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Adjustable Green Defaults Can Help Make Smart Homes More Sustainable

Nicole D. Sintov [1,*] and P. Wesley Schultz [2]

[1] School of Environment and Natural Resources, Ohio State University, Columbus, OH 43210, USA
[2] Department of Psychology, California State University San Marcos, San Marcos, CA 94132, USA; wschultz@csusm.edu
* Correspondence: sintov.2@osu.edu

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Abstract: Smart home technologies offer exciting opportunities to promote more efficient uses of energy. For instance, programmable thermostats, centralized lighting controls, and rooftop solar panels all have potential for energy conservation and efficiency. However, these technologies alone will not guarantee energy savings. Whereas previous research on smart homes has focused on the technologies themselves, relatively little work has addressed the factors that shape the human-technology interface. In this review paper, we argue that in order to ensure any savings, smart home technologies must first be adopted by end-users, and once adopted, they must be used in ways that promote energy efficiency. We focus on three areas of behavioral research with implications for smart home technologies: (1) defaults; (2) perceived adjustability or control; and (3) trust in automation. Linking these areas, we propose a new concept for improving the efficiency gains of smart homes. First, although smart device controls can help save energy, considerably larger energy efficiency gains can be realized through smart automation. But importantly, the default settings of systems should be "green", to maximize energy savings. Second, many people have concerns around relinquishing decision-making to technologies, which can reduce the likelihood of adoption. People want to be, or at least to feel, in control of their homes, even if they do not adjust settings post-installation. Further, consumer trust in technologies encourages adoption in the first place; trust also impacts consumer interactions with installed devices and can impact default acceptance. Combining these concepts, we recommend that smart home technologies build consumer trust and come pre-programmed with *adjustable green defaults*, which permit consumers to change initial green settings.

Keywords: technology adoption; psychology; behavioral economics; smart homes; green defaults; trust in automation

1. Introduction

Smart home technologies have grown tremendously in recent years. Many, if not all of these technologies, can assist in home energy management, including smart thermostats, solar panels, electric vehicles (EVs) and charging systems, internet-enabled lighting systems, and even white goods (e.g., washing machines and refrigerators). These innovations can contribute to a more stable and adaptable electricity infrastructure, maximize energy efficiency, and reduce greenhouse gas emissions. Additionally, these technologies add value to homes by offering enhanced functionality [1,2].

1.1. Emerging Research at the Human-Technology Interface

As appealing as smart technologies may be, they alone will not guarantee energy savings. In order to achieve any savings, they must be first be adopted by consumers, and once adopted used in ways that promote energy efficiency. Recognizing this reality, an emerging body of research has begun to investigate consumer perceptions of smart homes, and several studies have identified barriers to smart home technology adoption and use. Among the most commonly cited barriers include system complexity, system reliability, and concerns over control and privacy.

- **Complexity**: initially learning how devices work can require a great deal of time and effort, which are seen as drawbacks [3,4]. Furthermore, complex and confusing interfaces can discourage people from adjusting settings post-installation [5].
- **Reliability**: consumers report concerns about how smart home technologies would respond in the case of malfunction (e.g., heating system goes down in winter), and unreliable system behavior can be frustrating [3,5].
- **Control**: consumers want to be in control of their homes. In many instances, residents prefer the ability to manually adjust smart technologies versus allowing them to operate autonomously without human intervention [3,5,6].

As an example, programmable thermostats typically do not result in greater savings than manual thermostats, due to factors such as improper installation, usability issues, and misunderstanding of how thermostats and heating-ventilation-air conditioning systems work [1,7–9]. In this review paper, we propose that greater energy efficiency gains can be achieved through augmented automation rather than relying entirely on either full automation or human intervention alone. Maximizing the energy efficiency potential of devices often requires people to think about adjusting settings and take action (which may involve several devices). Well-intentioned individuals may forget, become distracted, or otherwise fail to make adjustments; they may select non-optimal settings; they may simply not be motivated to adjust to sustainable settings, or may be making trade-offs between sustainability and other objectives, such as comfort or convenience [1,2].

