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Sustainable product innovation and changing consumer behavior: Sustainability affordances as triggers of adoption and usage

Jonatan Pinkse[1] | René Bohnsack[2]

[1]Manchester Institute of Innovation Research, Alliance Manchester Business School, University of Manchester, Manchester, UK

[2]Católica Lisbon School of Business & Economics, UCP, Lisbon, Portugal

Correspondence
Jonatan Pinkse, Manchester Institute of Innovation Research, Alliance Manchester Business School, University of Manchester, Manchester, UK.
Email: jonatan.pinkse@manchester.ac.uk

Abstract

This conceptual paper argues that for sustainable product innovation to make a contribution to addressing sustainability issues, we need to understand not only why consumers adopt sustainable products but also what makes them use these in sustainable way. To explain how specific product features can change the ways in which consumers engage with sustainable products in the adoption and usage phase, we draw on affordance theory. Affordances refer to the potential for agentic action of users in relation to a technological object. We develop a conceptual framework that explains how sustainable product innovation can lead to the design of sustainability affordances that stimulate adoption and sustainable usage. The framework shows how three forms of agency—material, firm, and user agency—interact and together influence a product's sustainability affordances that drive adoption and a change in consumer behavior. The framework explains how trade-offs between a product's environmental features and consumer expectations regarding desired functionalities and user experience can be overcome.

KEYWORDS
adoption, consumer behavior, sustainability affordances, sustainable product innovation, usage

1 | INTRODUCTION

Sustainable product innovation aims to design products that deliver environmental benefits to consumers, such as CO_2 emission reductions, improved recyclability of products, and energy savings (Varadarajan, 2017). There is widespread agreement on the importance of sustainable product innovation in addressing concerns about sustainability issues, such as climate change, the circular economy, and biodiversity loss, because it enables more sustainable consumer behavior (Adams et al., 2016; Dangelico, 2016; Nidumolu et al., 2009). The literature on sustainable product innovation has investigated various factors that influence adoption, including sustainability features, functional performance, consumer beliefs, aesthetic design, and policy support (Bohnsack et al., 2020; Luchs et al., 2012; Olson, 2013; Pickett-Baker & Ozaki, 2008). Because sustainable product innovation creates both novelty and environmental benefits, sustainable products could have a relative advantage over existing products (Rogers, 1995) and be attractive to early adopters that value the environment (Paparoidamis et al., 2019). However, sustainable products contend with an attitude–behavior gap: even if consumers state having green preferences, many still shy away from buying sustainable products

Abbreviations: CO_2, carbon dioxide; EV, electric vehicle; LED, light-emitting diode; R&D, research and development.

(Olson, 2013; Peattie, 2010; Pickett-Baker & Ozaki, 2008). Trade-offs between sustainability and functional features are one reason for this gap; sustainable products are sometimes perceived to have lower functional performance (Luchs et al., 2012; Olson, 2013).

Research on sustainable product innovation has increased understanding of the adoption of sustainable products (Luchs et al., 2012; Olson, 2013; Paparoidamis et al., 2019; Varadarajan, 2017). However, this line of research implicitly assumes that higher adoption will automatically result in the realization of a product's environmental benefits. Yet it is questionable whether the environmental benefits will be fully realized. This also depends on how consumers engage with a product in the usage phase (Kaaronen, 2017). In real-life situations, each consumer uses a sustainable product differently (Hutchby, 2001; Pucillo & Cascini, 2014) with consequences for the realization of the environmental benefits (Bhamra et al., 2011; Wever et al., 2008). Do consumers, for example, adapt their behavior to make the most of a product's environmental features or do they ignore these instead? Although products such as smartphones have energy-saving features, consumers have the agency to decide to use these features or not (Faraj & Azad, 2012). Energy savings could have a rebound effect when they induce consumers to start using the product more frequently (Olson, 2013). Do firms emphasize the environmental features in their marketing communication to consumers or downplay these because they feel that functional features or aesthetic design have more appeal (Luchs et al., 2012; Olson, 2013)?

In this conceptual paper, we argue that for sustainable product innovation to make a contribution to addressing sustainability issues consumers are concerned about, we need to understand not only why consumers adopt sustainable products but also what makes them use these sustainably. To address this question, we draw on affordance theory (Gibson, 1979; Hutchby, 2001) which has its roots in ecological psychology (Gibson, 1979) and has been applied in information systems (Seidel et al., 2013; Zammuto et al., 2007) and sustainable design (Bhamra et al., 2011; Lockton et al., 2008) to explain the interaction between people and technology (Gaver, 1991). Affordances refer to "functional and relational aspects which frame, while not determining, the possibilities for agentic action in relation to an object" (Hutchby, 2001, p. 444). Affordances capture "the variable process that mediates between properties of an artifact (features) and what subjects do with the properties of an artifact (outcomes)" (Davis & Chouinard, 2016, p. 242). Applying affordance theory to sustainability suggests that a product's affordances can request, demand, allow, or encourage consumers to use it sustainably *or* discourage or refuse to use it unsustainably (Davis & Chouinard, 2016). Drawing on affordance theory, we develop a conceptual framework that explains how firms can use sustainable product innovation to create and market products with affordances that not only stimulate adoption but also invite consumers to use them sustainably. Specifically, our framework shows how three forms of agency—material, firm, and user agency—interact in allowing firms to create sustainable products with myriad sustainability affordances, for example, circularity, longevity, decarbonization, and transparency, and use these in their marketing to invite more sustainable consumer behavior.

