where he is Professor in the Department of Engineering and Public Policy (EPP). He served for thirty-eight years as the founding Department Head in EPP, stepping down in August 2014. He also holds academic appointments in the Department of Electrical and Computer Engineering and in the H. John Heinz III College of Public Policy and Management. His research addresses problems in science, technology, and public policy with a particular focus on energy, environmental systems, climate change, decision-making, and risk analysis. Much of his work has involved the development and demonstration of methods to characterize and treat uncertainty in quantitative policy analysis. Morgan is Codirector of the Center for Climate and Energy Decision Making and Codirector of the Carnegie Mellon Electricity Industry Center. He serves as Chair of the Scientific and Technical Council for the International Risk Governance Council. He is a Member of the National Academy of Science (NAS) and involved in a variety of NAS activities as well as public- and private-sector advisory committees. Morgan cochairs the American Academy of Arts and Sciences' Alternative Energy Future project.

Robert O'Connor directs the Decision, Risk and Management Sciences Program at the National Science Foundation (NSF). At NSF, he also serves on the management teams for the Decision Making under Un-

certainty for Climate Change centers and two competitions: Critical Resilient Infrastructure Systems and Processes; and Innovations at the Nexus of Food, Energy, and Water Systems. O'Connor represented the NSF on the National Climate Assessment and Development Advisory Committee, a federal advisory committee that prepared the National Climate Assessment. He currently serves on the Subcommittee on Disaster Reduction of the National Science and Technology Council of the Executive Office of the President. Prior to coming to NSF, O'Connor was a Professor of Political Science at the Pennsylvania State University. The U.S. Department of Energy, U.S. Environmental Protection Agency, the National Oceanographic and Atmospheric Administration, and the National Science Foundation funded O'Connor's research into public perceptions of cumulative, uncertain long-term risks such as climate change. His most recent articles have appeared in the *Agricultural and Resource Economics Review*, *Environment and Behavior*, *Global Environmental Change*, *Journal of Environmental Education*, *Journal of Natural Resources and Life Sciences Education*, *Risk Analysis*, the *Journal of Risk Research*, and *WIRE's Climate Change*. O'Connor earned his undergraduate degree at Johns Hopkins University and his Ph.D. in Political Science at the University of North Carolina at Chapel Hill.

Varun Rai is an Assistant Professor at the LBJ School of Public Affairs at the University of Texas at Austin, where he directs the Energy Systems Transformation Research Group. He studies technological change in energy, with a focus on the barriers in the energy innovation-diffusion process. His research combines energy systems modeling with the political economy of energy markets to understand how changes in energy technologies, market conditions, policies and regulation, and environment could impact energy generation. He has presented at several forums, including United States Senate Briefings, Global Economic Symposium, and Climate One at Commonwealth Club. His research has been discussed in *The New York Times*, *Wall Street Journal*, *Washington Post*, and Bloomberg News. He was a Global Economic Fellow in 2009 and has held the Elspeth Rostow Centennial Fellowship since 2010. In July 2013 he was appointed as a Commissioner for the vertically integrated electric utility Austin Energy, City of Austin (Texas). Rai received his Ph.D. and M.S. in Mechanical Engineering from Stanford University and his undergraduate degree in Mechanical Engineering from the Indian Institute of Technology Kharagpur.

Maxine Savitz is the retired General Manager of Technology Partnerships at Honeywell, Inc. During her time at Honeywell, she oversaw the development and manufacturing of innovative materials for the aerospace, transportation, and industrial sectors. From 1979 to 1983, she served as Deputy Assistant Secretary for Conservation in the U.S. Department of Energy. She was Vice President of the National Academy of Engineering from 2006 to 2014. She serves on advisory bodies for the Sandia National Laboratory and Pacific Northwest National Laboratory and is a Member of the Board of Directors of the American Council for an Energy Efficient Economy. She served on the National Academy's Committee on America's Energy Future and was Vice-Chair of the Energy Efficiency Committee.She is Vice-Chair of the President's Council of Advisors on Science and Technology. She was elected a Fellow of the American Academy of Arts and Sciences in 2013 and cochairs its Alternative Energy Future project.

