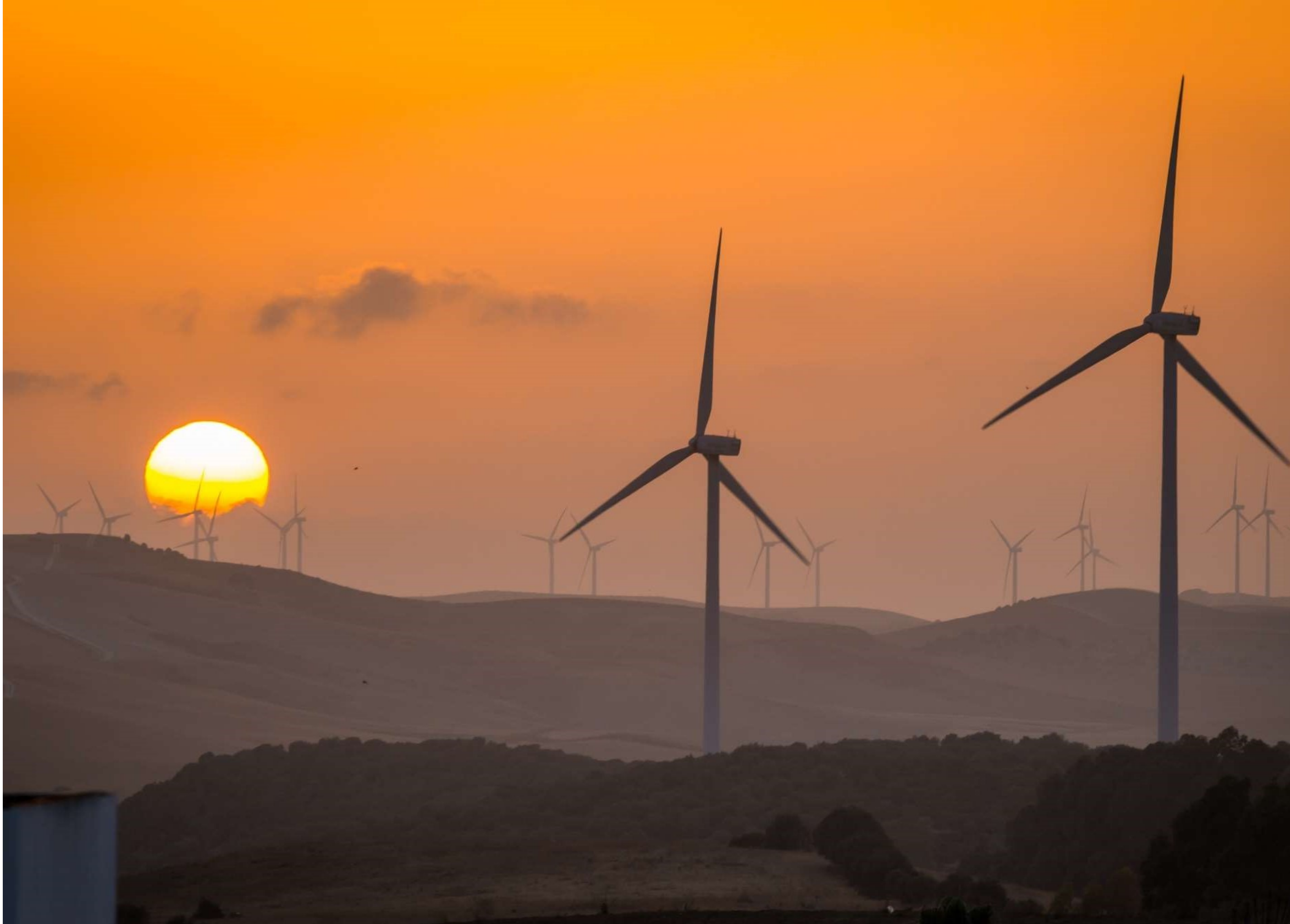

# Twenty questions about design behavior for sustainability

## How behavioral scientists, engineers, and architects can work together to advance how we all understand and practice design—in order to enhance sustainability in the built environment, and beyond.

**A Report from the *Nature Sustainability* Expert Panel on 'Behavioral science for design'**

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# Introduction

Our era, the Anthropocene, is defined by the fact that human behavior has become the dominant influence on the natural environment[1]. Given this essential role of human behavior, behavioral science must inform our pursuit of sustainability[2]. Promisingly, behavioral science is being used to encourage more sustainable *end-use* behavior, from learning generally why and when people act in more sustainable ways[3], to identifying specific ways to present information so that such behavior becomes more likely[4].

Our panel believes *design* behavior offers untapped potential for similar impact. Whether the result is a new building or a new policy, **design behavior turns existing situations into preferred ones[5], on a large scale** (full definitions are on the next page). Whereas end-use behavior can determine what happens in a situation, design behavior often determines the situation itself. End-use behavior is an office worker deciding whether to put on a sweater or turn up the thermostat. Designer behavior is deciding whether to heat that office with renewable solar energy or with mechanical systems powered by fossil fuels. What's more, designer behavior is what leads to entirely new approaches to more sustainable energy use in buildings.

While there is certainly overlap between end-use and design behavior, the latter cannot be understood by simply extending what has been learned about the former. Design behavior for sustainability is part of an interdependent network of judgments and decisions that are shaped by specific professional and socioeconomic contexts and that must consider both existing and preferred states of complex Anthropocene situations.