With this paper, we contribute to the sustainable product innovation literature by explaining theoretically how affordances lead not only to the adoption of sustainable products (Luchs et al., 2012; Olson, 2013; Paparoidamis et al., 2019) but also to the realization of their environmental benefits through behavioral change. We show how a product's sustainability affordances can create possibilities for *actions*, *experiences*, and *learning* that jointly have the potential to invite consumers to behave more sustainably. We argue that sustainable product innovation can help in addressing sustainability issues, but that adoption is not enough. The environmental benefits of sustainable product innovation will only be significant when the adoption of sustainable products leads to a realization of the benefits in the usage phase. Our framework provides guidance on the different ways sustainable products can be designed and marketed to better realize their potential environmental benefits.

2 | AFFORDANCE THEORY AND THE NATURE OF AFFORDANCES

Affordance theory proposes a middle ground between determinism and constructivism in explaining the relationship between people and technology (Hutchby, 2001). Whereas determinism stresses the unavoidable impact of technology on people, constructivism argues that technology only gets meaning through people's interpretations (Zammuto et al., 2007). Through an affordance lens, "technologies can be understood as artefacts which may be both shaped by and shaping of the practices humans use in interaction with, around and through them" (Hutchby, 2001, p. 444). Affordance theory, like technology-as-practice, understands technology both as artifact and in its use (Orlikowski, 2000). As Orlikowski (2000, p. 408) explains, "in both research and practice we often conflate two aspects of technology: the technology as *artifact* (the bundle of material and symbol properties packaged in some socially recognizable form, e.g., hardware, software, techniques); and the *use* of technology, or what people actually do with the technological artifact in their recurrent, situated practices." Technology-as-practice assumes that a technology consists of several features which only get meaning through a technology's use (Griffith, 1999). Firms can design features into a technological object—a product—but when these remain invisible to consumers, they fail to get meaning (Norman, 1999). From a user perspective, the technology will not be associated with these features and they will not have impact on its adoption or usage.

Affordance theory has a relational ontology (Faraj & Azad, 2012; Leonardi, 2011); it "presumes that the social and the material are inherently inseparable" (Orlikowski & Scott, 2008, p. 456). It is a sociomateriality approach (Jarzabkowski & Pinch, 2013): it shows "how materiality is intrinsic to everyday activities and relations" (Orlikowski & Scott, 2008, p. 455). Affordance theory highlights the materiality of technology: an object has agency without human intervention (Leonardi, 2011). "[A]n affordance perspective recognizes how the materiality of an object favors, shapes, or invites, and at the same time constrains, a set of specific uses" (Zammuto et al., 2007,

p. 752). Yet it also highlights a technology's social embeddedness; it only has meaning when in use (Orlikowski, 2000). Technology affordances are mutually constituted by material and human agency (Leonardi, 2011). Material agency posits that a technology has *natural* affordances *and* constraints in what it can perform (Leonardi & Barley, 2008), but human agency can influence a technology's affordances, thus creating *designed* affordances (Norman, 1999).

Although affordance theory tries to reconcile deterministic and constructivist views, it has been criticized for definitional ambiguity, creating a false binary where products afford or not and neglecting situational factors (Davis & Chouinard, 2016). For an affordance lens to have value for our analysis, we follow Evans et al. (2017, p. 36) who define affordances as a "'multifaceted relational structure' (Faraj & Azad, 2012, p. 254) between an object/technology and the user that enables or constrains potential behavioral outcomes in a particular context." Evans et al. (2017) stress the need to make a distinction between features, affordances, and outcomes: affordances mediate between the features of a product and the outcomes of what people do with these features. We take into account, too, Davis and Chouinard's (2016, p. 242) view that "affordances operate by degrees," thus moving away from affordances being binary. They show "how affordances work," suggesting various technology–user relationships—that is, request, demand, allow, encourage, discourage, and refuse—which capture how a technology puts a specific bid on a user and/or responds to a user's desired action. How these different relationships play out depends on situational factors. For example, a product's high-tech features will be encouraging in a context of technologically savvy people who know how to use them, but they will be discouraging in the context of technological novices. Hence, affordances will be perceived differently depending on the social and cultural context (Davis & Chouinard, 2016).

3 | AN AFFORDANCE PERSPECTIVE ON SUSTAINABLE PRODUCT INNOVATION

3.1 | Sustainability affordances

Applying affordance theory to sustainability raises questions such as what a sustainable product affords in terms of environmental benefits, how it affords these benefits, and under what circumstances. For a product innovation to be sustainable, it should have an "environmental impact during the lifecycle of the product, spanning resource extraction, production, distribution, use, and post-use disposal, [which] is significantly lower than existing products for which it is a substitute" (Varadarajan, 2017, p. 17). However, sustainability can refer to a wide range of issues, including climate change, resource scarcity, (air, water, or soil) pollution, and biodiversity loss. What makes a product sustainable could be narrowly focused on one outcome, for example, reduced carbon emissions, or broadly focused targeting multiple outcomes, for example, reduced resource extraction, no habitat loss, and zero air pollution. A product innovation is considered sustainable when it introduces new features that aim for one or more of such outcomes.