Ben Sigrin is an Energy Systems Modeling Engineer in the National Renewable Energy Laboratory's (NREL) Energy Forecasting and Modeling group. His research focuses on capacity expansion and grid operations in distributed generation and bulk power markets, and he is the Principal Investigator for the NREL-led SEEDS project. He received his M.S. in Energy and Earth Resources from the University of Texas in 2013.

Margaret Taylor investigates how policy and innovation interact in climate and energy-related industries in order to inspire practical solutions to the public challenges associated with energy use. A former Professor of Public Policy at the University of California, Berkeley, and Cochair of the annual Behavior, Energy, and Climate Change conference, Taylor has dual appointments at Stanford University's Precourt Energy Efficiency Center and at Lawrence Berkeley National Laboratory. Her research, which has won awards from the Academy of Management and the International Institute of Applied Systems Analysis, is empirically grounded and multidisciplinary, drawing insights from economics, organization science, and engineering. Her many publications have spanned innovations in the pollution control, renewable energy,

automotive, buildings, and appliance industries, among others, and her research has encompassed both the policy process and the direct and indirect effects of a wide variety of policy instruments. Her current research focuses on the energy implications of the many innovations underway in the transportation sector and on how energy policy can better contend with product design and market power.

Jessika Trancik is the Atlantic Richfield Career Development Assistant Professor in Energy Studies at MIT's Institute for Data, Systems, and Society. Her research centers on evaluating the environmental impacts and costs of energy technologies, and setting design targets to help accelerate the development of these technologies in the laboratory. This work involves assembling and analyzing expansive datasets and developing new quantitative models and theory. Projects focus on electricity and transportation, with an emphasis on solar energy conversion and storage technologies. Trancik was a Postdoctoral Fellow at the Santa Fe Institute and a Fellow at Columbia University's Earth Institute. She earned a B.S. in Materials Science and Engineering from Cornell University and a Ph.D. in Materials Science from Oxford University, where she studied as a Rhodes Scholar. She has also worked for the United Nations and as an advisor to the private sector on investment in low-carbon energy technologies. She has published in journals such as *Nature Climate Change*, *Nature*, *Proceedings of the National Academy of Sciences*, *Nano Letters*, and *Environmental Science and Technology*.

Elaine Ulrich is a Program Manager at the U.S. Department of Energy, where she leads the SunShot Balance of Systems/Soft Costs team, which works to reduce the nonhardware (soft costs) of solar, lower barriers to solar adoption, and foster market growth through support for state and local development and technical assistance programs; information and data assets; finance and business model development; workforce and training programs; and policy and regulatory analysis. A former American Association for the Advancement of Science Fellow, Ulrich has spent the past few years working on renewable energy. She previously held positions in the office of former U.S. Senator Ken Salazar, with the U.S. House of Representatives Committee on Science and Technology, the U.S. Department of Energy's Office of Strategic Planning and Analysis, and in the office of U.S. Representative Gabrielle Giffords, where she worked to build a comprehensive solar energy portfolio.

Michael Vandenbergh is Professor and David Daniels Allen Distinguished Chair of Law; Codirector, Energy, Environment and Land Use Program; and Director, Climate Change Research Network, at Vanderbilt University Law School. His work with Vanderbilt's Climate Change Research Network involves interdisciplinary teams that focus on energy use and carbon emissions from the household sector. His corporate work explores the social influences on firm behavior and the emergence of private environmental governance. Vandenbergh's articles have appeared in leading law journals, including the *Columbia Law Review*, *Harvard Environmental Law Review*, *Michigan Law Review*, and *New York University Law Review*, and in science journals such as *The Proceedings of the National Academy of Sciences*, *Nature Climate Change*, and *Energy Policy*. Three of his articles have been selected by *Land Use and Environmental Law Review* as one of the top environmental law articles of the year. His research has been discussed on National Public Radio's *All Things Considered* and in publications such as the *Miami Herald*, *National Geographic*, *Smithsonian*, *Scientific American*, the *Washington Post*, and *USA Today*. Before joining Vanderbilt's law faculty, Vandenbergh was a Partner at Latham & Watkins in Washington, D.C. He served as Chief of Staff of the Environmental Protection Agency from 1993 to 1995 and as a Law Clerk to Judge Edward R. Becker of the United States Court of Appeals for the Third Circuit in 1987 – 1988. A winner of the Hall-Hartman Teaching Award, he teaches courses in environmental law, energy, and property.