To advance understanding of design behavior for sustainability, our panel engaged more than three dozen experts from diverse fields—and spanning academia, practice, and policy. Panelists' perspectives were synthesized over the course of a year, with two days of in-person discussion preceded and followed by virtual collaboration. As an entry point to study design behavior for sustainability, our panel focused on the design of the human built environment. Such design shapes the quality of human life, and it sets in place long-term patterns of climate changing emissions and other planetary impacts[6]. Within this context, our panel identified ways to **advance current understanding and practice of design for sustainability** in the built environment. We also highlighted opportunities to **learn about design behaviors common to many sustainability challenges**, beyond the built environment.

The panel's findings are presented here as twenty high-priority questions, including challenges and opportunities embedded in each question. The questions are organized roughly according to the overlapping factors that influence behaviors:

- **individual and interpersonal** (i.e., designers' knowledge, values, customs, and social networks),
- **organizational** (i.e., designers' institutions and processes),
- **community** (i.e., designers' relationships with users and other stakeholders), and
- **enabling environment and policy** (i.e., designers' ability to contribute to global sustainability efforts, codes, and laws).

The opportunities abound. Our panel's sincere hope is that this report will inform and inspire others to join in this important work for shaping our Anthropocene present and future.

**Definitions.** The following definitions emerged from the panel and guide this report.

**Design behavior** - Creating with intent, informed by an understanding of humans and relevant contexts, to go from how things are to how we want them to be. Our panel focused on the design of the built environment. At the same time, we agree with the designer, behavioral scientist, and Nobel Laureate Herbert Simon, who wrote that 'everyone designs who devises courses of actions aimed at changing existing situations into preferred ones'. For this reason, we expect that many of the questions and insights from built environment design will be generalizable to design for sustainability in other contexts.

**Behavioral science** – Systematic analysis and study of human perception, judgment, and decision making and their influence on memory, learning, and action. In addition to considering individual reasons for behavior and interventions to change it, our panel also focused on behavior at scale: the interpersonal, organizational, cultural, and policy environments that also shape individual behavior.

**Sustainability** – Seeking the well-being of current and future generations within the limits of the natural world, balancing the ways in which short-term interests at the individual and organizational levels enhance or are at odds with those of global systems and communities in the longer term. Our panel sought integrated consideration of environmental, social, and ethical aspects of sustainability.

# The 20 Questions

# Behavior of designers (individual and interpersonal)

**Individual & Interpersonal**
Organizational
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The consequences of climate change are an example of how the large-scale systems humans have designed have brought about a situation that does not appear to be in our species' best interest. Economics[7] and law[8] have been able to broaden their theoretical foundations by rigorously incorporating behavioral science to extend and account for systematic deviations from 'rational' models of consistent thinking and behavior. Embracing and applying analogous advances to designer behavior can extend the boundaries of sustainability research and practice.

## 1. How does design behavior differ from end-use behavior?

Panelists prioritized the need to understand when it is appropriate (or not) to generalize from research on end-use behavior. Generalized research on human behavior can be used to develop and test hypotheses about when to expect differences for the specific context of design.

**Challenges.** Based on the distinctive attributes of design, as mentioned in the opportunities below, design behavior is likely to deviate in important and systematic ways from findings that have been observed more broadly across human populations.

**Opportunities.** In addition to research on human behavior in general, other lines of behavioral science research provide jumping off points for the specific study of design. Research on **expert and high-stakes decision making** is one such area of study. Designers, for example, are often highly trained experts operating in competitive environments, and both experience and competition are known to moderate human behaviors[9]. Another relevant line of research studies differences between decisions made for oneself and decisions made for others. These **self/other differences** have been found in behaviors relevant to design. Research shows, for example, that people can be more creative when making decisions for others when they make them for themselves[10]. And finally, a line of behavioral science research is uncovering cases in which cultural differences can lead to demonstrably different manifestations even of well-known and well-established behavioral tendencies[11]. The importance of any subculture must be considered when studying and designing for behavior change. The same is true of **designer culture**. Studying it through the lens of behavioral science might uncover ways the culture enables and inhibits more sustainable design.

## 2. What time scales do (and should) designers consider?

One cross-cutting behavioral challenge is to align the time scales humans use when making decisions with the time scales required for sustainability. The time scale that is incentivized, or just implied, can inhibit more sustainable choices. For example, consider a homeowner who decides not to install solar panels because they plan to sell their home in a few years, or a mayor who is not motivated to support a policy that would create green jobs because the jobs would not be filled until the next mayor is in office. Incentive structures or visioning techniques that help the homeowner expand the time scales they are considering may also be helpful for the mayor.

**Challenges.** Design for sustainability requires weighing costs and benefits that are often distributed over long periods of time. Discounting, a dominant approach to predicting and comparing future financial outcomes, is a central issue for sustainability, for example in the valuation of ecosystem services[12], in cooperative efforts to mitigate climate change[13], and in risk forecasts for infrastructure design[14]. An overarching challenge in these and other cases is that humans tend to overly discount future risk events, with daily concerns taking precedence over planning for the future[15].

Two related challenges when dealing with such long time scales and large projects are lock-in effect and path dependency. Lock-in occurs because the cost of changing outweighs the benefits of doing so. Path dependency explains the continued use of a product or practice based on historical preference or use. All facets of design are vulnerable to these effects, which behavioral science has shown tend to increase with physical size, the scale of resources required, and the number of people affected. As a result, some of the greatest effects of lock-in and path dependence are in the built environment[16].