New product features can provide a range of sustainability affordances—for example, circularity, longevity, eco-efficiency, decarbonization, biodegradability, compostability, organic production, resource substitutability, or traceability, for example, which invite consumers to behave more sustainably and help achieve outcomes such as lower carbon emissions or less water pollution. A product affords circularity when it uses raw materials that can be more easily recycled or reused, so it extends how many times a resource is used; it affords longevity when it lengthens a product's lifetime, so it extends how long a resource is used; and it affords eco-efficiency when it requires less energy for the duration of use (Figge et al., 2018). Sustainability affordances can work in tandem but there can also be trade-offs between them (Hahn et al., 2010). Improving a product's longevity also benefits decarbonization as it requires less energy-intensive resource extraction. However, although solar panels afford decarbonization by substituting for fossil fuels, they contain toxic materials that constrain circularity, with soil pollution as undesirable outcome.

We will analyze the influence of sustainability affordances on behavioral change by looking into the role of material agency and human agency, respectively. We separate human agency by distinguishing between two types of actors: the firm as designer of a sustainable product and the consumer as its user.

3.2 | Material agency: Sustainability affordances as possibilities for actions

For sustainable product innovation to deliver on its promise to deliver environmental benefits, sustainable products need to afford consumers the action possibility of using them sustainably (Kaaronen, 2017). Assuming consumers have a desire to behave sustainably, how would a sustainable product's natural affordances that shape its material agency afford them to realize this desire? We argue that the answer depends on whether a product's underlying technology has advanced enough for it to meet user demands regarding multiple expected environmental benefits. It also depends on the functionality the sustainable product offers, in particular compared with products currently in use (Luchs et al., 2012; Wever et al., 2008). A lack of sustainable consumer behavior is not necessarily the result of consumers' missing desire to change behavior but can be due to insufficient possibilities to act sustainably (Kaaronen, 2017). For example, low-carbon long-distance travel is a challenge because flying is currently the only speedy solution. In the following, we argue how challenges for sustainable behavior are related to a sustainable product's material agency as embodied in its technology's *natural affordances* that shape possibilities for action (Hutchby, 2001; Leonardi, 2011).

The natural affordances of a product's underlying technology are important in creating possibilities for actions (Pucillo & Cascini, 2014). They allow consumers to realize sustainable behavior. Technologies that address similar user needs vary in their potential to enable

sustainable behavior. They differ in terms of their *natural affordances for sustainability* (Kaaronen, 2017) which frame possibilities for agentic action (Hutchby, 2001). A technology's materiality can also lead to *natural constraints*, when the technology refuses certain use (Zammuto et al., 2007). Although scientists can manipulate a technology to broaden affordances and reduce constraints, this process takes time and has limits (Leonardi & Barley, 2008). Compared with fossil fuels, for example, biofuels have a lower energy density. If used for aviation, more fuel is needed to cover the same distance. Biofuels also tend to gel at low temperatures, causing issues when used in airplanes (Hari et al., 2015). Due to a sustainable technology's constraints, it cannot simply replace products currently in use which rely on proven technology, because it does not provide the same possibility for action. A technology's natural affordances and constraints define the boundaries of the possibilities for agentic action and the degree they offer consumers the potential to realize sustainable behavior (Hutchby, 2001; Markus & Silver, 2008).

A technology's material agency provides insight into adoption "by paying attention to what a technology lets users do, what it does not let them do, and the workarounds that they develop to address the latter" (Leonardi & Barley, 2008. p. 164). It suggests how a technology's natural affordances allow consumers to realize intentions to behave sustainably. First, natural affordances reflect a product's environmental benefits and whether it lets consumers contribute to one specific outcome, for example, lower carbon emissions, or multiple outcomes. We argue that a sustainable product has a higher chance of adoption when the affordances allow consumers to achieve a wider range of environmental outcomes and do not create dilemmas between them. Electric vehicles (EVs), for example, have the potential to address several environmental issues simultaneously, including climate change and air pollution. Although doubts have been raised about EVs' carbon footprint—many still use electricity produced from fossil fuels—and the batteries' toxicity, zero tailpipe emissions is an important environmental benefit stimulating adoption (Ellsmoor, 2019). In contrast, adoption of biofuels for mobility has stalled partly because they are no longer considered socially and politically acceptable. The link between ethanol production and land use change (including land grabs and deforestation) has led to public contestation about "Food versus Fuel" and the adverse impact of deforestation on the claim of biofuels' lower carbon footprint, discrediting biofuels as a solution for low-carbon mobility (Tomei & Helliwell, 2016).

Second, natural affordances affect to which degree a product either requests, demands or encourages particular usage, or, instead, discourages or refuses functionalities that consumers desire (Davis & Chouinard, 2016; Wever et al., 2008). In response to media attention for the plastics crisis, for example, bioplastics have emerged as a potential solution. Bioplastics are made from plant-based or organic sources and have sustainability affordances such as decarbonization as they are not oil based, biodegradability as they can decompose into natural substances, and circularity as they are nontoxic. However, bioplastics have natural constraints regarding their biodegradability and functionality. Products with the label "compostable" tend to be industrially compostable only, not home compostable, as they require industrial composters. These products will not solve the (ocean) waste problem because in many parts of the world, the waste management is not yet able to compost them. Moreover, home-compostable plastics are not as strong as less sustainable ones, reducing their potential application. The material properties of compostable bioplastics request a specific usage which limits their application.[1]

When a sustainable product discourages or refuses a consumer's desired actions, its underlying technology will either have to be adapted through R&D or the product will require a change in application (Bohnsack & Pinkse, 2017). Wever et al. (2008, p. 14) argue that adoption is more likely when "mismatches between delivered functionalities and desired functionalities" are eliminated, which they refer to as "functionality matching." However, there are two shortcomings to this argument. First, when sustainable alternatives hit the market, they tend to underperform on desired functionality for some time (Bohnsack & Pinkse, 2017); full functionality matching is not very likely. Second, it assumes that sustainable product innovation is a linear process aimed at reaching performance parity with existing products. However, technology development tends to take unexpected turns (Pinch & Bijker, 1984). Whereas certain consumers will not have a willingness to compromise on functionality, others might perceive the sustainability affordances as a starting point of discovering new functionality. So instead of seeing a sustainable product's natural affordances as a problem limiting desired functionality, they can be an incentive to develop workarounds and discover new types of functionality.