Yevgeniy Vorobeychik is an Assistant Professor of Computer Science and Computer Engineering at Vanderbilt University. Previously, he was a Principal Member of Technical Staff at Sandia National Laboratories. From 2008 to 2010 he was a Postdoctoral Research Associate at the University of Pennsylvania Computer and Information Science Department. He received his Ph.D. and M.S.E. in Computer Science and Engineering from the University of Michigan and a B.S. in Computer Engineering from Northwestern University. His

work focuses on game-theoretic modeling of security and privacy, algorithmic and behavioral game theory and incentive design, optimization, complex systems, epidemic control, network economics, and machine learning. Vorobeychik has published more than seventy-five research articles on these topics. He was nominated for the 2008 Association for Computing Machinery Doctoral Dissertation Award and received honorable mention for the 2008 International Foundation for Autonomous Agents and Multiagent Systems Distinguished Dissertation Award. In 2012 he was nominated for the Sandia Employee Recognition Award for Technical Excellence. He is also a recipient of a National Science Foundation Integrative Graduate Education and Research Traineeship Interdisciplinary Research Fellowship at the University of Michigan, as well as a Distinguished Computer Engineering undergraduate award at Northwestern University.

Appendix C: Participant List

Jeffrey Alexander: Associate Director for Research and Analytics, Center for Science, Technology and Economic Development, SRI International

Doug Arent: Executive Director, Joint Institute for Strategic Energy Analysis, National Renewable Energy Laboratory

Shahzeen Attari: Assistant Professor, School of Public and Environmental Affairs, Indiana University Bloomington

Sam Baldwin: Chief Science Officer, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

Ruth Greenspan Bell: Public Policy Scholar, Environmental Change and Security Program, Woodrow Wilson International Center for Scholars; Research Associate, Center for Decision Sciences, Columbia University Business School; Visiting Scholar, Environmental Law Institute

Bryan Bollinger: Assistant Professor of Marketing, The Fuqua School of Business, Duke University

Sarah Brookhart: Executive Director, Association for Psychological Science

Adam Cohen: Science Team Lead, Split Technology, Inc.; Cofounder, CertainSolar, Inc.

Craig Connelly: Special Assistant to the Program Director, SunShot Initiative, Solar Energy Technologies Office, U.S. Department of Energy

Fay Lomax Cook: Assistant Director for the Social, Behavioral, and Economic Sciences, National Science Foundation; Professor, Human Development and Social Policy (on leave), Northwestern University; Faculty Fellow, Institute for Policy Research, Northwestern University

Alex Davis: Assistant Professor, Department of Engineering and Public Policy, Carnegie Mellon University

Julia Day: Assistant Professor, Department of Apparel, Textiles, and Interior Design, Kansas State University

Andy DeSoto: Methodology Fellow, Association for Psychological Science

Cheryl Eavey: Program Director, Methodology, Measurement, and Statistics, Directorate for Social, Behavioral & Economic Sciences (SBE), National Science Foundation

Karen Ehrhardt-Martinez: Associate Director and Social Science Expert, Navigant Consulting

Kenneth Gillingham: Assistant Professor of Environmental & Energy Economics (on leave), Yale University

Michael Hand: White House Social and Behavioral Sciences Team, Office of Evaluation Services, General Services Administration

Tianzhen Hong: Scientist, Simulation Research Group, Lawrence Berkeley National Laboratory

Josh Huneycutt: Program Manager, SunShot Initiative, Solar Energy Technologies Office, U.S. Department of Energy

Stephanie Johnson: SunShot Science & Technology Policy Fellow, Solar Energy Technologies Office, U.S. Department of Energy

Shalin Jyotishi: Program Coordinator for Science, Engineering and Technology, American Academy of Arts and Sciences

Beth Karlin: Research Director, Norman Lear Center, University of Southern California