**Opportunities.** Better understanding how designers do and should discount the future would inform long-term responses to sustainability challenges. For example, behavioral scientists have found that one reason for temporal discounting is that, as temporal distance increases, mental representations become more abstract. This suggests that **more vivid representations of the future** might help designers more accurately perceive the longevity of their projects and therefore help them frame planning on a longer time scale.

In a similar way, better understanding path dependence and lock-in might help designers more fairly compare the costs of changing our predecessors' designs with the benefits of a new design. For example, such comparisons are needed to weigh the benefits of building a new energy efficient building, versus maintaining an old one, thereby avoiding the need for new materials. More importantly, designers who are aware of path dependence and lock-in effects would be more likely to **consider how current designs will enable or constrain options for the future**.

## 3. How can designers overcome perceptions that sustainability is a trade-off?

Sustainability can be mistakenly seen as a trade-off, pursued at the expense of goals such as equity, wellbeing, culture, or cost-savings. One reason this is a harmful misperception is because all of these sub-goals are part of sustainability. A second reason this is a damaging misperception is because, while some trade-offs between these sub-goals are inevitable, in other cases, benefits in one goal lead to benefits in another. For example, a building that eliminates the need for central air conditioning through passive design will likely not only use less energy but also cost less in the first place and provide a healthier environment for occupants.

**Challenges.** Perceptions of sacrifice and trade-off perpetuate the idea that sustainable design costs more. Panelists noted that it is imperative to break this mold and show that sustainability is not only necessary but cost-effective. Sustainability is not a nice-to-have; it is the evolution of good design.

**Opportunities.** Behavioral science could help uncover reasons for these misperceptions of trade-off and how they manifest across various stakeholder groups, including among designers themselves. There is an opportunity to **study perceived trade-offs through the stakeholder engagement required for sustainable design**. For example, design thinking tools such as empathy mapping would not only yield insights for the design at hand, but also about more general perceptions of trade-off. With this more general understanding, behavioral scientists could then move on to finding ways to alleviate and even redefine these perceptions.

## 4. What mental models do (and should) designers bring?

Different designers bring different mental models to the task. Among built environment designers, for example, engineers and architects will likely bring very different blends of an openness to embracing creativity (a strength of many architects), and the need to be pragmatic and objective in order to solve problems (a strength of many engineers)[17]. In a similar way, different designers will assign different weights to quantitative performance measures, such as cost and energy use, and qualitative ones, such as the 'quality without a name'[18] expressed by great design works. These different mental models will shape how each designer strives to serve the needs of multiple stakeholders in both present conditions and projected future states.

**Challenges.** Panelists noted that designers' mental models must accommodate the range and interplay of multiple factors that influence human behavior, including environmental conditions, societal influences, and individual psychology, biases, heuristics, values and preferences. The conditions within which designers work and, in the case of professional design, the nature of those who are drawn to and thrive in the profession might result in some specific and predictable variance from the norm. Yet there is little behavioral research focusing directly on different groups of designers that could inform this view.

**Opportunities.** Inquiring into designers' mental models promises to deliver systematic insight into designers' thought processes to allow a better understanding of the value equation between creative expression, traditional pragmatic concerns, and new concerns that the Anthropocene brings. For example, to what extent do architects think of their role as stewards of more responsible energy use as opposed to one focused on cultivating people's relationships with space? Is a plan to 'bring the outside in' through a bank of continuous windows at the expense of energy performance considered a worthwhile sacrifice in the interest of providing better daylighting and views? How might this value equation be perceived differently by others who help with design, such as engineers or building owners and occupants? **Translating evidence from behavioral science to the design context**[19] can help us better understand and ask more pointed questions about the mental models we bring to design for sustainability.

## 5. What mental shortcuts do (and should) designers use?

We all use mental shortcuts and rules of thumb (or 'heuristics') to save time and thought. Rather than find the very best pasta sauce at the grocery store, for example, we may choose the first option we find that is under a certain price and sodium content. Or, we might simply choose the same sauce as last time. Panelists noted that designers use those kinds of shortcuts, just like everybody else. And, like other trained professionals operating in high-stakes situations, designers have evolved their own special heuristics for the task[20].

**Challenges.** Design of the built environment is a complex undertaking. Engineers and architects, for example, are expected to apply technical expertise while balancing structural, functional, and aesthetic objectives in a superior design solution within a specific context[21]. Designing for functionality relies on considering a range of factors, including usability[22], the accommodation of users' diverse preferences and capabilities[23], and respectful acknowledgement of users' intrinsic humanity and desire for autonomy[24]. These choices must also be responsive to the realities of cost, schedule, resources, and creative aspirations. What's more, making these decisions requires considering shifting uncertainties and incentives. To cope with such complexity, heuristics are necessary. These natural tendencies to create and use mental shortcuts can be heightened further when we're facing pressures of time and budget. Unfortunately, not all heuristics lead to positive outcomes. The heuristic to begin a new design from a previous successful project, for example, might limit our tendencies to pursue transformational changes in the interest of increased sustainability.