1.2. Contributions

This review paper makes several contributions. First, whereas much research on smart homes focuses on technologies themselves, relatively little work addresses factors that shape the human-technology interface. Second, emerging studies on consumer perceptions of smart homes have illuminated key challenges surrounding the adoption and use of smart home technologies, but have fallen short of offering theoretically-justified approaches for overcoming them. To begin to address this gap, the present paper brings to bear multiple perspectives from behavioral science to suggest a new concept for promoting the adoption of energy-efficient smart home technologies, and influencing the ways in which individuals interact with them. Specifically, the literatures on the default effect, perceived control, and trust in automation are each individually well-developed, but they have largely operated in parallel. Synthesizing theory across these three areas, we present the idea of *adjustable green defaults* in trustworthy technologies as one avenue for addressing consumer concerns and shaping the human-technology interface in smart home contexts.

As an illustration, to simultaneously address the goals of reducing system complexity and maximizing energy savings, we suggest that devices can be pre-programmed with settings that maximize efficiency outcomes [10]. In essence, such settings remove the need for people to think about adjustments, making sustainability the "default" setting. Although these "green defaults" have tremendous potential for reducing energy consumption, it is also important to respond to consumers' desire to be, or at least to feel, in control of the devices in their homes by permitting adjustments and opt-outs [6,11]. We argue that perception is what matters here, as people may not repeatedly adjust settings once they are comfortable. Finally, to address reliability concerns, devices should be trustworthy. Smart home innovations are well-suited to address these tensions—if they are manufactured with green default pre-sets, which consumers can then adjust if they choose, thereby promoting a sense of control while also maximizing energy savings [12].

In the following sections, we review evidence from the field of behavioral economics on the default effect, followed by perceived control and trust in automation. We conclude that smart home technologies can improve energy efficiency by cultivating consumer trust and using *adjustable green defaults*.

2. The Default Effect

One approach to reducing system complexity is to manufacture devices that are ready for automation and pre-programmed with default settings. Although smart home technologies are typically manufactured with default settings, these settings are rarely designed for energy efficiency. For instance, smart thermostats may arrive with temperature and/or schedule pre-sets, and electric vehicle chargers may arrive with scheduling pre-sets. These pre-sets represent default options, or the choice alternative that someone is taking if they do not make a different choice [13]. Where such defaults are involved, an individual may not make an active choice, nor realize there is a choice to be made in the first place. Instead, a choice is often made passively by accepting the default setting.

A wealth of literature from the field of Behavioral Economics has demonstrated that people are substantially more likely to stay with default options than to deviate from them. These finds come from a wide range of domains, including organ donation choices [14], participating in retirement or work-sponsored investment plans [15–17], and choosing a green electricity provider for home power [18]. These findings are robust and constitute a significant departure from standard economic models. For instance, Johnson and Goldstein [14] demonstrated that people are significantly more likely to agree to be organ donors when the default choice is donation and people must opt-out to not be donors (82% agree when default is organ donation) vs. opt-in choice framing (42% agree when the default is no donation). Supporting these experimental results, field data from 11 European countries found donor prevalence ranging from 4 to 28% vs. 86 to 100% among opt-in vs. opt-out countries, respectively. Similarly, Madrian and Shea [17] examined the effects of default options on employee participation in employer-sponsored retirement plans. By changing the default option from non-enrollment to enrollment (with retirement contributions matched up to 50% by the employer), the participation rate was 86% (vs. 49% in the non-enrollment default). Similar findings with regards to personal finance decisions have been reported by Choi et al. [15] and Cronqvist and Thaler [16].

Several studies have also found defaults to be effective in promoting pro-environmental decisions. For instance, in laboratory experiments, Pichert and Katsikopoulosu [10] found that significantly more participants chose a “green” power utility when it was the default option than when “grey” electricity was the default. Further, once a green default was established, people showed hesitancy to shift, or required relatively large remuneration to do so. Moving out of the laboratory, a default introduced at Rutgers University set printers to print both sides of pages, resulting in more than 7 million pages saved in one semester [19]. Finally, an experiment conducted with conference-goers found that attendees were significantly more likely to agree to pay carbon offsets associated with conference travel if the offset choice was positioned as the default rather than opt-in [20]. Taken together, the literature on defaults illustrates that seemingly minor changes in choice framing can meaningfully influence decisions, including environmentally-relevant ones.