An affordance lens suggests it is not just the product that needs to change until it meets user expectations. Sustainability affordances can encourage consumers to consider different action possibilities. Favorable conditions for sustainability affordances to have such impact are markets with large green segments more willing to compromise on functionality (Peattie, 2001). There are other conditions, too, for which an initial lack of functionality matching is less problematic. For example, making a technology modular or detachable to let it progressively be integrated in products does not require giving up on known functionalities straightaway and lets consumers change behavior gradually (Garud & Kumaraswamy, 1995; Paparoidamis et al., 2019; Pinkse et al., 2014). Solar panels were long considered expensive and unable to fulfill a typical household's energy needs. As their costs have come down, though, adoption has not only increased to replace electricity from the grid, but their modularity has also led to new applications such as solar home systems in developing countries. Modularity has also been applied in the smartphone industry. Fairphone offers a modular phone which has the sustainability affordance of repairability and the functional affordance of upgradability, which jointly afford longevity.

3.3 | Firm agency: Sustainability affordances as possibilities for experiences

Considering firms as product designers (Norman, 1999), how do they use their human agency to design sustainability affordances into

products or leverage natural affordances in the commercialization process (Tromp et al., 2011; Wever et al., 2008)? We argue that the answer depends on how firms design environmental features into products that appeal to consumers and reflect particular sustainability affordances. Firms are always exploring what a product's salient features are, because these will lead to higher consumer response (Griffith, 1999). Environmental features might not be among the salient features, though. Whether a technology delivers environmental benefits depends on a firm's willingness to design features into products which afford sustainable behavior in a way that improves—not deteriorates—the user experience (Tromp et al., 2011; Wever et al., 2008). In the following, we argue how challenges to behave sustainably relate to firms' human agency of designing features into a product which shape possibilities for user experiences (Norman, 1999; Pucillo & Cascini, 2014).

Affordances do not derive directly from a technology's material agency; human agency plays a role, too. In designing products, firms have different options for how to leverage material agency (Leonardi, 2011). Technology features can be designed into a product (Griffith, 1999), creating *designed affordances* (Norman, 1999). A technology is complex, both as an artifact and in its use, because it embodies different features that all vie for the attention of the prospective user (Griffith, 1999). Features trigger how users make sense of the product and play a role in the decision process of whether to adopt the product innovation and, if adopted, how to use it (Jelsma & Knot, 2002). Firms design specific features into a product to convince users to adopt it (Norman, 1999). Design plays a key role in sustainable product innovation (Wever et al., 2008). However, although firms might design features into products that afford sustainability, consumers will not always notice these (Tromp et al., 2011) and change behavior in the desired way (Griffith, 1999).

Environmental features aim to address collective concerns about the environment, but consumers might not share these and fail to see them making products more attractive (Tromp et al., 2011). Products labeled "sustainable" will have other instrumental and symbolic features that address users' individual concerns such as safety, comfort, luxury, or status (Ali et al., 2019; Noppers et al., 2014). Firms might highlight instrumental and symbolic features in their marketing if they expect these to lead to a more positive response (Griffith, 1999). Competition between features is particularly pertinent in the case of complex products (Danneels, 2004). Yet this complexity also motivates consumers to more consciously compare product features (Paparoidamis et al., 2019). Cars, for example, have many features that vie for user attention; an electrical engine that affords decarbonization is just one of them (Danneels, 2004; Pinkse et al., 2014). Although decarbonization might be a key selling point for EVs, Tesla has highlighted fast acceleration and a luxurious design to win over customers (Bohnsack & Pinkse, 2017). It tends to be the bundle of environmental, instrumental, and symbolic features that makes a product attractive (Delmas & Colgan, 2018; Noppers et al., 2014).

A key question for sustainable design is how firms can leverage environmental features to change consumer behavior (Jelsma & Knot, 2002; Lockton et al., 2008). Many approaches have been identified that range from information provision, feedback, and incentives to more forceful ways to prompt consumers to behave sustainably (Bhamra et al., 2011; Tromp et al., 2011; Wever et al., 2008). Forceful ways include "scripting", which refers to design choices that invite sustainable behavior and discourage unsustainable behavior (Jelsma & Knot, 2002), and forced-functionality, which refers to products that can only be used sustainably (Wever et al., 2008). Comparing approaches, there is a tension between intrusiveness and effectiveness (Tromp et al., 2011). A less forceful approach, such as feedback on energy use, might not be perceived as intrusive but will not be very effective in prompting behavioral change. More forceful approaches, such as scripting energy conservation through light switch timers, could be effective, but consumers tend to perceive them as intrusive and be less willing to adopt them (Bhamra et al., 2011). Drawing on affordance theory, how features afford is forceful when they request, demand, or refuse and less forceful when they enable, encourage, or discourage (Davis & Chouinard, 2016).