Liz Keenan: Assistant Professor of Business Administration, Marketing Unit, Harvard Business School

Leidy Klotz: S. E. Liles, Jr. Distinguished Professor, Glenn Department of Civil Engineering, Clemson University

Lauren Kubiak: Energy Policy Analyst, Natural Resources Defense Council

Kiran Lakkaraju: Senior Member of Technical Staff, Cognitive Sciences and Systems, Sandia National Laboratories

Jared Langevin: EERE Science and Technology Policy Fellow, Building Technologies Office, U.S. Department of Energy

Alison Leaf: Hellman Fellow in Science and Technology Policy, American Academy of Arts and Sciences

Michael Li: Senior Policy Advisor, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy; Jack Mayernik Building Energy Analyst, National Renewable Energy Laboratory

Susan Mazur-Stommen: Principal and Founder, Indicia Consulting LLC; formerly Behavior and Human Dimensions Program Director, American Council for an Energy-Efficient Economy

M. Granger Morgan: Hamerschlag University Professor of Engineering; Professor, Department of Engineering and Public Policy, Carnegie Mellon University; Codirector, Center for Climate and Energy Decision Making

Cherry Murray: Benjamin Peirce Professor of Technology and Public Policy and Professor of Physics, Harvard School of Engineering and Applied Sciences

Christina Nichols: Contractor to the Solar Energy Technologies Program/SunShot Initiative, U.S. Department of Energy

Mary Ellen O'Connell: Interim Director, Board on Environmental Change and Society; Deputy Executive Director, Division of Behavioral and Social Sciences and Education, National Academies of Sciences, Engineering and Medicine

Robert O'Connor: Program Director, Decision, Risk and Management Sciences, Directorate for Social, Behavioral & Economic Sciences (SBE), National Science Foundation

Christopher Payne: Department Head, Building and Industrial Applications; Group Leader, Sustainable Federal Operations, Lawrence Berkeley National Laboratory

Patrick Phelan: Emerging Technologies Program Manager, Building Technologies Office, U.S. Department of Energy

Ammar Qusaibaty: Senior Renewable Energy Consultant, SunShot Program, U.S. Department of Energy

Varun Rai: Assistant Professor at the LBJ School of Public Affairs; Director, Energy Systems Transformation Research Group, University of Texas at Austin

John Randell: Program Director, Science, Technology, and Global Security, American Academy of Arts and Sciences

Philip Rubin: Senior Advisor to the President, Chief Executive Officer emeritus, Haskins Laboratories; formerly Principal Assistant Director for Science, White House Office of Science and Technology Policy

Maxine L. Savitz: Vice Chair, President's Council of Advisors on Science and Technology; General Manager, Honeywell, Inc., retired

Steven Sexton: Assistant Professor, Sanford School of Public Policy and Department of Economics; Faculty Fellow, The Energy Initiative, Duke University

Tarak Shah: Senior Advisor to the Under Secretary for Science and Energy, U.S. Department of Energy

Keerthi Shetty: Hellman Fellow in Science and Technology Policy, American Academy of Arts and Sciences

Benjamin Sigrin: Energy Systems Modeling Engineer, National Renewable Energy Laboratory

Paul Stern: Senior Scholar, Board on Environmental Change and Society, National Research Council

Ryan Stolley: AAAS Science and Technology Policy Fellow, Solar Energy Technologies Office, U.S. Department of Energy

Margaret Taylor: Project Scientist, Lawrence Berkeley National Laboratory; Engineering Research Associate, Stanford University

Jessika Trancik: Assistant Professor of Engineering Systems, Massachusetts Institute of Technology

Elaine Ulrich: Solar Energy Technologies Office, Team Lead Soft Costs of Solar Deployment, U.S. Department of Energy

Michael Vandenbergh: David Daniels Allen Distinguished Chair of Law; Director, Climate Change Research Network; Codirector, Energy, Environment and Land Use Program, Vanderbilt Law School

Yevgeniy Vorobeychik: Assistant Professor of Computer Science, School of Engineering, Vanderbilt University

Erez Yoeli: Research Scientist, Program for Evolutionary Dynamics, Harvard University

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