**Opportunities.** The literature on design heuristics in particular[25], and expert cognition in general, is a jumping off point for this question[26]. However, design for sustainability is likely to introduce, and require, its own heuristics. This is because designing for sustainability—with its need to consider varied, broad, and longer-term design goals about the built environment's impact on the Earth's ecosystems—further increases the cognitive load on designers. Panelists suggested that determining **which heuristics are barriers and enablers to achieving more sustainable outcomes** will be an important next step. Gaining this understanding would allow for study of purposeful introduction and removal of heuristics in order to enhance design outcomes. Study of end-users provides a promising example: a simple heuristic can lead to marked improvement in the understanding of energy use[27]. Heuristics promise similar potential to aid design behavior. Recognizing which heuristics may be more likely to be potent, and when, can guide how we test and develop new heuristic-driven mechanisms that enhance design for sustainability.

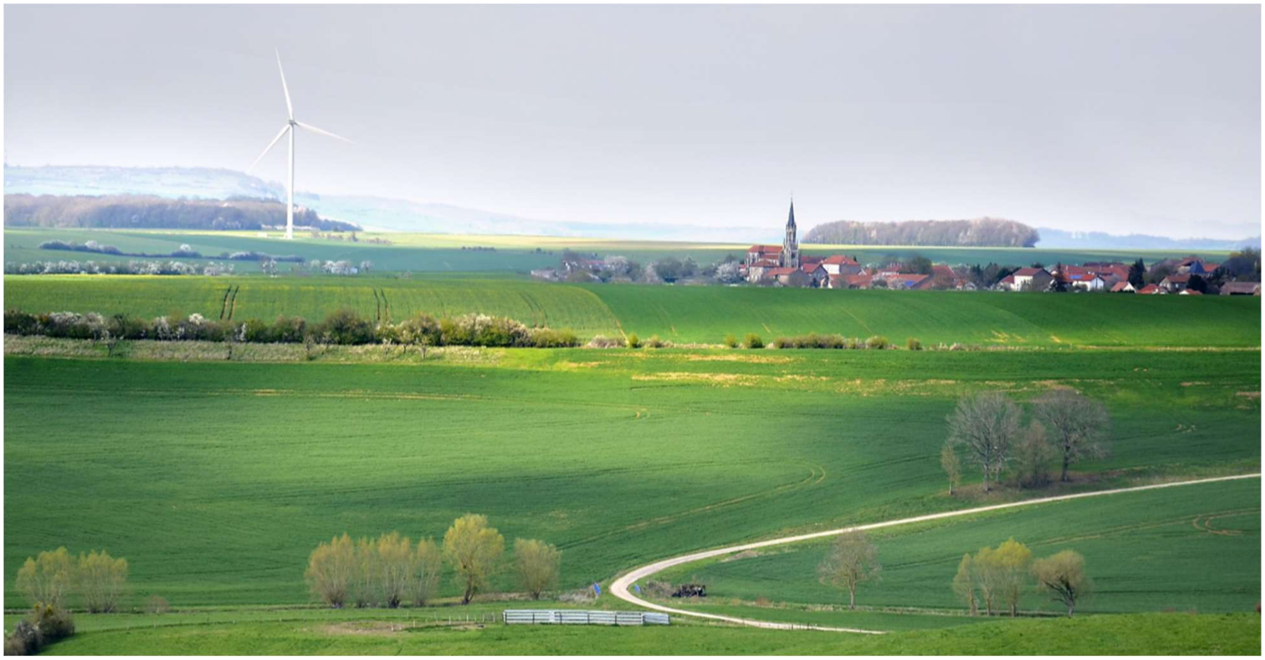
## 6. How can social norms encourage sustainable design?

Social norms represent accepted group conduct; that is, basic knowledge of what others do and think that they should do. Social norms can be a significant motivational contributor to sustainability behaviors[28] and can be made even more effective when combined with top-down policies[29]. In fact, simply showing how social norms are changing has the potential to significantly effect decisions about sustainability[30].

**Challenges.** Social norms in design are not currently for sustainability, which is why we have the specter of an Anthropocene era and related challenges like climate change. Finding ways to change this social norm in built environment design could lead to insights that are relevant across sustainability challenges.

**Opportunities.** Panelists highlighted two opportunities for studying social norms. The first is to examine **the role of analogy and story in changing these norms**. All over the world, in developed and developing countries, stories seeded in entertainment programs show measurable impact on public health behaviors, for example by reducing fertility rates in Brazil[31] and by increasing girls' school enrollment in India[32]. Working together, designers and behavioral scientists could seek similar changes in norms around sustainable design. The second related opportunity is to **learn from how social norms have changed quickly in other areas** such as

LGBTQ rights and even smoking in bars. Such cases will provide insight into how to change design norms, and also instill hope that it can be done in the time needed.



## Design processes (organizational)

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Panelists emphasized that individual design behavior occurs in the context of design processes that both intentionally and tacitly shape judgment, decision making, and actions, and therefore also shape the sustainability of outcomes[33]. Behavioral science can help us understand these organizational processes within which designers do their work, because when the same individual designer follows a different design process, the different process may produce a more or less sustainable new situation. Using behavioral science to learn more about these design processes promises to reveal ways of creating processes that enable more sustainable outcomes.

### 7. What process changes should be prioritized?

One reason our panel prioritized study of design behavior is because one designer, or a relatively small group of designers, influences the subsequent behavior of many users over long periods of time. In a similar vein, panelists also pointed out the need to compare the effectiveness of different design process interventions, in order to prioritize where efforts to change should be directed.