2.1. Defaults in Smart Technologies

A handful of studies have explored how individuals interact with smart technology default settings. For example, Brown and colleagues [21] examined thermostat adjustment behavior after default thermostat settings were instituted among employees at the Organization for Economic Co-operation and Development. An inflection point was found, whereby (presumed) thermal comfort overrode the default. Whereas temperature defaults of 19 °C were tolerated in the winter, decreasing the default setting to 18 or 17 °C resulted in employees adjusting settings upwards (and oftentimes above 19 °C). Interestingly, occupants who were more frequent thermostat adjusters at baseline were also more likely to override the defaults. This aligns with other findings that experience can attenuate default effects. This study also suggests the importance of getting default settings "right", as a swing too far in one direction may diminish the cost of overriding the default.

Another smart home default strategy is third-party control of home equipment such as air conditioning units. Such "direct control" programs are commonly offered to utility customers in geographic regions with hot summer afternoons and accompanying high demand peaks on the electric power grid. Customers in such programs permit utilities (or other entities) to remotely control home equipment (e.g., Southern California Edison's air conditioning cycling program) on a limited number of days as part of broader efforts to curtail peak grid load and maintain power reliability. The default option in such programs is to enable third party control or cycling of air conditioning units, resulting in warmer temperatures in the home. However, customers typically have the option to opt out and manually override the default cycling. Newsham and Bowker [22] reviewed six direct load control studies from several coastal and northwest regions of the United States, and concluded that a 30% load reduction could be achieved with minimal occupant discomfort. During direct control periods, indoor temperatures were likely higher than preferred, but occupants appeared to largely accept and tolerate these. One explanation for this is that indoor temperature increases slowly and such changes may not be perceived, or at least not until several hours into the event [23]. Alternatively, occupants may perceive the change in temperature and comfort, but be willing to tolerate it as a trade-off in exchange for greater grid stability or energy efficiency. Override rates did tend to increase with greater cycling durations [24,25], suggesting that there are limits to discomfort tolerances. This aligns with the findings on thermostat default overrides discussed above [21]. Interestingly, direct load control programs often involve cycling air conditioning units during periods when cooling is often most needed (i.e., hot afternoons). Hence, it is unclear how willing consumers would be to participate in such a program (or similar programs/technologies) if override capabilities did not exist [22].

2.2. Why Do Defaults Work?

The preceding section presented a number of examples of default effects, but a remaining is question is why they work. Here we summarize several competing explanations. First, *rational decision models* suggest that making a decision often involves effort and costs, whereas accepting the default is easy [14]. Effort and costs include the physical exertion needed to override a default by changing setting [26], as well as the cognitive effort needed to think through the changes. In the case of smart home technologies, initially learning how devices work requires time and mental energy, which is one of their most commonly cited drawbacks [4]. For instance, current users of smart home technologies report complex and confusing interfaces that discourage some occupants from interacting with the technology [5]. Additionally, emotional effort can play a role, whereby people may either passively or actively avoid a decision because it can be unpleasant and stressful (i.e., in the case of organ donation or sustainability decisions perceived to have moral connotations). In such situations, going along with the default essentially gives one a free pass to avoid the potential for negative emotions like guilt or shame that can be associated with a moral decision [10].

A second hypothesis about the mechanisms underlying default effects involves the consideration of the *cognitive heuristics* used in judgement and decision-making. Research on *anchoring effects* has shown that individuals tend to be strongly influenced by the status quo [20], and has identified a general reluctance to move away from an initial reference point. From the anchoring perspective, individuals will move away from the initial starting reference only when the alternative provides a clear and meaningful benefit in comparison [10,27]. Additionally, *loss aversion* research tells us that losses loom larger than equivalent gains [28,29], and changing from a default may involve one or more of the costs (i.e., losses) described above. Accordingly, aversion to incurring such losses can result in accepting the default, unless deviating promises substantial benefits or fewer costs [30].

On the other hand, going with the default may have nothing to do with rationality or cognitive heuristics [10]. A third explanation for default effects focuses on *social norms* and implied endorsement from others [21–23,31]. From this perspective, the default conveys the socially desired behavior [14,32].