To analyze the relation between sustainability affordances and user experience, we draw on goal framing theory (Lindenberg & Steg, 2007; Steg et al., 2014). This theory argues that "goals govern or 'frame' what people attend to, what knowledge and attitudes become cognitively most accessible, how people evaluate various aspects of the situation, and what alternatives are being considered" (Lindenberg & Steg, 2007, p. 119). In any given situation, people tend to satisfy multiple goals, but one goal—the goal frame—will be dominant, whereas other goals—the background goals—will be pushed to the back (but still be of influence). The theory suggests that three types of goals jointly motivate behavior: hedonic goals (how people feel), gain goals (what people gain in terms of resources), and normative goals (what people consider appropriate). A normative goal frame tends to be the main driver of long-lived sustainable behavior; when people adopt sustainable products mainly for how they make them feel in the moment or for cost considerations, such behavior will be more short lived (Lindenberg & Steg, 2007). Therefore, goal conflict is a challenge for the adoption of sustainable products: a product's environmental features satisfy normative goals but lead to a conflict with gain goals, when it is more expensive, or hedonic goals, when it is less pleasurable (Steg et al., 2014).

To improve the user experience, a product's designed affordances could reduce or resolve the goal conflict (Steg et al., 2014). By highlighting a product's instrumental or symbolic features, firms can make the product more attractive for consumers with a gain or hedonic goal frame. For example, the Toyota Prius' success in the United States has been attributed to the hybrid technology's more fuel-efficient driving, letting consumers save money (Ginsberg & Bloom, 2004), and an outspoken design, letting them signal green behavior to their peers (Delmas & Colgan, 2018). Luchs et al. (2012) found that firms can use superior aesthetic design as a symbolic feature that satisfies hedonic goals as it gives people confidence in sustainable products. However, resolving goal conflict by making hedonic or gain goals the goal frame bears the risk that the normative goal becomes a background goal only. Due to the shorter time horizon of hedonic and gain goals (i.e., the warm feeling of buying a green product

tends to wear off quickly), having these as goal frame is less likely to lead to lasting sustainable behavior (Lindenberg & Steg, 2007). For example, purchase incentives for green electricity and EVs have made these products attractive, but their impact on buying behavior only lasted so long as they were not watered down or removed.

It has been argued, therefore, that the normative goal of behaving sustainably should be the goal frame and be strengthened, not pushed to the background (Steg et al., 2014). Firms have several means at their disposal when developing and marketing sustainable products. First, they could target markets where normative goals are already dominant. Countries with a long history of strict environmental regulations tend to have higher environmental norms. Here, highlighting a product's environmental benefits is easier because people do not really experience a goal conflict. Second, firms could highlight environmental features that address sustainability issues that people are currently worried about (Thøgersen, 2006). Due to the widespread attention for plastic waste and the climate emergency, people will feel a stronger need to do their part. While a product could have multiple sustainability affordances designed into them, this suggests that firms should only highlight features that reflect affordances linked to such salient issues. Moreover, firms can be more forceful in how they market these features because consumers are more willing to make compromise (Peattie, 2001). As mentioned, bioplastics have several sustainability affordances, but the current attention for plastic waste means that features affording biodegradability could be marketed more forcefully than other environmental features which get less media attention.

Alternatively, firms can target multiple goals with their sustainable products (Steg et al., 2014). However, they have to make sure that hedonic and gain goals strengthen normative goals, instead of pushing them to the background. Although goal conflict is common, under certain conditions, consumers will not perceive a conflict. For certain sustainable products, there is a clear business case. LED lights, for example, have become so energy efficient that cost savings have created a business case. Moreover, the modularity and flexibility of LED lights allow them to be used for various purposes and create new user experiences. Philips Hue, for example, is a consumer lighting system that uses LED light bulbs with a chip. The ecosystem of apps that complement the Hue system has created a whole new user experience, making LED adoption more attractive (Hilbolling et al., 2021). For some environmental features, it is clearer how hedonic and gain goals can strengthen normative goals than it is for others and firms likely highlight these. There is the risk, therefore, that firms only design affordances into products for which they can make a business case. If the business case becomes strong, hedonic and gain goals might replace rather than strengthen normative goals as goal frame with concomitant consequences for sustainable behavior.

3.4 | User agency: Sustainability affordances as possibilities for learning

While a product might have sustainability affordances, these only denote *possibilities* for actions and experiences (Hutchby, 2001; Pucillo & Cascini, 2014), a potential that might not be realized (Markus & Silver, 2008). Firms can design environmental features into their products to solicit a change in behavior (Wever et al., 2008), but how will consumers respond to these features (Griffith, 1999)? According to affordance theory, the answer depends on how consumers interact with a product's sustainability affordances, regardless whether these are natural or designed. Consumers might fail to act on the sustainability affordances by not using the product as intended (DeSanctis & Poole, 1994). We argue that the interaction of users with a product's sustainability affordances depends on how they cognitively process these affordances (Kannengiesser & Gero, 2012; Still & Dark, 2013) and translate them into sustainable behavior (Kaaronen, 2017). A key issue is, therefore, how the sustainability affordances help consumers to use the product so that it initiates a process of learning to behave sustainably (Kaaronen, 2017). In the following, we explain how challenges to behave sustainably are related to users' human agency of interacting with natural and designed affordances in ways that shape possibilities for learning.