**Challenges.** From initial problem identification to broad planning to detailed designs and specifications, there are countless steps and relationships in the design process. There are also interdependencies between the steps, feedback loops where outputs of one step determine inputs to another, and vice versa. Information flows and incentives also influence the design process, as do interwoven goals such as cost, feasibility, client demands, and personal creative expression. As a result, there are more places to intervene in the design process than time to do so. What's more, the relative effect of interventions is not necessarily obvious.

**Opportunities.** Collaborative efforts between behavioral scientists and designers could identify high-leverage places to intervene in the design process. Designers bring an understanding of which points are most influential to design outcomes. And behavioral scientists have a sense for which interventions are likely to result in the biggest change in behavior. Given the infinite possibilities for intervention and the limited capacity for research in this area, panelists felt that such **prioritization of leverage points would be a valuable research investment**.

## 8. How can decision environments support design for sustainability?

Design processes often include support for decision making that is intended to aid design. Sustainability outcomes can be shaped by the various kinds of decision support used throughout the design process, ranging from design software to sustainability rating systems and measures.

**Challenges.** Although the role of this decision support is to guide – not to dictate – design behaviors, reliance on these systems can lead to autopilot perceptions and behaviors or blind spots. Rating systems, for example, might encourage performing to the lowest bar of acceptability, in which designs aim to achieve 'just good enough' specifications, rather than striving to exceed baseline measures[34]. Decision support might also lead to individual components of design being considered in isolation, rather than as a whole. Measures of home energy use, for example, might lead to highly insulated homes but neglect the need to make sidewalks or public transit accessible, which would reduce energy use outside of the home[35].

**Opportunities.** Behavioral science has long examined how decision environments can influence the decisions that are made[36]. Such decision support is already part of daily life in everything from food menus that disclose calorie information to retirement plans that automatically enroll employees and allow them to opt out, rather than the other way around. Study of built environment design shows promise for more sustainable outcomes through relatively simple changes to rating systems[37,38,39]. There is a need to **extend this study to other forms of decision support, and to test the effects in new contexts**. Such study would give behavioral scientists new applied contexts for their research. And it would provide designers with decision support that is grounded in science, and therefore more likely to result in more sustainable outcomes.

## 9. How do single sustainable design actions influence others?

The design processes that generate the built environment involve systems of actors and interconnected decisions. As a result, single design choices result in and influence other design choices.

**Challenges.** In some cases, spillover effects from one decision to another may be negative. Research in other sustainability domains has shown that relying on emotional associations can lead to instances in which actions on one environmental issue make other actions less likely. People receiving weekly feedback on their domestic water consumption, for example, lowered their water use but at the same time increased their electricity consumption[40]. In a similar way, focusing on less influential actions, like recycling, can divert attention away from more influential ones, like voting on climate change policy.

**Opportunities.** Research can identify and remediate instances in which negative spillover might occur. And research can **seek cases of positive spillover**, which is when one positive action leads to other positive choices, such as when people who have been convinced to recycle become more likely to car-share.[41] Panelists noted that researchers could have broad impact by identifying if and under what conditions single design interventions create positive spillover and therefore lead to a series of pro-sustainability choices throughout the design process.

## Designing with and for stakeholders (community)

Design for sustainability requires understanding the diverse and evolving needs of users and their communities. This, in turn, requires applying inclusive practices to recruit, support, and elicit the local knowledge of practitioners, researchers, and residents from marginalized groups. No one doubts that sustainability requires this approach, although generalizable examples that are grounded in science remain rare.

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### 10. How can designers engage with communities and users?

Stakeholder engagement, in order to improve design decision making[42], requires taking various approaches (interviews, workshops, and surveys, for example) to identify the social and environmental issues that matter most to users[43]. Investments in genuine stakeholder engagement, through practices such as design thinking[44] and participatory modeling[45], seek to help create a shared understanding of environmental, ethical, and social objectives.

**Challenges.** The first challenge in engaging stakeholders is getting access to them. Like designers, stakeholders are busy, and unlike designers, stakeholders are not typically getting paid for their contributions to the design. Moreover, most stakeholders unfamiliar with how they might influence a design. And stakeholders may speak a different language, or in the case of projects intended to serve communities for a long time, stakeholders may not yet have been born. Even when designers manage to engage with communities and users, these stakeholders are susceptible to the same cognitive biases as designers. They may not know what their needs are or may inaccurately predict their needs[46]. Mass transit riders, for instance, cannot be expected to understand the costs and benefits of every alternative type of transportation. Stakeholder perspective is essential, but should complement, rather than override, the training and experience of designers.

**Opportunities.** Guided by behavioral science, designers can **do their homework even before engaging with users**. In order to define problems, develop possible solutions, and embrace participation, designers need to understand how social structures, such as groups' histories, cultures, cognitive biases, power relations, differing access to resources, and knowledge systems, define, steer and inform stakeholders' mental models and perspectives. Behavioral science provides a systematic approach to doing so.

In a similar way, behavioral science, specifically as it applies to group processes[47], can also be used to **evaluate methods for engaging stakeholders**. Such methods include charrettes, integrated workshops, participatory 3D mapping, and participatory modeling. While these various participatory and collaborative methods all seem better than not engaging stakeholders at all, there is limited evidence showing whether and how these approaches work. Any such evidence from the context of built environment design would produce useful insights for other sustainability pursuits.

Technology offers new opportunities to engage stakeholders. The World Climate Simulation, for example, is being used to build climate change awareness and enable people to experience some of the dynamics that emerge in the UN climate negotiations. The interactive tool allows participants to see, in real time, how their proposed policies impact the global climate system. Behavioral science can be used to **identify attributes of games and simulations which help designers and stakeholders merge their complementary perspectives**[48].