For example, when companies offer a 'standard product' [13] as a default option, consumers may interpret this product as the one that fits most consumers [10]. Non-default choices imply a departure from the norm and, thereby, the possibility of social rejection [33]. Those with limited experience or knowledge may be particularly susceptible to defaults by this route. How this may play out in a private, smart home context has yet to be studied and offers a potentially fruitful area for future research.

2.3. Moderators of the Default Effect

As summarized above, default settings can exert a strong influence on behavior, but there is also evidence that defaults do not function identically across all people. Individual differences such as experience with a given domain, knowledge, and attitudes have been found to moderate the impacts of defaults. For instance, as mentioned above, default effects are thought to be stronger among those who are unfamiliar with a product or have little knowledge about it [34]. Similarly, Lofgren and colleagues [35] found that default choice framing for carbon offsets did not influence offset purchases among experienced consumers (i.e., environmental economists), and concluded that experience in a given domain can attenuate the default effect. This aligns with work suggesting that some individuals may actually enjoy information gathering, weighing choice alternatives, and making a decision on their own ("market mavens") [36]. For instance, some smart home occupants perceive that automation is "dumbing down" their experience [3], and value the ability to make their own decisions about the functions of smart home technologies.

Defaults have also been found to interact with self-standards in goal-setting contexts. In a home energy savings experiment, going along with default electricity conservation goals led to significantly more savings. However, this was only true for goals that roughly matched participants' self-standards: those for whom default goals were much lower or higher than self-set goals saved less energy [37]. This finding aligns with others on presumed thermal comfort limits to the default effect [21,22].

Additional research suggests that attitudes may moderate how defaults work. Similar to the effect of experience, researchers argue that "insurmountable attitudes" [38] should attenuate the effect of a default [36]. However, experimental work has found that attitude strength only overrides the default effect among those with extremely strong attitudes (i.e., top 7%) and only for very specific attitudes (i.e., toward renewable energy vs. general environmental attitudes) [39]. Hence, there is mixed support for the notion that strong attitudes can override defaults [33].

Finally, default framing tends not to work when cost differences are too large. For example, customers will not accept a default tariff when it costs $1000 more each month than an alternative option. Likewise, based on the results of a field study in the United Kingdom, employees may opt out of retirement savings plans with atypically high default contribution rates (12% pre-tax income): only about 25% of employees remained at that rate after a year, whereas about 60% of employees shifted to a lower default contribution rate [40]. In summary, various individual difference factors can impact the likelihood of default acceptance, indicating the value of considering these factors in the design and dissemination of smart home technologies.

3. Perceived Control

Research on smart homes and smart energy systems has found that consumers prioritize autonomy even more than convenience: they prefer the ability to manually adjust smart energy technologies versus allowing them to operate without human intervention [3,4,6]. Because convenience is often seen an important added value of smart home technologies, this is an important finding. Practically speaking, a large portion of funding for energy research goes toward the development of new technologies [41], many of which are largely focused on automation. However, consumers may not accept such technologies if they believe that they will not have the option to manually adjust or control them. Although Newsham and Bowker's review of direct load control programs [22] found that consumers seldom executed overrides, the fact that they were used at all highlights their value, and suggests that merely having an opt-out option may provide consumers with a measure of perceived control, while at the same time preserving reductions in peak demand for electricity. In other words, it is important that consumers *could* override default settings if they wanted, even if they don't exercise this control. In psychology, this concept is known as perceived control [42].

Perceived control is determined by a broader set of beliefs about the factors that may facilitate or hinder performance of relevant behaviors, including the availability of knowledge, resources, and conditions required to perform a task [43]. Often these factors pertain to an individual's own internal experience, but in the case of technology, characteristics of a given device also play an important role. Perceived control is thought to include two components:

1. Internal, referring to one's beliefs about his or her abilities to operate technologies in general (i.e., computer self-efficacy); and
2. External, or environmental conditions specific to a device.

For instance, a person may believe that she has the skills and knowledge to operate a smart lighting system, but if the system itself is unreliable or buggy, perceived control over the ability to operate the system may be low. Indeed, current smart home owners have reported frustration with unreliable or unpredictable smart home devices such as automated lighting systems that turn on and off unpredictably [5]. Timeline also plays a role here. Before interacting with a new technology, perceptions of external control are thought to be neutral or tied to a specific device, which get updated after people interact with it [43]. Thus, experience with a given system affects perceptions of external control, and these perceptions are technology-specific, highlighting the importance of particular contexts and device properties.