A product's affordances capture a potential, yet it still depends on how users act on the affordances whether such potential is realized (Markus & Silver, 2008). Firms might leverage a technology's natural affordances or design affordances into a product, but consumers will notice only some affordances while ignoring others, let alone act upon them. The interaction between a technology and users over time will show which affordances influence adoption and usage. As Orlikowski (2000, p. 412) argues, "[u]sers have the option, at any moment and within existing conditions and materials, to 'choose to do otherwise' with the technology at hand." To capture the phenomenon of consumers shaping a technology by using it, DeSanctis and Poole (1994) refer to *appropriation* to denote how technologies are used in practice. They make a distinction between faithful and unfaithful appropriation where "[f]aithful appropriations are consistent with the spirit and structural feature design, whereas unfaithful appropriations are not" (DeSanctis & Poole, 1994, p. 130). Firms could propose a product with sustainability affordances, but how these stimulate behavioral change depends on customers' appropriation. Users have the option to ignore the sustainability affordances or appropriate the product unfaithfully. In the case of waste treatment technology, for instance, there are various household waste collection systems that afford circularity, but they differ in effectiveness to induce people to recycle. Compared with door-to-door collection, drop-off points have been found less successful in encouraging people to separate waste. Moreover, comingling systems, where several materials such as bottles and cans are collected together and sorted in a centralized facility have been used incorrectly, leading to contaminated material flows. Contamination has the consequence that the materials cannot be used for high-quality purposes, hindering circularity (Seyring et al., 2015).

A product feature's ability to speak to consumers' imagination depends on its symbolic expressions: "the communicative possibilities of a technical object for a specified user group" (Markus & Silver, 2008, p. 623). Faithful appropriation assumes a user's successful interaction with a technology based on a correct understanding of

how it can be employed in practice; affordances need to express a product's intended use so that consumers understand it. However, users can also interact with a technology not as the firm intended but still lead to sustainable behavior. Sustainable products can have several environmental features which reflect different affordances; whereas some might lead to a user response, others might be ignored or lead to unexpected usage. Smart meters, for example, provide consumers with more information about their energy consumption and allow firms to use price signals to change consumption patterns. Recent research has shown that smart meters affording transparency on price and consumption have led to diverse consumer responses (Batalla-Bejerano et al., 2020). Some consumers used continuous energy information feedback to reduce their consumption, but others had no response or even increased consumption. Adding a price signal to information feedback increased behavioral change but mainly for business users, not households. To what extent smart meters drove behavioral change varied across demographic groups and how the information was personalized. As most research on smart meters is based on pilot projects, there is still much uncertainty about long-term impact on energy consumption (Batalla-Bejerano et al., 2020).

In what way affordances drive behavioral change depends on how users cognitively process them (Kannengiesser & Gero, 2012; Still & Dark, 2013). As Still and Dark (2013, p. 288) argue, how affordances are perceived depends on "the user's process of transforming sensory input into task usable representations"; that is, "the object's use is apparent to the user through its cognitive representation." Users with pre-existing knowledge based on previous interactions with similar technologies more easily understand how to use a specific product. The authors distinguish between automated and controlled processing to denote how easy it is for users to understand how a product can be used (Still & Dark, 2013). Automated processing assumes that users are unaware of actively perceiving the affordances because it requires low cognitive effort. Controlled processing presumes that users are aware of the need to make a cognitive effort to understand a product's possibilities for actions or experiences. This distinction suggests that if understanding and acting upon a product's sustainability affordances requires automatic rather than controlled processing, users will more easily adopt and appropriate it in a way that results in environmental benefits. As automated processing results from a product's resemblance to technologies users have interacted with before, adoption is effortless. However, automated processing could make sustainability affordances into hidden affordances, "i.e., ones for which obvious perceptual cues are not provided by the artifact" (Kannengiesser & Gero, 2012, p. 55). Automated processing makes adoption so effortless that it could lead to rebound effects: consumers start using a product more and reverse the marginal improvements in environmental impact (Hertwich, 2005; Olson, 2013). Some evidence suggests that owners of energy-efficient cars travel more which offsets the efficiency gains (Whitehead et al., 2015).

For sustainability affordances to have a lasting impact on behavioral change and counteract rebound effects might require a high cognitive effort from consumers to initiate possibilities for learning (Still & Dark, 2013). Kannengiesser and Gero (2012) argue that consumers can either draw on reflexive, reactive, or reflective reasoning to make sense of affordances. Reflexive reasoning is automatic; reactive reasoning requires more effort as consumers make a selection among several alternatives; and reflective reasoning is a high-effort process that involves a change in consumer expectations about how a product is supposed to be used. Reflexive affordances will be acted upon swiftly, whereas reactive and reflective affordances will lead to a much slower response (Kannengiesser & Gero, 2012; Still & Dark, 2013). When a product's sustainability affordances are reflective at first, they require users to rethink their behavior before they can adopt and use the technology. This reflective process is important because it "can generate new worlds of action possibilities through reflection and through exploratory discovery of possible behaviors" (Kannengiesser & Gero, 2012, p. 61).

Reflection, even if cognitively daunting, could lead to a "ratchet effect": consumers learn cumulatively how to use the product in different ways based on self-reinforcing feedback loops and find a way that best fits their preferences (Kaaronen, 2017). Initially, it might take early adopters much cognitive effort to use a sustainable product, but what feels forced at first can become a routine over time. "Reflective affordances, through their use, tend to become reactive and then reflexive" and "can shift the space of possible affordances into previously unexpected or unknown regions" (Kannengiesser & Gero, 2012, p. 61). Going back to the example of waste management, door-to-door collection based on strict separation in households tends to require more cognitive effort from consumers than a comingled approach. Evidence from across the EU shows that when consumers learn how to do strict separation correctly, they contribute to higher recycling rates (Seyring et al., 2015). A ratchet effect can lead to unexpected usage which also result in more sustainable behavior. The process of user reflection can open up new, unimagined possibilities for sustainable behavior. Different people have different interpretations of a technological artifact (Pinch & Bijker, 1984). It is this "interpretative flexibility" that can lead to unusual developments in the way sustainable products find their usage. While bioplastics are used in the packaging industry to replace oil-based plastics, they are also increasingly adopted in other industries for new applications. In the car industry, for example, they are used to improve fuel economy, weight reduction, and recyclability.[2] So while a sustainable product might be launched to afford decarbonization, other sustainability affordances such as circularity and biodegradability could start driving adoption instead when people learn to use it for these purposes.