## 11. What are equitable ways to distribute benefits, costs, and risks?

Communities affected by designs include not only those who directly use the designs, but also those whose physical, economic, and social environments are altered by the designs. One major reason to engage with affected communities is that doing so helps designers distribute benefits, costs, and risks equitably across populations in the present and future[49].

**Challenges.** Disadvantaged populations often have limited access to design decision making and the goals it produces. If not considered, the differential structure, agency, and power of the involved groups can produce inequitable goals and designs.

**Opportunities.** Design can **learn from other areas that have been able to enhance community participation and equity** in decision making. For instance, research on the global HIV epidemic highlights not only ways in which risks can be effectively communicated to different segments of the public, but also how researchers and organizations can involve vulnerable communities in decision making in ways that can influence public policy[50]. In this case, diverse community participation led to nuanced findings: messaging to promote HIV testing was viewed as marginalizing and fear-inducing for people of color or target groups, making these groups less likely to want to be tested[51]. **Openly published evaluations of project impact**, to which we will return in questions 14-16, also allow the communities affected by research to hold researchers accountable to those communities' interests.

## 12. How do designed forms influence end-use behavior?

The behavior of end-users is influenced by individual, social, and physical factors[52]. Basic social and decision science has yielded important insights into which individual and social factors affect sustainable behavior[53], but effects of physical factors have been understudied in these disciplines[54]. Does an office building that makes energy use transparent encourage occupants to think about energy use in their homes, or even on their commutes? Can a change in the placement of thermostats make office occupants more likely to adjust them? In each of these examples, the physical form that designers produce create a context that may suggest or discourages sustainable behaviors among occupants. Understanding which physical factors generally influence sustainable behavior among end-users would give designers new ways to create a built environment that encourages this behavior—including when end-users encounter other situations.

**Challenges.** Panelists noted that, while designers may have assumptions about which elements their designs affect users' sustainability-related behaviors, these assumptions may not always be true, and typically are not tested systematically, if at all.

**Opportunities.** Panelists highlighted an opportunity for designers to create physical structures that encourage more sustainable end-use behavior by **translating and extending findings from humans' senses of touch (haptics), and body movement and position ("proprioception").** Staircases painted to look like piano keys, for example, can lead people to enjoy taking the stairs, which has health benefits[55]. This suggests that similar mechanisms may be able to prompt sustainable behaviors.

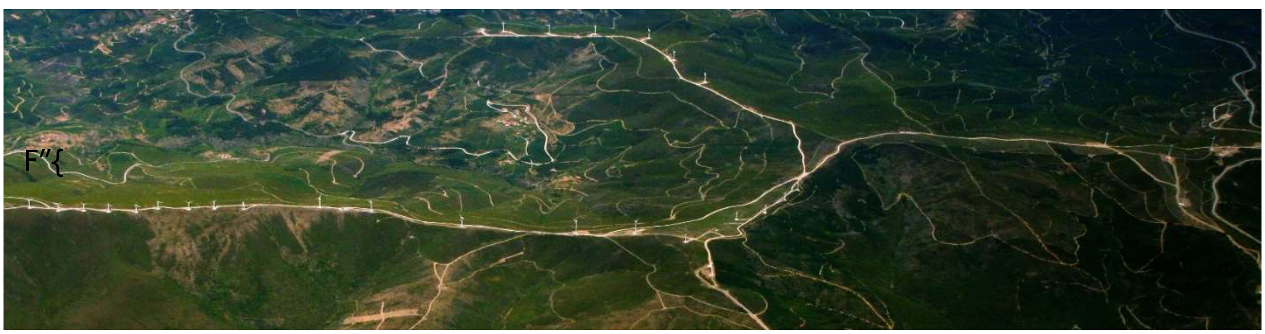
Panelists also highlighted the opportunity presented by the fact that human behavior increasingly sits at the **intersection of personal digital worlds and shared physical ones**. A simple example is how telecommuting can eliminate the need for a new highway lane. In a similar way, smart digital systems and sensors embedded in physical infrastructures can add capacity to infrastructure without any physical construction. And augmented reality products, such as Google Glass, are providing new ways to connect physical and digital environments. While there can be negative environmental and social impacts to such technologies, they also have the potential to help alleviate such impacts. In the hands of designers who understand behavioral science, such technologies could possibly be used to decouple environmental impact from human behaviors.

## 13. How are designed forms perceived by users?

Designers may define the original intent and form of built environments, but users are the ones who shape how these physical contexts are actually perceived and used. Psychology's construal theory recognizes that users base their judgments, decisions, and actions more on mentally constructed representations of the world than on the conditions that objectively exist[56]. As a result, panelists recognized that even when physical forms are explicitly designed for specific purposes, the behaviors we eventually observe may be more influenced by users' perceptions than the objective characteristics of the designed element.

**Challenges.** This gap between objective and perceived reality can lead to unintended consequences when the designers' intended usage is reframed or misperceived. A recent example can be seen in the intentionally humorous and stigmatizing plastic bags produced by a Vancouver grocery store. These bags, emblazoned with the logo 'Into the Weird: Adult Video Emporium', were designed with the intent of shaming customers into bringing reusable carryalls. Despite their intent, the bags' novelty made them instant collectibles rather than mechanisms to dissuade unsustainable behaviors[57]. It is challenging to consider all of the possible interpretations of designs?