Research in social psychology has shown that perceived control can act as a proxy for actual control. For instance, perceived control has been found to account for at least as much variance in health symptoms and thermal comfort as actual control and actual temperature, respectively [44,45]. In a study of over 6000 office building occupants across nine European countries, no associations were found between actual and perceived control over a variety of building controls including lighting, temperature, and ventilation. However, occupants who felt more in control of temperature, ventilation, and noise were more satisfied with air quality and thermal comfort. Going beyond measures of comfort, occupants with greater perceived control also had better health scores based on Building Symptom Index measures (i.e., dry eyes, stuffy nose, dry throat, headache, fatigue). This was true for both summer and winter [46]. In sum, perceived control is strongly linked to building occupant health and comfort, whereas actual control seems less related to these outcomes.

In other domains, perceived control has also been tied to more adaptive responses to environmental conditions. For instance, Donnerstein and Wilson [47] assessed interpersonal aggression among participants who were exposed to a noxious stimulus (i.e., loud noise) and were either given the ability to control it or not. Interestingly, the results showed that very few of the participants actually changed the intensity of loud noise, but those who could control it subsequently showed less aggression than participants who did not have the option to control the noise. In studies of pain control, participants who are given some measure of control over a painful stimulus tend to report lower pain ratings than when they receive the same pain relief delivered by someone else [48]. Similarly, patients trained in cognitive (vs. pharmaceutical) pain management strategies are typically better able to tolerate and alleviate pain [49].

Taken together, these results suggest that the perceived ability to control one's environment—and not the actual impact of exerting control over it—increases tolerance for discomfort across several domains. It may be that merely believing one has agency over one's environment shifts discomfort set points to enable greater tolerance of stimuli that may otherwise be perceived as uncomfortable. Alternatively, belief in one's own agency may enhance skills for coping with discomfort.

4. Trust in Automation

On the flip side of perceived control, it is also important that consumers trust that a technology will operate as intended. This may be particularly germane when it comes to adopting smart home technologies in the first place [3], and when consumers first begin interacting with innovations. For instance, Australian power customers with lower levels of trust in their utility were less likely to participate in utility-managed direct load control programs [50]. Muir [51] suggested that trust in automation develops in stages, beginning with predictability, moving onto dependability, and finally ending with faith. We argue that the early stage of predictability may be a particularly critical time for smart home technologies, as this is the stage at which default settings may either be accepted or not. According to Muir [51], predictability can further be broken down as stages of:

1. Actual predictability of machine behavior, with greater predictability leading to greater trust;
2. User ability to estimate the predictability of machine behavior, which can be enhanced by user experience; and
3. Stability of the environment in which the machine operates, where highly variable environments can result in more erratic machine behavior which can be perceived by consumers as less predictable and hence lead to lower levels of trust.

To illustrate, experimental research has found that consumers extend trust to technologies, ascribing human-like qualities to them, and that this predicts adoption intentions [52]. Research on barriers to smart home adoption reveals that potential adopters express concern about how smart home technology would respond if things go wrong or malfunction (e.g., heating system goes down in winter). Indeed, unreliable behavior of devices is reported as frustrating among current adopters [5].

5. Future Directions

The rapid expansion of smart home technologies has created new opportunities to achieve energy conservation and efficiency, but has also raised a number of important practical and ethical questions. Research in the behavioral science can play an important role in making smart homes more sustainable, and we have reviewed the research in the areas of defaults, perceived control, and trust. However, this area of research is just beginning, and more work is needed. Here we highlight five future directions:

- **Device specificity**. People may not respond uniformly to defaults of different smart home technologies, particularly if levels of knowledge or experience vary across devices. However, the extent to which a smart home ecosystem may foster compliance with defaults for multiple devices is unclear. For instance, if an occupant accepts default thermostat settings, will he be more likely to subsequently accept default demand response settings? This may be driven in part by trust in automation, whereby higher levels of general trust could lead to similar outcomes across devices. Alternatively, a "spillover effect", whereby trust in one smart home technology may foster trust in another, could occur. Future research should employ behavioral experiments to evaluate spillover effects in the context of smart home technology adoption and use.
- **Experience: a double-edged sword?** Greater experience with a device or domain can diminish the default effect, while simultaneously increasing perceived control and trust. How these conflicting effects impact acceptance of smart home defaults has yet to be investigated. One possibility is that more experience affects the self-focused aspects of perceived control and trust (e.g., I have the ability to control this device, I know how to get it to do what I want), and increases default overrides. Another possibility is that experience enhances perceived control, which increases trust in the device, such that people are more willing accept defaults. Future behavioral studies should flesh out the ways in which experience may decrease or increase compliance with green defaults.
- **Tailoring defaults.** Smart home technologies require a nuanced understanding of human behavior in order to meet unique and often shifting occupant preferences [53]. Some studies have found

that when occupants are unhappy with learned thermostat programs, they adjust settings until they are comfortable [2]. Hence, a goal of green defaults for smart home technologies is to learn optimal settings for individual occupants, removing the need for the occupants themselves to repeatedly adjust. This is a multi-agent challenge, as one household's preferred setting may not be the same as another household's, and within a given household, multiple occupants may have different preferences [54–56]. Furthermore, occupant preferences can change over time, and there may be differences between what occupants thought they wanted before installation, and what functionality actually works in practice [54]. For some, this means that devices with automated schedules may be too rigid. Indeed, most households with smart technologies describe an initial period of adjusting settings to customize to occupant needs [5]. Hence, smart home technologies should permit and respond to natural changes in occupant routines [54]. Finally, there is a difference between technologies predicting human behavior versus sensing where an occupant is, what activity s/he is engaged in, where s/he is going, and responding intelligently to these inputs [57]. Because household behavior is often not particularly predictable, intelligent sensing or other occupant inputs can aid in getting settings "right" [3,4]. Although sensors (in the home, mobile, or wearable) are subject to environmental noise, redundancy (i.e., multiple sensors), occupant prompting, and specificity in sensing (e.g., RFID to identify individuals) can help address this [53]; video and audio sensing have also been proposed but carry privacy concerns [58]. Future work should take an interdisciplinary, multi-modal approach combining sensors and behavioral studies to elucidate occupant preferences around optimal settings.

- **Interoperability.** Although smart home technologies have arrived, they are not arriving as a seamless, integrated solution. Instead, individual products are becoming available one at a time, such as smart and/or learning thermostats, smart door locks, camera systems, etc. In fact, in the near future, it may be impossible to find devices that are not connected- this is already becoming true for televisions, most of which are now internet-enabled out of the box. People may acquire individual devices, and over time, accumulate several of these, each of which adds some "smartness" to their home, car, on physical person. But if devices do not work together, occupants may become confused or overwhelmed, which would be counterproductive to the smart home enterprise [59]. Imagine a consumer who uses two dozen applications per day to control individual smart devices in her home. This level of effort can take away from her user experience for any of the individual products, and negatively impact perceptions of such products and smart homes as a whole. Thus, as more and more devices become available, they will need to function together as a unified system to maximize value to consumers. Moreover, devices should seamlessly and naturally integrate into home life. Designing smart homes in such a manner will require drawing on behavioral science theory to deepen our understanding of occupant needs, the household social context, and how needs and social interactions shift over time [55,59]. To ensure the long-term viability of the smart and connected home, "future proofing" is needed, whereby the design of current devices considers compatibility with subsequent generations of devices, as well as regulatory frameworks, standards, and policies [55]. Developing such solutions will require interdisciplinary integration across many fields, including the behavioral sciences, public policy, engineering, and computer science to name a few.
- **Ethical considerations.** In the smart home literature, among the most commonly cited barriers to adoption are concerns over sharing private/sensitive information, "big brother"—type control of home equipment, as well as data security [4,54,55,58]. People have reported that they do not want utility companies having data on their home's occupancy nor private activities [3], and in addition are also concerned that such data may be sold or could fall into the wrong hands [3,4]. Addressing these concerns can help promote the uptake of smart home technologies and should be a priority for the smart home research agenda. Policies and standards need to be developed to safeguard consumer privacy and information, and foster greater levels of transparency and accountability for these data on the parts of product manufacturers, energy utilities, and other

actors that may have access to occupants' data [4,55]. Another ethical consideration stems from our above discussion around perceived control, which assumes that occupants also have actual control. However, what range of control should occupants be permitted when the goal is to reduce energy waste [31]? Should occupants in different settings be permitted different ranges of control? Currently, in many office settings, occupants do not have much if any control over various comfort settings (e.g., thermostat, airflow). Future studies of consumer preferences and behavior can help to shed light on these ethical questions.