4 | AN AFFORDANCE FRAMEWORK FOR THE ADOPTION AND USAGE OF SUSTAINABLE PRODUCTS

To create insight into how sustainability affordances invite consumers to adopt and use a product sustainably, we now develop a framework that brings together the main conceptual insights from the previous sections (see Figure 1). The framework shows how the three types of

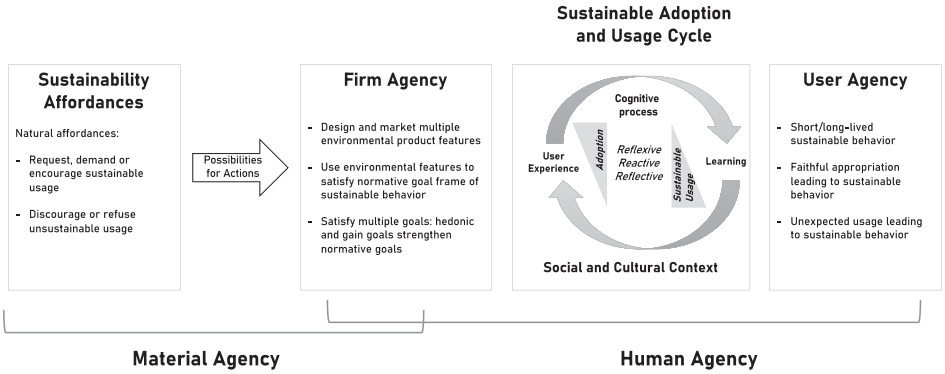

FIGURE 1 Sustainability affordances framework

agency—material, firm, and user agency—together influence technology affordances, the adoption of sustainable products, and the implications for behavioral change. The interaction between the three types of agency suggests how sustainability affordances affect the adoption and usage of sustainable products. Affordance theory's key insight is that affordances invite but do not determine different ways for users to engage with a technology (Hutchby, 2001). The general logic of our framework is, therefore, that the more a product's technology affords consumers possibilities to achieve multiple environmental outcomes while engaging with it in their preferred way, the more likely they will adopt and use it in a way that contributes to addressing sustainability issues such as climate change and environmental waste. For a technology to play a fundamental role in addressing such issues, affordance theory highlights that it matters how users interact with the technology. That is, what possibilities for agentic action do users act on? To this end, we further divided the possibilities to interact with a technology into *possibilities for actions*, *experiences*, and *learning*.

As Figure 1 shows, a technology's material agency suggests sustainability affordances—for example, circularity, longevity, eco-efficiency, decarbonization, biodegradability, compostability, organic production, resource substitutability, or traceability—which request, demand or encourage, or discourage or refuse specific *possibilities for actions*. We argue that sustainable products are more likely to be adopted if they address multiple environmental outcomes that do not conflict and offer either similar functionality to products currently in use or a wide range of new functionalities. Natural affordances and constraints that relate to material agency form the foundation of our framework. Yet a product technology's material agency alone will not set off behavioral change. The interaction between material and human agency is pivotal (Leonardi, 2011); it shapes how firms and users engage with sustainability affordances in product design and adoption and usage. In our framework, human agency manifests itself in the *sustainable adoption and usage cycle* that shows how firm agency and user agency influence each other within a specific social and cultural context. The cycle demonstrates that firms can leverage sustainability affordances by designing products around them that generate a positive user response and mitigate goal conflict between normative, gain and hedonic goals. Firms can do this by designing environmental features into products that make the normative goal of behaving sustainably the goal frame and use hedonic and gain goals to strengthen this normative goal. That is, firms should highlight how a product's sustainability affordances offer consumers myriad *possibilities for experiences*.

So far, the framework assumes that the more sustainability affordances align with existing user experience, the more likely it is that consumers adopt the sustainable product. Alignment presupposes that consumers make relatively little cognitive effort to use the product because they do not have to radically change their behavior (Kannengiesser & Gero, 2012; Still & Dark, 2013). However, cognitively effortless adoption might have the unintended consequence that users ignore sustainability affordances in the usage phase. This posits a paradox: adoption of a sustainable product will be faster if it requires a low cognitive effort from consumers; yet using the product sustainably requires a high cognitive effort instead for it to have a long-lasting impact on consumer behavior. A sustainable product's environmental benefits will only be realized in practice when consumers learn how they to change behavior and make the most of the product's sustainability affordances (Kaaronen, 2017). Here, firms face an intricate balance between intrusiveness and effectiveness (Tromp et al., 2011). In striking this balance, though, the general logic of our framework still applies: the more a sustainable product offers consumers different *possibilities for learning* for behavioral change, the more likely they will adopt and appropriate it in a way that reduces environmental impact. Firms need to grant consumers interpretative flexibility (Pinch & Bijker, 1984) and different possibilities for learning (Kaaronen, 2017).