**Opportunities.** The architect Eliel Saarinen famously advised that one should 'always design a thing by considering it in its next larger context – a chair in a room, a room in a house, a house in an environment, an environment in a city plan'. Behavioral scientists, with their practice systematically studying the relationship between the extended environment and discrete physical forms within it, can help designers apply this advice. In the case of the shopping bag, this would have led the designers to consider the bag itself, and also the people who might buy it. At the most basic level, **behavioral science can help designers gain a more thorough understanding of user perceptions**.



## Evaluating—and growing—impact (enabling environment and policy)

Individual & Interpersonal
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Community
**Enabling Environment & Policy**

To realize the opportunities highlighted in this report, the community studying design behavior for sustainability must extend far beyond this panel and beyond existing researchers and practitioners. To support this growing community, and to justify moving research findings to policy, evaluation is essential: to find how and when interventions can be scaled up, are cost effective, and can be implemented quickly. Such evaluation will also hold designers and researchers accountable to a wide variety of stakeholders, including those who are not in immediate proximity to the design we aim to influence. However, evaluating design behavior for sustainability in the built environment presents challenges in the form of the low frequency of interventions, the need to study behavior in context (with communities and users), and the fact that individual decisions are made within systems of influence and are difficult to isolate.

## 14. What are practical ways to evaluate impact in low-frequency cases?

The experimental methods often associated with behavioral science lend themselves to evaluating high-frequency end-use behaviors. For example, home energy reports that provide feedback on how energy is being used[58] can be sent to tens of thousands of households that are randomly assigned to treatment or control conditions. By comparison, interventions to change design behavior are relatively low-frequency and will therefore require different approaches. Consider, for example, a case in which a large purchaser of architectural and design services—say, a government or a major corporation—agrees to alter its procurement process to boost the energy performance of their facilities. Such an initiative holds the potential to avert tremendous quantities of greenhouse gas emissions over the lifetime of the facilities, and even more potential to learn and hone interventions for application with other governments or corporations.

**Challenges.** While the example changes to procurement processes promise tremendous impact, evaluating this impact will pose new challenges. The number of purchases per year will likely be in the tens and the situations are likely to be very different from each other, ranging, for example, from state police building retrofits to new construction of university science laboratories. In such circumstances, it is not obvious what would be the best method of modeling a plausible counterfactual. Further, data on facility performance may not be available for years after procurement, if it is available at all.

**Opportunities.** Nevertheless, there are **research and evaluation methods, such as case studies, ethnography, and focus groups, which are suited to smaller sample sizes**. What these methods sacrifice in generalizability, they make up for in specificity and detail, even allowing evaluation to capture unexpected impacts. Panelists noted that it is our responsibility to consider a wider net of methods when evaluating impact, even if they are more resource-intensive, or unfamiliar. Doing so will help the design-behavior research community learn which interventions are effective and revise their theories, leading to more effective interventions in the future, and growing confidence among those who fund the interventions.

## 15. How can evaluation balance perfection and relevance?

To determine which design behavior interventions are fit to be adapted to diverse contexts and scaled up, it is critical to evaluate each intervention's effectiveness with respect to its specific contextual factors.

**Challenges.** Decisions regarding sustainability are constantly being made in practice, regardless of whether research has advanced to a stage at which it can weigh in. This raises difficult questions about balancing research precision with relevance. For example, only reporting findings that meet conventional levels of statistical significance will result in incomplete scientific understanding, and given the urgency of sustainability challenges, may be socially irresponsible.

**Opportunities.** Panelists felt that design behavior offered an opportunity to **rethink measures of success**. To capture and communicate the uncertainty in evaluations, for example, panelists noted that statistical significance levels can be reported together with confidence intervals and effect sizes. Whatever the format of results, they should be reported as they are. Those considering a similar intervention can then combine this reported and more comprehensive information with their understanding of context in order to make a more informed choice.

## 16. How can evaluation be encouraged?

In theory, there is universal agreement that evaluation of prior efforts is a cornerstone for improved behavior change interventions. And, in some cases, evaluation is simply required. Public agencies and private foundations have begun requiring evaluation of long-term social impacts as part of their funding strategies, incentivizing the recipients of funds to measure impacts.

**Challenges.** Still, only a fraction of programs are integrating evaluation into their upfront planning. Panelists noted that this ambivalence toward evaluation not only plagues academia, it is also prevalent among practitioners and the public sector. One explanation is that evaluation is a resource-intensive activity that is not paired with the same incentives as creating a new behavior change program. Higher resource costs, and fewer career incentives are some of the factors that may deter researchers from the important work of evaluation. In addition, evaluation might bring to light shortcomings in the behavioral intervention itself, which can be interpreted as reflecting poorly on those who implemented the intervention.

**Opportunities.** Panelists felt that many of these challenges could be overcome if evaluation were seen as an integral part of any behavior change program, be it research project or a private initiative. Evaluation would provide an opportunity to **define measures of academic success that extend beyond the number of publications, conference presentations, and citations**[59]. Such measures, of course, should incentivize evaluation towards long-term social impact, rather than short-term payoff to individual agents. To overcome the challenge that evaluation might bring to light shortcomings, evaluations can **focus less on outcomes and more on process**, seeking to understand why and under which conditions the intervention is effective. Panelists recognized that good evaluation is not easy, but it remains an untapped opportunity to help demonstrate and enhance the value in design behavior interventions

## 17. How can researchers and practitioners work together?

Behavioral science is not a purely academic domain. There is a growing community of behavioral science practitioners, many of whom have extensive training in research and connections to universities[60]. As insights from behavioral science increasingly penetrate corporations and governments, the potential for research collaboration has soared. This offers unique opportunities for synergistic relationships between behavioral science practitioners and academic researchers of design behavior for sustainability.