6. Conclusions and Recommendations

Smart home technologies have arrived, and they can offer enhanced comfort, safety, security, convenience, *and* energy efficiency [53]. However, the ways in which humans interface with smart home technologies critically impacts their energy efficiency and sustainability potential more generally. From a practical standpoint, although product manufacturers have involved end-users to some extent in product design, the focus tends to be on creating products that consumers will buy, and consumer behavior is typically not the central consideration [55,59]. Moreover, the ways in which consumers interact with products post-purchase, and the resulting consequences, have received limited attention. To achieve the sustainability goals of the future, we argue that it is necessary look beyond technologies themselves, and account for the complex human factors influencing their adoption and use.

A growing body of work has begun to investigate consumer perceptions around smart home devices. Although this literature illuminates important barriers to the adoption and use of smart home technologies, theoretically-supported approaches for overcoming these challenges are lacking. Addressing this gap and contributing to theoretical synthesis in behavioral science, the present review paper links three areas of literature that have largely operated in parallel to suggest a new concept that can be applied to smart home contexts. In particular, in line with prior working showing that automation can improve energy savings [60], we discuss how *green defaults* can help to maximize the energy efficiency potential of certain smart home innovations. However, to maximize adoption rates and default acceptance, override options must be available, and the technologies themselves must be trustworthy. Hence, combining concepts from the literatures on defaults, perceived control, and trust in automation, we introduce the concept of *adjustable green defaults* in technologies that foster consumer trust. We recommend this as one approach to help overcome barriers to smart home adoption and use and shape the human-technology interface. Figure 1 presents a schematic of this new concept. Our idea aligns nicely with prior advocacy of a "peripheral design" approach, which suggests that occupant interactions with smart home technologies should be designed to occur in the periphery of occupants' attention, only requiring active attention for select purposes [59].

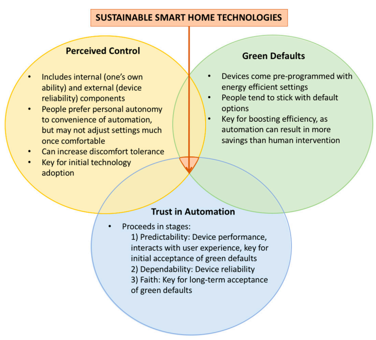

Figure 1. Enhancing smart home sustainability with trustworthy technologies and adjustable green defaults.

Further, we argue that increased trust and perceived control can work to enhance the likelihood of green default acceptance. However, the specific ways in which this may play out likely varies based on the stage of interaction with smart home devices and warrants further study. To illustrate, we consider the following three broad stages of interacting with smart home technologies: information gathering, learning and initial use, and long-term use. We focus our consideration on cases in which a consumer has an active and explicit interest in acquiring a device; passive interactions, in which a consumer may passively receive information about devices, e.g., via friends or family, are important but not a focus here. To start, when consumers are considering adopting a technology, they gather information on available options and features. They may be more likely to purchase a device that they perceive that they can: (1) operate and *adjust* as desired; and (2) *trust* to execute the desired function(s). Next, after adoption and installation, occupants go through a phase of learning the device and possibly adjusting settings. As occupants interact with the device, they develop some level of perceived control over their ability to operate its various functions. Trustworthiness plays a role as occupants experience how the device actually functions in their home and whether it is reliable. At this stage, perceived control and trust may interact. For instance, if one believes he can control a device, trust in the device may increase, and enhance the likelihood of accepting green default settings. Over the long run, as occupants build up experience with the device, trust is likely to take over as the more dominant factor in predicting default acceptance. Future research is needed to investigate how these processes actually play out.

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