For a sustainable product to have a lasting impact on consumer behavior—not just of early adopters but also of the majority of consumers (Rogers, 1995)—our framework suggests that alignment between sustainability affordances and user experience will only materialize after the process has gone through the sustainable adoption and usage cycle with its feedback loops where usage initially requires considerable cognitive effort from users (Kaaronen, 2017). If consumers repeatedly go through this cycle, they will learn how to work their way through the paradox so that, through repeated usage, the sustainability affordances no longer require reflective reasoning but can be acted upon through reflexive reasoning only (Kannengiesser & Gero, 2012). As the social and cultural context influences consumer preferences, it forms an important boundary

condition for how the relation between sustainability affordances and adoption and usage materializes. If consumers already behave sustainably, alignment of sustainability affordances with existing user experience will be beneficial for adoption and faithful usage because there is less need for learning. The more affordances match desired functionalities and experiences (Pucillo & Cascini, 2014; Tromp et al., 2011), the more consumers process them cognitively in a reflexive manner and act upon them fairly swiftly. When consumers do not yet behave sustainably, there will be a more pertinent need for behavioral change. This requires reflective learning, because there is a much larger gap between user attitude and action (Kaaronen, 2017; Olson, 2013; Peattie, 2010).

5 | CONCLUSIONS

This paper develops an affordance perspective on sustainable product innovation. Existing literature on sustainable product innovation explains what factors influence adoption intent and behavior of sustainable products (Luchs et al., 2012; Olson, 2013; Paparoidamis et al., 2019). To understand how sustainable product innovation contributes to tackling sustainability issues—for example, climate change, the circular economy, and pollution—insight into adoption behavior is not enough because the environmental benefits will only be realized in the usage phase. Adoption provides a partial picture only of how sustainable products make a difference in driving a transition toward a more sustainable economy. To explain more fully how different features of sustainable products affect the decisions of consumers to adopt *and* use them sustainably, we draw on affordance theory (Gibson, 1979; Hutchby, 2001). Our affordance framework shows how material, firm, and user agency together influence a product's sustainability affordances and outlines the implications for adoption and usage. The framework's logic is that the more a sustainable product addresses multiple environmental outcomes that do not conflict and affords consumers different possibilities to engage with it, the higher the likelihood that they will adopt the product and use it in a sustainable way. We make a distinction between sustainability affordances as *possibilities for actions*, *experiences*, and *learning* that together have the potential to drive sustainable behavior.

Our framework has several implications for business. First, we suggest how trade-offs between sustainability and consumer expectations regarding desired functionalities and user experience can be overcome. Firms can manage a perceived lack of functional performance and conflicts between normative, gain, and hedonic goals by designing affordances into products that address multiple environmental outcomes simultaneously and create wide-ranging possibilities for action, experience, and learning. Firms should realize that products can benefit the environment in myriad ways through different sustainability affordances. However, managers should think about the sustainability issues that are most salient in a specific market and highlight environmental features that resonate with concerns of consumers in this market. So, instead of focusing on features with the strongest environmental outcome, firms might have to focus on environmental features consumers care about most.

Second, managers need to be aware that sustainable products cannot always be a simple substitute for existing products. Managers need to get a good grasp of user expectations, experiences, and typical product usage. When they adopt sustainable products, consumers often compromise on satisfying some of their hedonic and gain goals. Still, managers should appreciate the influence of these goals, even if they are in the background, and design their sustainable product as bundles of environmental, instrumental, and symbolic features. Focusing on the normative goal frame of helping the environment will only be successful in markets with a mature green segment. In other markets, firms will have to put more emphasis on features that satisfy gain or hedonic goals. Yet they will have to make sure, too, that normative goals do not become marginalized.

Third, using sustainable products should not be made too easy for consumers, at least at first. Firms face a trade-off between minimizing the required cognitive effort of consumers to go for fast adoption and forcing consumers to make significant cognitive effort to have a more lasting impact on consumer behavior instead. We suggest that firms need to strike a balance here where the sustainability affordances initially require significant cognitive effort to then allow consumers to gradually get used to the sustainable product. This way, consumers learn what the sustainable product can and cannot do, and they discover how the product can lead to new types of experiences as they learn about different ways to behave more sustainably. Managers need to be aware that it is very difficult to predict what makes a product innovation attractive. They should let consumers discover for themselves how a sustainable product can be of delight.

Our affordance perspective on sustainable product innovation opens up new questions and research avenues. With regard to user agency, for example, to gain insight into user appropriation and the consequences for sustainable product innovation, research can draw on disciplines such as consumer psychology to better understand the role of user values and emotions in the appropriation of affordances and how these can be influenced. Valuable insights can also be found in design thinking, behavioral economics, and open innovation literature as they all highlight the need for more empathy toward the user (Brown, 2008; Chesbrough, 2006; Tversky & Kahneman, 1974). Regarding firm agency, future research should study designed affordances more carefully and provide a fine-grained distinction, especially how bundles of features create environmental, social, and economic value. Our framework also invites scholars to study how firms can leverage natural and designed affordances and deal with the conflicts between them in their efforts to stimulate sustainable consumer behavior. Future research should examine the relation between the cognitive effort sustainable products require in the usage phase and the rate of adoption and the change in consumer behavior, respectively.

ORCID

Jonatan Pinkse https://orcid.org/0000-0003-3237-2776
René Bohnsack https://orcid.org/0000-0002-7498-4810

ENDNOTES

[1] https://www.bbc.com/future/article/20191030-why-biodegradables-wont-solve-the-plastic-crisis.

[2] https://www.thomasnet.com/insights/do-bioplastics-have-a-place-in-automotive-manufacturing/.

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