**Challenges.** To realize the benefits of collaboration, researchers need to see an academic benefit of spending time with practitioners, including the opportunities it presents for bilateral learning. On the practitioners' side, a challenge is the real or perceived intrusion of scientific methods on day to day operations, data privacy, and intellectual property rights. For both researchers and practitioners, realizing full benefits requires connecting at the most influential early stages of project implementation, rather than after a behavioral issue has already emerged. This early engagement is especially relevant for complex sustainability challenges, which need to be addressed at the strategic level to ensure long-term, systemic change.

**Opportunities.** To determine behavior change interventions to implement, academic researchers can consult with practitioners to **confirm whether a particular point in the design process is indeed viewed as high-leverage**. Conversely, researchers can help practitioners with the systematic evaluation of impacts. Such an approach would demonstrate added credibility to project funders, many of which are seeking integrated teams of researchers and practitioners. Panelists noted that these collaborative arrangements can provide significant financial incentive for behavioral scientists to participate, because the funding behavioral scientists require is mostly for personnel and therefore a relatively small piece of the larger project.

Research-practice partnerships also offer **potential for sustained data sharing**. Good data from beyond the laboratory are difficult for researchers to obtain. At the same time, practitioners often have more data than what they can make sense of. One-off examples of data sharing show potential for more sustained efforts. Panelists thought that these efforts might benefit from engaging neutral third parties like national labs and NGOs to ensure secured data storage and sharing.

Finally, panelists noted that perhaps the greatest benefit of research-practice partnerships is that they **offer a pipeline for moving insights to impact**. Even the most successful behavioral change intervention in the laboratory still requires a pathway to implementation. However, if the intervention has been tested in context, there is no additional step needed to achieve impact.

## 18. What will support and grow the community to answer these questions—and ask more?

The questions in this report require expertise that extends beyond any single domain, instead pulling from skill sets and perspectives that have historically resided comfortably within the well-defined boundaries of individual disciplines. In addition to blurring perceived boundaries between these diverse fields, advancing understanding of design behavior for sustainability will involve creating more porous boundaries between academic theory, methodology, and practical application.

**Challenges.** Collaborating effectively in this way, however, is often easier said than done. The incentive structures in each discipline and between research and practice are very different. Even if all involved are sincerely aligned on the end goal of increased sustainability, the varied mindsets and contexts in which we work typically reward different activities and suggest different measures or proof of value. In departments or schools where such collaborations are not yet happening, academics who participate in these interdisciplinary exchanges may need to devote scarce time to explaining the reasons for the new approach.

**Opportunities.** Panelists noted that growing these collaborations is an opportunity for those involved to **learn new processes and modes of inquiry**, and even to embrace tensions and productive discomfort. Tenured faculty can lead by example to show the benefits of such work, clearing the way for untenured faculty and graduate students to have similar experiences. In so doing, there are opportunities to **expand notions of design and behavioral science** by defining and classifying the skills that researchers and practitioners require to engage in this work. From these skills, educators can develop classroom and online education experiences for students and professionals to develop these skills.

## 19. How can this community influence policy?

A common question across research areas is how to move the 'best practice standards', as documented in the literature, into policy. And so, when it comes to what we know about design behavior for sustainability, panelists felt that, rather than reinvent the wheel, we should begin with the rich literature that has emerged in the past three decades on the supply of and demand for the use of science in both environmental policy[61,62] and knowledge usability[63,64].

**Challenges.** It has been well-documented that the conventional 'loading dock approach' to producing science (e.g., peer review publications, professional communications) does not fully consider potential users' needs, and thereby misses opportunities to produce usable knowledge for sustainability[65]. Thus, one of the focal areas of the supply and demand literature—and the related emergent field of evidence-based policy—is identifying the specific barriers that impede the use of science[66,67,68,69]. A perceived lack of time and the difficulty of seeking out relevant academic evidence and expertise are particularly seen as barriers for policy makers[70]. Barriers for academics include a lack of trust regarding policy makers' intentions and inexperience working together with policy makers[71].

**Opportunities.** Unfortunately, few emergent recommendations for the communication of science to decision makers have been found to be universally generalizable across a wide diversity of circumstances, or even specific to certain contexts[72,73]. However, **investing in high-quality communication** is one approach that has been shown to be relatively consistently linked to increased use of research in policy[64,72]. Panelists agreed that we should challenge ourselves to contextualize our findings beyond academic impacts, delineating aspects of our research that are practically useful and how.

## 20. Will you join us?

Our panel believes that identifying the questions in this report is an important milestone, albeit an early one. Going forward to pursue these, and other yet-to-be-uncovered, questions will require persistence and teamwork far beyond this initial panel.

**Challenges.** Ultimately, success will be defined not by the extent to which we are able to articulate the problem, but our capability of bringing solutions into reality.

**Opportunities.** We are hard at work building and enhancing the network—to learn about and from design for sustainability through long-term interactions across multiple communities. **Please contact any of the co-chairs or panelists if you would like to contribute**. We are eager to hear from you!

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